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Educating the educators: international approaches to scaling-up professional development in mathematics and science education. Proceedings of the conference hosted jointly by project mascil (mathematics and science for life) and the German Centre for Mathematics Education (DZLM), 15 -16 December 2014 in Essen, Germany

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Conference Proceedings

Educating the educators: international approaches to scaling-up professional development in mathmatics and science education

15 -16 December 2014 in Essen, Germany

Teachers are the decisive factors in ensuring the achievement of creative and sustainable learning outcomes in mathematics and science education, in fostering young peoples' competences and enabling them to become critically thinking, responsible and active citizens. Teacher professional development (PD) is the key to effecting change in mathematics and science education throughout Europe. Whilst the relevance of teacher PD is beyond dispute, there is still too little knowledge about how to scale-up professional development successfully and sustainably.

Initiating discourse and leveraging international exchange about concepts and experiences concerning this essential topic were the main aims of the conference 'Educating the Educators – International approaches to scaling-up professional development in mathematics and science education', which took place in December 2014 in Essen, Germany.

The conference was hosted by the EU-funded project mascil (mathematics and science for life), coordinated at the University of Freiburg, Germany, and the DZLM (German Centre for Mathematics Teacher Education) and brought together researchers and practitioners: teacher educators, multipliers and teachers who are all engaged in the field of maths and science education. This volume reflects participants' conference experiences.

Further, we are pleased to provide here background information and aims of the conference issue, as well as conference conclusions and an outlook on future needs and trends. The papers relate to four conference tracks, each addressing a different approach to scaling-up professional development in maths and science education:

(1)   Scaling-up with multipliers in face-to-face professional development courses

(2)   Blended learning concepts and e-learning support

(3)   Disseminating and scaling-up through materials

(4)   Professional learning communities.

Conference Proceedings in Mathematics Education

Band 2

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EDUCATING THE EDUCATORS:
INTERNATIONAL APPROACHES TO SCALING-UP PROFESSIONAL DEVELOPMENT IN MATHEMATICS AND SCIENCE EDUCATION

Proceedings of the Conference hosted jointly by the project mascil (mathematics and science for life) and the German Centre for Mathematics Education (DZLM),
15 -16 December 2014 in Essen, Germany

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1 Conference: Educating the educators
K. Maass, D. Wernisch, K. Reitz-Koncebovski, E. Schäfer

1.1 Aims and objectives

This was the first international conference specifically devoted to the topic of educating the educators. The conference targeted teachers and teacher educators, researchers, multipliers and relevant networks, educators of multipliers, policy makers, teacher professional development (PD) centres, maths and science education support centres, presidents and heads of PD institutions/centres and relevant networks. These participant groups are key to the aim of disseminating innovative teaching approaches, such as inquiry-based learning. In particular, 'Educating the Educators' served as a lever and platform for international exchange about concepts and experiences concerning such questions as: What are the features of successful concepts and professional development? What are the needs and experiences of the different target groups? Which pitfalls have to be avoided?

This international conference connected researchers and practitioners engaged in the field of maths and science education in order to discuss concepts of scaling-up teacher professional development. A special feature of this conference was that it brought together researchers and practitioners (including the target group of teacher educators themselves) and initiated an exchange between teacher education centres in the different countries. Key to scaling-up concepts - and core to the conference - was the education, professional development and support of multipliers. The conference approached the subject from the perspectives of: 1. Individual countries and their particularities; 2. Different target-groups and their needs (policy makers, educators of teacher educators) and 3. The end-users (teacher educators, teachers and their everyday classroom practice).

Innovative and interactive formats were used during the conference to bring out the specific benefit of gathering a circle of participants from both research and practice. Relevance for, and impact on, practice was ensured by using oral presentations and discussion, demonstrations (e.g. simulation of professional development situations, demonstration of materials) with subsequent facilitated reflection and practice-oriented reports from teacher educators, training centres and policy makers. The conference was rounded out with keynote lectures, a poster session and a closing plenary discussion based on the reports of track rapporteurs.

To ensure a wide distribution as well as a sustainable information basis of the conference, we created a conference website that was continuously updated to include the latest information. The website can be viewed at: http://educating-the-educators.ph-freiburg.de. The conference proceedings and detailed papers of the presentations may also be downloaded from the website.

1.2   Conference tracks: Four different means of scaling-up

The conference was organised in four different tracks that each addressed a different means of scaling up professional development in maths and science education. Each track covered the fields of science and mathematics. The aim was to present and discuss different approaches which ensure a high quality of the education of educators:

(1) *Scaling-up with multipliers in face-to-face professional development courses:*
   Approaches to scale-up using training sessions provided by multipliers where participants and their educator are in the same physical space. This track examined both the research and practice-oriented perspectives

(2) *Blended learning concepts and e-learning support:*
   Opportunities and limitations of teacher professional development with the help of blended learning concepts and e-learning support

(3) *Disseminating and scaling-up through materials:*
   Scaling-up through appropriately designed materials that support teachers' professional development and ways to disseminate materials

(4) *Professional learning communities:*
   Challenges to, and opportunities for, encouraging professional development through professional learning communities. In such groups of teachers, one member acts as a facilitator. However, learning in a PD group is considered to be much more self-organised than in a professional development course organised by a multiplier.

Each track was supported by a so-called track chairing team consisting of three to four international experts with regard to the specific track issue. Furthermore, a scientific board was established to support the track chairing teams with scientific and conceptual advice to assure a high scientific quality of the conference.

1.2.1 Track 1: Scaling-up with multipliers in face-to-face professional development courses

Reaching a large number of teachers with an innovative content, such as inquiry-based learning (IBL) or connecting school to the world of work, in face-to-face professional development courses, is accomplished by using a pyramid model: Engaged teachers or researchers are trained to become multipliers, who then go on to train other teachers. This pyramid model has proven efficient and effective within various contexts and projects (e.g. Sinus project in Germany, EU project PRIMAS). Nevertheless, educating multipliers poses considerable challenges inherent to the specific requirements of the multipliers' dual role. Multipliers act as experts in some subject-related content,

and at the same time, as professionals in adult education. Therefore, training multipliers has to cover both of these requirements.

This conference track offered an opportunity for presenters and participants to exchange experiences from the practical field and to discuss relevant research results. The track focused on key questions such as:

- What are the features of successful concepts for educating multipliers?
- Which pitfalls have to be avoided?
- How can multipliers be adequately prepared to impart key approaches that promote more meaningful and motivating science and mathematics learning consisting of complex content and competences like IBL and/or a closer connection of school to the world of work?
- How can multipliers effectively be supported in the implementation of professional development?
- In what ways can cultural factors, such as national specifics in how teachers cooperate at school – or not, or common classroom culture, be addressed and handled?
- What are the needs and experiences of the different target groups: educators of teacher educators, teacher educators themselves and teachers in their everyday classroom practice?

1.2.2 Track 2: Blended learning concepts and e-learning support

Information technologies have rapidly transformed the landscape within which both academic and applied learning now takes place. Innovative technologies enable new approaches and powerful possibilities for collaborative, learner-centred and research-oriented learning and provide unrivalled access and flexibility to individuals.

E-learning courses, for example, provide opportunities not found in face-to-face educational situations. With e-learning, teachers can work together despite being geographically wide-spread. Further, teachers can work according to their own schedule, thus not affecting school hours. Teachers can work as a virtual community, mediated through synchronous (chats and virtual meetings) and asynchronous communication (forums, uploading documents and resources, giving feedback to the work of others). Asynchronous communication through e-forums allows more time for reflection and the ability to revise and repost on the given forum. Blended learning combines the advantages of e-learning support with face-to-face meetings, and thus ensures sustained interaction and collaboration both within and across school communities and networks.

Further, this track examined the issue of to what extent e-learning is suited for complex content that also affects teachers' focal points and attitudes.

This track addressed the following questions:

- What are the features of successful, blended learning concepts?
- How can e-learning impart complex content that affects teachers' focal points and attitudes (i.e. IBL, more closely connecting maths and science learning to the world of work.)?
- Which features do excellent e-learning materials have? How can existing PD materials be modified and adapted for use in an e-learning environment?
- How can e-learning support be tailored to the needs of the target groups? What do suitable tools for self-assessment, the monitoring of teachers' success and evaluation of users' experience with the e-learning environment look like?
- How can engagement and sustainability in virtual learning communities be ensured? Can a virtual learning community be as effective as one that meets in the same physical space?
- What are the needs and experiences of the different target groups: teacher educators, facilitators/instructors of e-learning forums and/or virtual meetings, and teachers using e-learning support?

1.2.3 Track 3: Disseminating and scaling-up through materials

Carefully designed classroom tasks can be a powerful tool for enhancing the quality of maths and science teaching, influencing the classroom culture and fostering students' learning. Classroom tasks stimulating inquiry and/or based on real problems from the world of work give rise to more meaningful and motivating maths and science learning. Appropriate tasks support students in developing scientific reasoning, as well as transversal competences such as: critical thinking; problem solving; creativity; teamwork and communication skills. Simultaneously, good tasks secure basic knowledge, allow learning from mistakes and cumulative learning and also facilitate autonomous learning. Other possible benefits include promoting student co-operation, offering interdisciplinary approaches and contributing to the reduction of gender stereotypes. Obviously, tasks have to complement current school curricula.

In the process of developing a task culture and implementing good tasks in classrooms, a spiral model of professional development has proven efficient and effective within various projects (e.g. EU projects LEMA, COMPASS, PRIMAS). In the spiral model, teachers themselves actively experience inquiry learning with new tasks – and subsequently implement the tasks in their classes and reflect on their experiences. Teachers thus work in continuing cycles of analysis – implementation – reflection. After gaining some experience, learning communities are able to develop their own tasks. This process ensures shared ownership of tasks, and thereby facilitates their use.

In addition to exemplary, high quality classroom tasks, the spiral model of professional development requires appropriate materials designed for a learning community's teacher educator or facilitator to use and that support them in the work of supervising teachers.

Hence, this track addressed the following questions:

- What are the quality criteria for the design of materials for classrooms and/or PD?

- How can suitable quality assurance of materials be ensured?

- How can the design of materials meet the affordances out of education systems and policy context? How can constraints for the flexible design of materials be overcome?

- What are the features of materials for classroom and/or PD that are suitable for promoting IBL and/or more closely connect science and mathematics learning to the world of work?

- Which factors promote or impede the implementation of innovative materials in practice?

- How can self-explanatory materials be designed that have large potential for scaling-up?

1.2.4 Track 4: Professional learning communities

Regardless of the intervention mode (face-to-face, e-learning, blended learning…), professional development is most successful and sustainable when it involves collaboration between teachers and encourages reflection and mutual support. This is especially true when the PD focuses on innovative content (i.e. IBL, school lessons more closely connected to the world of work). Maximum intervention impact is achieved when several teachers (either from a single school or neighbouring schools) take part in a PD course and form a learning community. Such learning communities of teachers are sustainable because the members have a common aim, are mutually engaged and supportive, and share the experience and passion of involvement in a joint enterprise.

Learning communities that involve teachers from secondary and primary schools, or from general education and vocational schools have proven to be particularly interesting and valuable. Experience (i.e. in the EU projects PRIMAS and mascil) has shown that in such diverse learning communities, teachers benefit mutually from their different areas of pedagogical and content-related expertise.

This conference track offered an opportunity for presenters to exchange experiences from the practical field and discuss relevant research results.

The track focused on key questions such as:

- What are the pre-conditions for setting up self-sustaining learning communities? How can sustainability be ensured?

- What are the requirements for learning community facilitators? How can teachers be educated and prepared to take on the role of learning community facilitators in their schools?

- What are the experiences with supporting learning communities in e-learning or blended learning environments?

- Which methods of working within the group have proven efficient?

- How can learning community members be effectively supported in acquiring complex content and competences that are key approaches to promoting more meaningful and motivating science and mathematics learning? (i.e. IBL, more closely connecting school to the world of work).

- What does research say about the cultural dimension? In what ways can cultural factors, such as national specifics in how teachers cooperate at school – or not, or common classroom culture, be addressed and handled?

- What are the needs and experiences of the different target groups: facilitators of learning communities, educators of teacher educators, and teachers in their everyday classroom practice?

2   Conference outcomes and conclusions
K. Maass, D. Wernisch, E. Schäfer

2.1 Teacher professional development: Europe-wide perspective on current needs and trends

Mascil was strongly committed to focusing the mid-term conference on connecting researchers and practitioners engaged in the field of maths and science education in order to discuss concepts of scaling-up teacher professional development. The need for this is great as teachers are the key factor in ensuring the achievement of creative and sustainable learning outcomes in mathematics and science education, in fostering young peoples' competences and enabling them to become critically thinking, responsible and active citizens. Therefore, teacher professional development is of great relevance and always an essential key to effecting change in education, regardless of the national educational system. Teacher PD and research about it is a growing field throughout Europe. The difficulty consists in the fact that there is little knowledge about how to scale-up PD successfully – and sustainably.

For these reasons, the conference was organised to provide opportunities for leveraging international exchange amongst target group members. Here, we were successful in promoting fruitful, mutually beneficial discussion about many relevant questions, such as PD concepts and approaches that work, target groups' particular needs and experiences, challenges and hindrances of successful PD and the crucial role of multipliers and their training and support. The four tracks (as described above in section 1.2) were also extremely useful for highlighting the major aspects involved when addressing how to effectively and successfully 'educate the educators'.

2.2 Bringing together a unique circle of participants: researchers, practitioners and policy makers

Addressing the conference issue by means of the four tracks also allowed a broad perspective on relevant approaches of educating the educators for research, as well as for practice. A dynamic and increasing field of research on professional development of teachers and teacher educators is arising. Scaling-up teacher PD in maths and science and, thus achieving improvement of education, is receiving increased public attention and policy support. We also see a beginning institutionalisation across Europe.

The tracks allowed discussions and insights into the concepts, approaches and programmes currently being developed and applied across Europe. Having over 170 participants with varying professional backgrounds and coming from more than 20 nations added to diverse perspectives given in discussions and contributions. Among the presenters and conference

participants were multipliers, teacher educators and multipliers, researchers, policy makers, relevant networks and representatives of national ministries. A high-level policy maker introduced core topical issues in the conference welcome address: Sylvia Löhrmann is the Minister of Schools and Further Education of North Rhine-Westphalia, Germany and president of the Standing Conference of the Ministers of Education and Cultural Affairs of the States 2014 (KMK). Her attendance emphasised the importance and timeliness of our chosen topic. Highly regarded keynote and track plenary speakers presented state-of-the-art research and practice with regard to scaling-up teacher professional development.[1]

2.3 Innovation: Establishment of a future-oriented, European network of teacher training centres

Through the attendance of teacher professional development centres and institutions in maths and science education, the conference organisers brought together a further group of actors who are of increasing importance in the European arena. The relevance of this group for issues relating to teacher professional development becomes apparent through an increasing number of specialised centres which have been set up across Europe in recent years. Mascil and the DZLM responded to these current developments and needs by offering a special pre-conference meeting for presidents and heads of professional development centres and institutions. Especially important to the field, and also a particular success of the conference, is that this was the first meeting of teacher professional development centres in maths and science education from across Europe. More than a dozen such institutions were represented at the first meeting.

The main goal of the pre-conference was therefore to provide a platform for the mutual exchange of ideas and experiences. The centres all have similar aims and agendas, namely: investing in teacher professional development to substantially improve maths and science education as it happens day-to-day in schools. The meeting enabled discussion about the challenges and opportunities such institutions face. The circle of participants shared critical aspects that need to be considered when cooperating with the educational administrations, appropriate strategies for doing so and how the various centres might benefit from an exchange on the similar scope and focus of their work in the different countries. A further major issue that was discussed centred on different approaches for promoting professional development of teachers and making these activities sustainable.

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[1] For more details on the keynote issues, please see section 3.

One of the most significant developments of the pre-conference was: those attending strongly urged the conference organisers to provide an opportunity for a second European meeting of the professional development centres. We are therefore pleased to announce that a second meeting of the centres is in the works. It will take place in connection with the 2015 mascil project meeting in Lithuania. Due to the high topicality of the discussed issues in the pre-conference, many participants have already confirmed that they will take part in the next meeting. As we aim to enlarge the circle of participants, we are currently inviting professional development centres from all over Europe to participate in the second European professional development centres network meeting. European Schoolnet has already accepted our invitation to present the SCIENTIX teacher support platform to the meeting participants.

In the long run, it would be desirable and advantageous to hold such meetings on a regularly basis. Indeed, the dates for a third meeting are already being fixed (2-3 December 2015 in Sofia)and we see this as an encouraging development with respect to forging stronger links and networks between these important actors in teacher professional development in maths and science education.

2.4   mascil and DZLM - combining research and practice

The conference was jointly hosted by mascil and the German Centre for Mathematics Teacher Education (DZLM). This collaboration of two important entities from the fields of research and practice proved highly successful. Mascil is coordinated at the University of Education Freiburg, Germany. The institution has been coordinating international projects fostering innovation in math and science education for over a decade. This made it possible for the conference to revert to an international network of currently almost 1000 stakeholders in 'scaling-up professional development in maths and science education' across Europe. The DZLM has a leading role in the field of mathematics teacher professional development in Germany, and therefore represents particularly the practice side.

This co-organisation and co-responsibility were foundational to conference success. Collaboration between research and practice, as demonstrated at the conference, is not only fruitful - but indeed essential, so as to take innovation in maths and science education forward in a coherent and effective manner. Projects like mascil and the research teams and universities behind them and the international community of researchers in maths and science education contribute the research perspective: concepts, approaches, materials and the research-based development, evaluation and improvement of these. Organisations such as the DZLM, other teacher professional development centres across Europe, as well as further actors (multipliers, teacher trainers, etc.) bring in the practice perspective: the needs, affordances, the experiences and feedback to research including calls for where more research is needed. Providing a platform for exchange between researchers and practitioners and

achieving impact became possible only through such collaboration at the organisational level. In fact, this need for continuing to support an exchange between research and practice was one of the core conclusions reached by conference participants.

2.5 Trends and needs in Europe to scale-up teacher professional development

The conference was highly topical, meaning that the platform provided by the organisers served to foster discussion and exchange about approaches and challenges to improving the education of educators in maths and sciences – and thus, improve education in these subjects and schools. A final panel and plenary discussion brought key insights from the different tracks together, looked to the future and defined core strategies that are needed for a 'scaled-up' teacher professional development.

One of the core messages from the conference is that further and more strongly linking of research and practice is indispensable to moving forward. Also, linking policy to research and practice is necessary.

An example of the urgent need of these links is the demand from the side of policy for innovation in class which could be implemented through use of new teaching and learning materials, such as those based on inquiry-based-learning methods and/or that combine school subjects with the world of work. However, successful, classroom innovation also requires curriculum updates and modification – which, in turn, are reliant upon the availability of appropriate example materials. With this example, the mutual dependency of, and the need for, coordinated action between policy and practice becomes obvious. In addition to having good tasks and providing for their distribution, innovation in class also necessitates knowledge of which learning processes and goals are addressed. This is where the link to research becomes relevant.

A further outcome of the conference and its final discussion was the acknowledgement that policy, practice and research might have different perspectives on learning processes and goals. Such differences are legitimate - however to achieve well-founded and sustainable innovation, such differences need to be the subject of open, mutual exchange. Here, it is the task and demand for practitioners, researchers and policy makers to increase collaboration and communication amongst each other and step up coordinated efforts. This is especially apparent when it comes to detecting and responding to current national and European-wide trends and perspectives. Developing a strong network for European teacher training centres and strengthening the voice of the practice side is therefore an important approach – and a next step towards doing so is the aforementioned second meeting of the centres' representatives in May 6-7, 2015 in Vilnius, Lithuania.

Another important conference conclusion is that although a range of promising approaches already exists about PD for multipliers who in turn carry out professional development for teachers, much more needs to be done. There is an increased need for development activities (such as the development and evaluation of materials for multiplier and facilitator PD) and most of all, a strong need for more research. Conference participants discussed that it is essential to strengthen further conceptualisation, research and practice-based

testing of effective concepts - like the multiplier concept - in order to implement teacher professional development on a solid basis. Open questions in relation to the multiplier concept are, for example: What are the needs of multipliers when carrying out professional development activities? How can they support teachers who struggle with the implementation of innovative teaching approaches? How can they deal with teachers' fears and complaints?

Furthermore, bringing together different concepts and trends, like the 'use' of multipliers and the establishment of professional learning communities in schools needs to be further elaborated in research. Although a research need, such elaboration should involve the practice side from the beginning. Responding to these research needs will require the support of specific projects, the use of existing networks in research and practice and possibly setting up specialised new research groups to facilitate progress.

This leads us back to the broad need of conceptualising scaled-up teacher professional development in order to target and overcome obstacles to its success. A viable approach discussed at the final plenary was to in future more strongly utilise the concept of professional learning communities. In such communities, one of the teachers, or on occasions, an external 'expert', acts as the facilitator. This means that the learning community is more self-directed and immersed in the realities of day-to-day professional practice than in multiplier-provided PD courses. Combining both the concepts of multiplier-led PD with that of professional learning communities (both in research and in practice) promises to lead to sustainable approaches to scaled-up teacher PD. Professional development is most successful and sustainable when it involves collaboration between teachers and encourages reflection and mutual support. Learning communities are an excellent method of fostering these practices, as teachers' day-to-day professional lives contain inherent hurdles to setting up self-sustaining and sustainable learning communities. These hindrances include factors such as time, engagement or distances – and school-based, professional learning communities can help overcome such obstacles.

In addition, e-learning environments may also be a strategy that helps surmount hindrances to scaled-up teacher PD and at the same time, facilitates the use of professional learning communities. However, as we also learned during the conference, e-learning in teacher professional development has its own inherent obstacles. These include: some educators have reservations about using online learning, difficulties involved in adapting PD materials for use in an e-learning environment and the challenge of securing engagement and sustainability in virtual learning communities. In consequence, the use of e-learning in teacher professional development has been identified as an area with tremendous research needs.

The conference made first crucial contributions to achieving scaled-up professional development of European maths and science teachers by discussing different means of scaling up. In the course of the conference and especially during the final plenary discussion, it became clear that it is

necessary to delve even deeper into key issues relating to 'educating the educators' and the improvement of maths and science education at school. The mascil project and the DZLM are working intensively to meet this request within the framework of the project's final conference to be held in 2016.

3 Conference Hosts

3.1 mascil: maths and science for life!

K. Maass, D. Wernisch, E. Schäfer, A.-M. Aldorf
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Mascil is a research, development and dissemination project that aims to advance a widespread use of IBL in mathematics and science in primary and secondary schools. A second – but equally important – mascil goal is to directly connect IBL with the world of work (WoW). This second aspect is a major innovation of the mascil project, so as to make students' learning experiences more meaningful and further, to eventually motivate their interest in careers in science and technology.

Education today needs to go beyond helping students increase their knowledge of various subjects. Greater emphasis must be placed on helping young people achieve competences and skills crucial to their lives beyond school, for example being able to work both autonomously and in teams, engage in critical citizenship and take on responsible roles in a knowledge-driven and technology-based society. However to date, 21st century school lessons remain all too often teacher-centred and do not leave much space for students to acquire relevant competences and skills. Next to subject-matter knowledge, students should learn how to: critically investigate problems and phenomena on their own; find solutions independently (supported by the necessary guidance of their teachers); work in groups; and also justify and present their procedures and conclusions. IBL is an effective way to support building such student competences in mathematics and science lessons. Further, IBL equips young people with skills needed to flexibly acquire new competences within their jobs, use their knowledge in concrete situations and to work successfully in teams and become life-long learners. In the dissemination of IBL within the mascil project, much attention is paid to connecting maths and science, as well as to clearly linking these subjects to work-related contexts and using real-life situations. This helps students to experience mathematics and science as meaningful for their personal – and future professional – lives.

Mascil therefore aims to support a stronger uptake of IBL and connection to the WoW in everyday teaching practices in mathematics and science in schools across Europe. The question essential to reaching mascil's goal is: How can we achieve such a change in teaching and learning methods? Despite the manifold activities and important work of mathematics and science educators in the last decades, changes in day-to-day teaching continue to take place slowly. The key element in the trajectory of change and innovation in schools and education is the teacher. This is why the project activities are centred around the teacher, their teaching and their professional development.

Strategies that effectively support the scaling-up of teachers' professional development are therefore at the core of the mascil project. A distinguishing feature of mascil is the interaction of the work carried out on the international level and the concrete efforts on the regional and local level with teachers, schools and national advising boards. This multi-level cooperation supports an effective and sustainable implementation of project activities.

The key project actions can be summarized as a complex multi-level dissemination and implementation strategy of five pillars:

1. Developing and implementing high-quality teacher training courses in IBL. Teachers taking part in mascil training courses experience inquiry-based teaching methods and are able to integrate these into their school practice through interactive cycles of implementation followed by reflection. Within this concept, IBL-trained teachers become mascil multipliers who in turn offer courses to further teachers.
2. Creating IBL materials for use in mathematics and science classrooms which support engaging students in inquiry in rich contexts form the world of work.
3. Carrying out dissemination activities with target groups ranging from policy and educational authorities, to schools and practitioners to parents and pupils to inform them about inquiry-based learning and the activities of mascil. The regularly published mascil newsletter, two international project conferences, (inter)national project website(s) as well as an international teacher communication platform round off mascil's strategies aimed at achieving maximum dissemination and impact at the international level.
4. Fostering local and European level networks that have the potential to scale up the professional development of teachers and support the take-up of inquiry-based learning with a variety of stakeholders such as representatives from industry, teachers from vocational education and school authorities.
5. Supporting these key measures by a research-based analysis of the implementation and policy context(s) and also offering workshops that are specifically devoted to policy makers.

Integrated into the project is a rigorous continuous and summative evaluation strand. The summative evaluation focuses on the overall impact of the implementation of inquiry-based learning and the connection of mathematics and science to the WoW in day-to-day teaching. The ongoing, formative evaluation targets the implementation and dissemination processes and allows for optimisation during mascil lifetime, as well as a deeper insight into the processes, thus contributing to project sustainability and the informing of future work.

The summative evaluation focuses on teachers involved in teacher training and IBL uptake during mascil. Main objectives of this evaluation are: Evaluating IBL implementation in partner countries at national and European

levels; and gathering information to determine if change takes place. In order to accomplish these objectives, a baseline study was conducted. With this tool, the project investigated the current status of IBL and the connection of mathematics and science to the WoW in the different teaching cultures and collected data about existing approaches and implementation challenges in the partner countries. This study provides reliable information about the status quo at project begin:

cf. http://www.mascil-project.eu/images/pdf/mascilD102FinalVersion.pdf.

Mascil will be able to use its results to help ascertain changes that occur during and after mascil interventions. The pre-post study uses the status-quo study as a baseline and collects project-related data from the perspectives of 50 - 100 teachers per mascil partner country. This study will give information about participants' use of new knowledge and skills, their learning and their reactions to the experience. Furthermore the consortium will try to focus on organizational support. For example, the following aspects will be evaluated:

- beliefs about IBL
- problems with classroom management
- description of current teaching practice
- connection to the world of work

Additionally, analyses will be carried out looking for effects of independent variables like gender or subject. The overall aim is to identify successful ways of implementation and to describe problems and hindrances in terms of successful implementation.

The objective of the formative evaluation along the course of the project is to provide particular insight into: the professional development (PD) process; the impact of the PD courses; the dissemination process; the impact of the dissemination actions during project lifetime; and factors that either support or hinder the widespread uptake of inquiry-based learning and making connections to the WoW. The formative evaluation is based on the scientific case study approach and takes into account the following aspects of the project:

- It is based on the design of mascil as a whole.
- It takes into account the theoretical concept of the PD course and its aims.
- It takes into account the results of the analysis of the educational background.
- It takes into account the different ways of implementation in the various countries.

In order to make the case studies comparable, a common research question was committed. A definition of cases that should be covered within every partner country was constituted as well:

- Common research question: In relation to the implementation of IBL and WoW, what impact has our overall PD concept on participants? What are the reasons for this impact?
- Common definition of cases across all partnership countries. One professional development course in each country should form the framing from which all cases should be drawn. Within each framing data from the multiplier and several teachers will be collected

Data collection for the case studies involves interviews with teachers and multipliers, PD observations and classroom observations, short teacher questionnaires as well as portfolios of evidence from the teachers and the multipliers. By means of these methods of data gathering, amongst others, mascil aims to receive feedback relating to the professional development courses, the mascil professional development toolkit as well as the material collection.

This multi-faceted evaluation concept allows adapting the processes in mascil, if necessary, and gives in-depth insights into the impact of the professional development courses on selected participants, the multiplier concept and the impact of mascil on participants as a whole.

Background information

Mascil is the currently running project of a long series of European projects (LEMA, COMPASS, Primas) which all aimed at implementing innovative teaching concepts in day-to-day teaching. In all this projects knowledge from research was transferred into practice. All these projects were coordinated by Prof. Dr. Katja Maaß from the University of Education of Freiburg, Germany. Since the start of LEMA in 2006 the University of Education in Freiburg has developed into a hub for international cooperation. Within our international network we have more than 1000 contacts with a growing tendency. More information on the projects and especially on Primas, the precursor project of mascil, with a theoretical concept and a research similar to mascil can be found in Maaß & Doorman (2013).

Project mascil (www.mascil-project.eu) has received funding from the European Union's Seventh Framework Programme. During the four-year mascil lifetime (2013 – 2016), 18 partners from 13 countries are working together to achieve project goals:

- University of Education Freiburg, Germany, coordinating institution
- Foundation for Research and Technology Hellas, Greece
- Utrecht University, The Netherlands
- University of Nottingham, Great Britain
- University of Jaén, Spain
- Gesine Kulcke, Germany (terminated 30 April 2014),
- University of Nicosia (Educational Excellence Corporation Ltd.), Cyprus
- National and Kapodistrian University of Athens, Greece

- Sør-Trøndelag University College, Norway
- Leibniz Institute for Science and Mathematics Education at the University of Kiel, Germany
- Babes-Bolyai University, Romania
- University of Hradec Králové, Czech Republic
- Divulgación Dinámica SL, Spain
- Hacettepe University, Turkey
- Vilnius University, Lithuania
- University of Innsbruck, Austria (terminated 31 August 2013)
- Johann Wolfgang Goethe University Frankfurt a. M., Germany (terminated 28 February 2013),
- Institute of Mathematics and Informatics at the Bulgarian Academy of Science, Bulgaria
- University of Münster, Germany (accessed 01 March 2014)
- University of Vienna (accessed 01 September 2014)

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3.2 DZLM - German Centre for Mathematics Teacher Education – *DZLM Team*

Initiated and founded and financed by the Deutsche Telekom Stiftung, a consortium of eight universities started the German Center for Mathematics Teacher Education (DZLM for short) in summer 2011.

Mission

Both, the universities and all other partners involved in the DZLM have a common mission: To accompany mathematics teachers during their whole career. The continuous professional development (CPD) courses are following a competence framework and design guidelines according to the latest research results in teacher education.

Also, comparable concepts for the support and to secure early education in mathematics are developed. These concepts result in CPD courses for kindergarten and elementary educators.

Federal state laws regulates education in general, as well as teacher education in Germany. This autonomy results in a heterogeneity in the systems of further qualification of teachers and educators.

Activities

The DZLM is operating within the 16 German federal states in cooperation with partners in these states. Its activities are in line with a coherent concept for mathematics education from kindergarten and elementary education to upper secondary level that includes diagnosis and advancement of students' learning processes in mathematics. The theoretical framework constitutes the foundation of its activities and builds upon theory and is evidence based. A competence model and design guidelines have been derived from this and serve as a basis for the actual continuous professional development courses. All activities are monitored for quality with a systematic evaluation through transparent criteria.

The activities of the DZLM can be structured in four main strands:

Certified Qualification Measures

- Creation of a nation-wide master course for teacher educators
- Subject-specific and didactical qualification of teacher educators particularly for professional development
- Further qualification of out-of-field teachers
- Qualification events and courses for teachers and elementary educators

Networking and Information

- Networking on a national and international scale through conferences, institutional cooperation and the creation of regional branches
- Cooperation between educational and government institutions or ministries from different German federal states
- Creation of a web portal offering information, material for professional development and interactive teaching environments
- Inclusion of further education offerings from other people, projects or institutions through integration or linking

Research in Teacher Education and Professionalization

- Evaluation of activities of the DZLM and of other agencies
- Research in the effectivity of professional development courses and publication of the results on an international level
- Research based design of the quality framework (theoretical basis, design guidelines and competence framework)
- Initiation and financial support of professional learning communities (PLC) for peer coaching and competence development

Development of Material and Concepts

- Development of material used by teacher educators in CPD courses
- Development of material used by teachers and elementary educators for self-teaching
- Development of information material, videos and fliers
- Joint development of concepts with teacher education institutes and ministries in the German federal states.

4 Keynotes: Abstracts and Speaker Information

For the keynotes we could win renowned speakers from the fields of math and science education: Konrad Krainer, Professor and Director of the School of Education at the Alpen-Adria-University Klagenfurt, Austria; Justin Dillon, Head of the Graduate School of Education, University of Bristol, UK and Peter Birch, Coordinator for Education Policy and Systems Analysis, European Commission.

Scaling-up professional development: chances and challenges
K. Krainer

Professor and Director of the School of Education at the Alpen-Adria-University Klagenfurt, Austria

The keynote showed that scaling-up professional development as larger regional or even nation-wide initiatives needs taking into account the learning of individuals, schools, teacher education institutions, educational administration and policy and the whole educational system itself. Asking some questions related to the scaling-up of professional development (why, how, how long, with whom), a naïve, a technical and a reflective rationality approach are compared. Based on international experiences and research, the keynote elaborates crucial conducive and hindering factors for sustainable scaling-up of professional development. Finally, some of these factors are discussed elated to the Austrian PFL- and IMST-programme (focusing mainly on mathematics, science and language education) which combine nation-wide scaling-up professional development with other measures like the establishment of competence centres and networks.

Biography

Konrad Krainer is professor and director of the School of Education at the Alpen-Adria-University Klagenfurt (Austria). He worked several years as mathematics teacher and wrote his doctoral and habilitation theses in the field of mathematics education. His recent research focuses on mathematics teacher education, school development and educational system development. He is co-editor of several books (e.g., one volume of the International Handbook of Mathematics Teacher Education) and leader of the nation-wide IMST project. Krainer was associate editor of JMTE and is co-editor of the newly established "Journal Praxisforschung". He was founding and board member of ERME and is member of international scientific committees (e.g., Education Committee of EMS, advisory board of DZLM). He gave several plenary presentations at international conferences (e.g., ICME and PME) and is the Chair of the IPC for CERME 9 (Prague 2015).

The role of informal science institutions in teacher education

J. Dillon

Head of the Graduate School of Education, University of Bristol, UK

In many countries, preservice and inservice teacher education take place under the aegis of university/school partnerships. There is a danger, perhaps, that such a system perpetuates some of the weaknesses in the formal education system. In the US, a significant amount of professional development takes place in museums and science centres and has done for many years. A number of EU projects have provided opportunities for exploring the possible affordances of such informal science learning institutions.

This talk described some of the strategies that have been used in projects such as FEAST (Facilitating the Engagement of Adults in Science and Technology) and INQUIRE (which focused on teacher education in botanic gardens). A number of issues emerged from those and other projects which might assist in the development of more integrated approaches to teacher education across formal and informal institutions.

Biography

After taking a degree in chemistry from the University of Birmingham, Justin Dillon trained to be a teacher at Chelsea College (University of London). He taught in six London schools over a period of 10 years with spells as Head of Chemistry and Head of Science. During this time he studied for an MA (Science Education). Prof. Dillon joined King's in 1989 as a Lecturer in Science Education. He was Deputy Director of the PGCE (Postgraduate Certificate in Education) from 1992-5 and Director of International Education from 1995-2003. In 2006 Prof. Dillon was appointed Senior Lecturer in Science and Environmental Education having completed his PhD and he was awarded a personal Chair in 2010. He has been Head of the Science and Technology Education Group since 2007. Together with two colleagues, Prof. Dillon coordinated the ESRC's (Economic and Social Research Council) Targeted Initiative on Science and Mathematics Education and he has directed King's involvement in a number of research projects including PENCIL, INQUIRE, FEAST and IRIS. He co-edits the International Journal of Science Education and was President of the European Science Education Research Association from 2007-11.

Teacher professional development in Europe: perceptions, policies, and practices

P. Birch

Coordinator for Education Policy and Systems Analysis, European Commission

Peter Birch will provide an overview of policies and practices for continuous professional development (CPD) in European countries. His presentation focused on the status of CPD and the different approaches that responsible authorities in education have towards professional development of teachers.

The presentation also dealt with the relatively recent findings of the TALIS report (OECD, 2013) on professional training for teachers, and illustrate the paths of investigation that the Eurydice network is undertaking on the subject, as well as the main policies of the European Commission in this area.

Biography

Peter Birch is coordinator for education policy and systems analysis at the Executive Agency Education Audiovisual and Culture of the European Commission. Among other things, he is currently coordinating a report on the teaching profession in Europe focusing on initial teacher education, continuous professional development, job satisfaction, and attractiveness and retention. He has a degree in foreign languages and Master degree in Education with the Open University UK. He has been involved in projects dealing with e-Learning, language learning, and school quality assurance. He has experience as teacher and trainer.

5   Presenter Programme

Each track was opened by a track plenary presentation given by an expert of the field. Hereafter a brief summary of each track plenary speech is given.

5.1   Track 1 plenary: Scaling-up with multipliers in face-to face professional development courses

Long-term Teacher Professional Development: Lessons learnt from PRIMAS

J. Farrugia

Senior Lecturer, Faculty of Education at the University of Malta

This presentation aimed to identify and describe some lessons learnt from the experience of providing long-term professional development (PD) to a group of 50 Maltese teachers participating in the EU funded FP7 project aimed at promoting IBL in Mathematics and Science classrooms across Europe, PRIMAS. The teachers, who participated on a voluntary basis, were provided with professional development in small groups of five who met every two weeks with a PD facilitator (multiplier) for two scholastic years. The group of 10 multipliers involved, met once every two weeks with the team of university lecturers who were participating in PRIMAS. The two-hour sessions focused on a variety of matters: working out tasks/activities from the PRIMAS PD modules; discussing ways of adapting tasks and modules to the local needs; and sharing and discussing challenges and problems that teachers encountered together with feedback from schools. Together they reflected on ways of overcoming the difficulties.

This presentation was based on feedback about the model of professional development adopted, its effectiveness and limitations with emphasis on the experience of the multipliers. Data were obtained through interviews with multipliers and teachers; observations of PD sessions and lessons; as well as teachers' reflective journals.

Biography

Dr. Josette Farrugia has taught chemistry in Malta at the secondary and   post-secondary level for a number of years. She has also worked as the Principal Subject Area Officer for Sciences with the Matriculation and Secondary Education Certificate Examinations Board of the University of Malta (MATSEC) and is currently a Senior Lecturer in Science Education with the Department of Mathematics, Science and Technical Education of the Faculty of Education at the University of Malta. Her research interests relate to various

aspects of science education and educational assessment and include: problem solving; practical work and investigations; school-based assessment; inquiry-based learning and students' understanding of scientific ideas and concepts - especially those related to chemistry.

5.2 Track 2 plenary: Blended learning concepts and e-learning support

Blended learning and e-learning support within the context of Cornerstone Maths – The changing culture of teachers' professional development

A. Clark-Wilson

Research Fellow, London Knowledge Lab, Institute of Education, University of London

Cornerstone Maths is a collaborative US/UK project between Stanford Research International and London Knowledge Lab that has been designed to address (at scale) the underuse of dynamic mathematical technologies by lower secondary pupils in English schools. This is being achieved through ongoing design-based research that has resulted in three curriculum units of work that address the universally acknowledged 'hard to teach' topics of linear function, geometric similarity and algebraic patterns and expressions. The materials are designed to support mastery of these key concepts through context-based sequences of activities that combine pupils' materials, bespoke software, teacher materials and professional development.

This plenary focused on the design of the professional development, which blends face-to-face work, synchronous, asynchronous and on-demand online activity and an online teacher community. Data from the current project, which involves 243 teachers from 107 schools, was presented that will highlight how teachers are responding to such opportunities and the implications of these findings for the ongoing design of professional development.

Biography

Alison originally qualified in chemical engineering before training to teach secondary mathematics. She taught in inner city schools where she became both a Head of Mathematics and was recognised as an Advanced Skills Teacher. She holds a Master's degree and doctorate in mathematics education. She moved to the University of Chichester in 2001 where she designed and led postgraduate courses and projects for practising secondary mathematics teachers, often with an emphasis on the development of innovative pedagogies involving the use of mathematical technologies. She directed the UK evaluation of Texas Instruments' TI-Nspire and the European evaluation of their TI-Nspire TI-Navigator network classroom system.

From 2009-2012 Alison had the role of the project lead partner in the EU Comenius funded project EdUmatics, which involved 20 Partners from seven

EU countries (www.edumatics.eu). Alison took up her current role in 2013 where she is a full-time researcher on the Cornerstone Maths project (www.cornerstonemaths.co.uk). She has edited and authored 3 books, the most recent of which is The Mathematics Teacher in the Digital Age (with Ornella Robutti and Nathalie Sinclair, published 2014).

She is an active member of many of the UK professional and academic communities to include: the Association of Teachers of Mathematics, The Mathematical Association and a Fellow of the Institute of Mathematics and its Applications. She is an elected member of the Executive Committee of the British Society for the Learning of Mathematics and she convenes the mathematics education special interest group on behalf of the British Educational Research Association.

5.3 Track 3 plenary: Disseminating and scaling-up through materials

Prepared to use it? – Disseminating and Scaling-up Professional Development Through Materials

M. Welzel-Breuer

Professor for Physics and Physics Education at the University of Education Heidelberg, Germany

A huge amount of excellent teaching and learning materials already exists in Europe, but there is a slightly increasing practice and experience only at using these materials within regular classroom activities and outside. All over Europe, teachers have multiple possibilities to use ready-made and tested teaching and learning materials in their science classrooms. International projects – e.g. funded by the European Union - , specialised companies, schoolbook publishers, universities and teacher training institutions, offer these materials. Research results from science education show, that there are good chances for improving the classroom practice and scaling up professional development if the materials are appropriately used and adapted to the specific needs within the schools of different countries.

Starting with a view on existing practices, with this presentation, Welzel-Breuer intended to present selected resources ready to use for science teaching and teacher education. Ways on how to scale up professional development by networking were discussed. Some experiences and research findings were presented in order to encourage the trial.

Biography

Manuela Welzel-Breuer accomplished her PhD study in 1994 at the University of Bremen, Germany, focussing individual learning processes of single students through analysing videotapes in order to investigate their interactions while learning physics.

Since 1999, Manuela Welzel-Breuer is working as Professor for Physics and Physics Education at the University of Education Heidelberg. There, she is educating pre-service science teachers of different school types. In addition, she is involved in science education research and development in the fields of physics education for different age groups, the use of computer aided learning environments and the design of effective teaching-learning environments.

Being internationally active, she co-ordinated a European project on the use of computer aided teaching and learning materials (CAT) in science education, which resulted in an international teacher training course offer.

For several years, Manuela Welzel-Breuer served as member of the executive board of the German Physical Society (DPG) and the European Science Education Research Association (ESERA). Since 2011 she is leading ESERA as President.

5.4 Track 4 plenary: Professional learning communities

Learning on three levels – students', teachers' and educators' learning from the Learning study

U. Runesson

Professor in education at School of Education and Communication, and Faculty Dean at Jönköping University, Sweden

The Learning study was introduced in Hong Kong and Sweden some fifteen years ago. It combines the teacher driven Lesson study with the theoretical grounded Design experiment. In the Learning study, the educator (acting as a facilitator) and the teachers have a shared goal; to gain knowledge about the nature of the object of learning in order to enhance students' learning. In an iterative process of planning and evaluating lessons the teacher team collects data that is used for inquiring how teaching affect students' learning. In this process a theory of learning, commonly variation theory (Marton, Runesson & Tsui, 2004; Marton, 2014,) is used as a guiding principle. Several studies have demonstrated that the Learning study has effect, not just on students' learning, but on teachers' professional development too. However, the educator can benefit from the Learning study also.

In the presentation Runesson demonstrated how and what educators can learn from participating in the Learning study.

Biography

Ulla Runesson is professor in education at School of Education and Communication, and Faculty Dean at Jönköping University, Sweden. She is also a visiting professor at Wits school of education, University of the Witwatersrand, Johannesburg, South Africa.

Her research interest is learning and teaching in mathematics and the teaching profession in general. Ulla Runesson has been involved in international research projects studying and comparing classrooms in different countries. Several of her publications are based on research in cooperation with colleagues in Hong Kong, Australia and South Africa. She is also engaged in the development of variation theory, and Learning Study.

6   Papers

6.1 Track 1: Scaling-up with multipliers in face-to-face professional development courses

Professional Development of experienced Teachers -

H. J. Brenner

Albert-Schweitzer-Gymnasium, Erfurt, Germany

1   Preliminaries

Professional development of experienced teachers of mathematics should be a major issue, both school administrators and teachers should be concerned about. I have been dealing with proposals for improving the possibilities of learning mathematics for the past 13 years.

In workshops for teachers of mathematics in Thuringia I present my ideas, practise and discuss certain activities with them. The aims of my paper are to explain reasons for my suggestions, my approach to teaching and furthermore to introduce the mathematical contents I selected because of my contemplations. I would like to contribute to the clarification of the question of how to become a teacher educator. There is a real need of professional competence.

I am teaching the subjects mathematics and physics at the Albert-Schweitzer-Gymnasium Erfurt.

2   Professional development and lifelong learning

"The education of teachers of mathematics is an ongoing process … that spans a career. Teachers' growth requires commitment to professional development ... Their growth is deeply embedded in their philosophies of learning, their attitudes and beliefs about learners and mathematics, and their willingness to make changes in how and what they teach." (NCTM 2012)

According to this statement one has to find out what teachers' attitudes towards mathematics are influenced by (including school mathematics) and what leads to disturbances and to use these findings as a chance to manage problems in a positive manner. One has to pay attention to the fact that the attitudes are deeply rooted and the time for intensive learning processes is very restricted because of the sometimes difficult working conditions.

Apart from this one has to take into consideration that the mathematical content knowledge und the pedagogical content knowledge are closely combined with each other and should be developed at the same time. For the reason that the pedagogical content knowledge is linked with mathematical tasks prepared for the use in the lessons (Bromme 1992) special mathematical themes have to be presented by appropriate problems and in connection with tasks. "What many teachers lack is mathematical knowledge that is useful and

usable for teaching … The conditions to learn mathematics in ways that prepare teachers for their work are often unsatisfactory and few curriculum materials do effectively provide helpful mathematical guidance and learning opportunities for teachers." (Ball, Bass 2003)

We distinguish and are concerned with: Elementary mathematics: that part of mathematics we can draw conclusions with a few simple arguments and with the help of intuition and of common sense. School mathematics: that part of elementary mathematics which is described by the tasks of central examinations and by usual school books. Advanced mathematics: mathematicians deal with – in general you cannot reason and explain the results with a few arguments.

The teacher educator has to show how themes beyond school mathematics could help to increase the awareness of deep mathematical ideas and concepts which are used in school mathematics. Therefore, professional development courses consists mainly of two parts. Main part: Widely unknown problems, concepts, theorems of elementary mathematics combined with didactical explanations – chosen on the basis of experience and thorough analysis of the general situation. Further on: Ways to advanced mathematics which allow the development of a deeper understanding of fundamental concepts, of imagination, the use of visualization and which are connected to at least one part of school mathematics.

Educating the educators means to support the self-education of the educators. The main condition is a constant preoccupation with mathematics.

3 Observations and comments

Conclusions and proposals should be formulated after a critical analysis of the culture of teaching and the content of the school mathematics which is taught. I am going to describe some experiences I gained, which characterize the situation in Thuringia.

Facets of the professional knowledge of experienced teacher: skilful acting in the mathematically restricted area of school mathematics and passing central examinations successfully; focusing on methods of algebra caused by the striving for effectiveness and simplification; neglecting ideas and concepts which are related to the content taught, which use imagination and visualization and which make use of the concepts of natural science.

That has negative effects and consequences: some widely unknown ideas and concepts of elementary mathematics which serve connection between themes of school mathematics and natural sciences and which make a deeper understanding of the concepts of school mathematics possible; an uncritical attitude towards tasks of central examinations and the decline in the willingness to take part in training seminars.

3.1 The mathematical culture of classes

Many authors analysed the situation of German mathematics education and found out what has to be done in a better way. (TIMSS, PISA, Coactiv, expertises of Winter/Baptist, Borneleit et. al., Kaiser/Henn) In addition to all those findings I observe that mathematics teachers tend to use the known algorithms without reflecting critically about the specific task (tendency to uncritical attitude). The following examples show the uncritical attitude towards tasks of central examinations.

The first example of the final examinations 2011 gives an impression of what usually happens in classes: "Given is a box ABCDEFGH (the base is a square with length 3, height of the box: 13) by two points A(0,0,0) and G(3,3,13). Draw the image of the solid in a rectangular coordinate system …" Nobody noticed and complained about the incomplete description of the position of the solid. I talked with other colleagues after the examination. They did not recognise the gap. In their opinion this mistake within the task is not worth mentioning.

This attitude is reasoned by the belief system many teachers have. Mathematics is more and more considered as a set of knowledge that has to be known and as a set of procedures which have to be followed and executed. Unfortunately these attitudes are supported by the interpretations of the educational standards through simple and short tasks in tests and the final examination.

The second example is of the final examination in 2005. "A function f is given by $y = f(x) = \frac{8x}{4x^2+1}$ … Draw the graph … There exist exactly three tangents at the graph which have no further point with the graph in common. Give the equation of these tangents." There are 5 tangents of this property. Only four teacher considered this.

3.2 The mathematical contents which are widely unknown

For many the reasons mathematical contents and problems have to be selected carefully. But they are mainly given by the curriculum and central examinations. Therefore the domain of tasks and problems is very restricted. That shapes the professional knowledge of the teacher.

Example 1 (central examination): "Prove that y=2x-2 is the equation of the tangent at the graph of the function with y=x^2-2x+2 at P(2,2)." It was unknown to the teachers who was responsible for the tasks of the final examination that one could confirm this assertion by transforming x^2-2x+2=2x-2 to (x-2)^2=0. It is unusual to introduce the concept of tangents as a line that snuggles up to the graph and that gives the linear approximation at the point P. The competence which is desired is the use of the differential calculus which students should always practise.

Example 2: Drawing without replacement: a box with 8 white and 12 black spheres; drawing 5 times; X = number of white spheres which are drawn. Are

the spheres in a calculation model numbered or not if you use the formula
$P(X = 3) = \frac{\binom{8}{3}\binom{12}{2}}{\binom{20}{5}}$?

Example 3: Imagination of linearly independent vectors: "I am a runner in my free time. I run a very difficult circular route. It goes uphill every time."

Example 4: A jumping ball lose the same part of energy (altitude) during each impact. This leads to the exponential function.

Example 5: The fundamental theorem of calculus is not seen as a relationship between two quantities for instance $\frac{ds}{dt} = v \leftrightarrow s = \int_{t_0}^{t} v \cdot dt'$.

Example 6: The concept of a continuous function and the derivation of important properties have almost disappeared in mathematics education of Thuringia. We make no use of our deep understanding of the concept in connection with physical phenomena for instance when we want to describe an equilibrium.

4   Conclusions and proposals

Educational seminars on mathematics (school -, elementary and advanced mathematics) have to be a genuine part of the monthly schedule of each teacher. Teachers must have time and space for dealing with mathematics intensively. This should include the competence to explain natural phenomena mathematically and the identification of questions related to mathematics and its use in sciences.

The variety of appropriate topics is enormous. The choice has to take into account the special attributes of the mathematical culture and the distinctive needs. I discover the following crucial points for Thuringia: elementary analysis, combinatorial analysis and geometry; arguing, reasoning and proving; the combination of mathematics and physics. We have to pay attention to the interdependence of the themes and to the fact that there are very important examples and problems which lead to deep ideas. And we have many examples of less importance – we have to figure out.

Example 1: Determination of extreme values without calculating derivatives (Brenner 2009). That is a well-known suggestion which has not lost its importance.

Example 2: The exponential function y=a*exp(b*x)+c and its application (Brenner 2010A, Brenner 2013). Derive properties of (an unknown) solution from the functional equation, linear recursional equation and linear differential equations.

The main aims of the seminars are: a) using the method of direct and indirect argumentation; b) developing mathematical models of phenomena of natural sciences; c) getting a broader understanding of calculus and in particular of the fundamental theorem of differential and integral calculus and the mean value theorem; d) improving PCK by using analogies, imagination, models and heuristics and e) working on the problems independently at home by means of

literature and of a distributed flyer. Seminar participants should think and reflect about the following tasks for instance.

Which properties does the solution of $y' = 6 + 2 \cdot y$ and $y(0) = 0$ have? Do not use solving algorithms – we train arguing. Vary the problem to get different properties. Make suggestions to get solutions - guessing like a student would do.

Switch on a coil and a resistor connected to a constant voltage source. We get $U_0 = R \cdot i + L \cdot \frac{di}{dt}$. Why? Explain $\int_0^t (U_0 i - Ri^2) \cdot dt = \frac{1}{2} Li^2$ and that i is bounded: $i \leq i_{max}$ by examining the integrand.

Switch on a capacitor and a resistor. Show: $U_0 = R \cdot i + \frac{1}{C} \cdot q \rightarrow U_0 q - \frac{1}{2C} q^2 = \int Ri^2 dt$. Explain why the left side of the last equation is increasing. What is the implication on q?

Example 3: The method of Green (Brenner 2013). The intensive exploration of problems which leads to this method makes it possible that an important but neglected competence comes in focus: building up and strengthening imagination. We make use of the following fundamental concepts: indirect argumentation, the method of Archimedes, additive quantities – superposition, linear operators and linear combination. Here are two examples: falling bodies with friction force and a mixing process.

A sphere is falling in water – calculation of the velocity v at a moment t due to the assumption that the friction force $F_f \sim v$ and therefore $m \cdot a = m \cdot \dot{v} = m \cdot g - k \cdot v$. Give help to examine the problem (heuristic). Assume $\dot{v} = 0$ and draw conclusions. Describe the role of $v(0)$ and especially of $v(0) = \frac{m \cdot g}{k}$. Draw graphical representations. Simplify the equation: at first $\dot{v} = -v$ and then $\dot{v} = 1 - v$. Guess and discuss solutions. Use analogies: (1) sequences with $a_{n+1} = q \cdot a_n + b$ and $-1 < q < 1$ (take in consideration the restricted growth) and (2) switching on a capacitor and a resistor: consider the charge behaves analogously to the velocity.

Modelling and imagination for $v(0) = 0$: decomposition of the interval $0, t'_1, \dots, t'_n = t$. Interpretation of the solution of $\dot{v} = -v$ and $v(0 \dots t'_{i-1}) = 0$ and $v(t'_i) = g \cdot \Delta t'$ $v(t)$ is the sum of all component parts at the moment t: $v(t) \approx \sum g \cdot \Delta t' \cdot e^{-\frac{k}{m}(t - t'_i)}$.

Mixing process of saline solutions – calculation of the mass m(t) of the salt in the tank: A tank, with 1000L water, is filled with saline solution: 10L of water, in which 2kg of salt are dissolved, are added per minute. At the same time 10L saline solution leak out per minute. What considerations/imaginations lead to $m(t) = \int_0^t dt' \cdot 2 \cdot e^{-\frac{1}{100}(t - t')}$?

Example 4: The Brachistochrone-Problem (Brenner 2010B). The theme combines: elementary and advanced analysis, elementary geometry und the law of free falling. The use of modern calculators brings advantages.

5 Example for a hand-out

The hand-out is a self-study material and for the use in classes. Teacher get the hand-out after participating in the regional professional development course. It should help to become familiar with new ideas and concepts.

Introduction to the theory of probabilities for 10th graders

Examples of teaching maths using Computer Algebra Systems

The possibility of using computer algebra systems (CAS) in mathematics education gives grounds to think about changing the teaching and learning methods on the one hand and to realize them on the other one. Of course we do not think about the ways of using the computer primarily, but we consider mathematics education and the possibilities of improving teaching and learning. Secondly we search for models, tasks, tools etc. to turn these thoughts into reality. Sometimes CAS will be an appropriate tool for this.

In the following I want to have a closer look at two major problems.

First the new tools should be used in mathematics education more intensively to give students the possibility of getting a better understanding of mathematical contents and coherences because of greater clarity than before.

Second the students should get opportunities of learning with a partner or in groups. There are at least two reasons: the social dimension of learning on the one hand and the more practice they get on the other hand. (Pay attention to the difference between theory and practice.) The following requests should be clear to everyone: "To explain that to your partner" or "to find arguments for or against your conjecture and discuss that with your neighbour".

While introducing the probability calculation to 10th graders I have chosen the following aims.

1) Searching for models and considering them should be more intensified.

2) Students should find and examine algorithms by themselves and that should lead to a deeper understanding of concepts and coherences in the theory of probability.

3) Students should be able to develop first small programs on their own or with the help of their partner.

I would like to report on the methodology I have used and I want to explain some of my experiences.

In the beginning of this teaching unit the students have learned how to make an input or to get an output. They have learned how to use computer commands exactly with the help of the book or by listening to the lectures of students or of teacher.

Examples: linear and quadratic functions: zeros, points of intersection with coordinate axes, special values, tables of values; direct proportional and anti-

proportional magnitudes – asking for upper/lower bounds (simple examples); introduction of the "IF THEN instruction"

Further on the students have to familiarize themselves with FOR TO slope.

Examples:

a) What do the following orders cause?

    a1)   INPUT a : FOR b = 1 TO 7   DO a := a – 1 : NEXT b : PRINT a

    a2)   INPUT a : s := 0 :   FOR b = 1 TO a DO s := s + b : NEXT b :   PRINT s

    a3)   FOR i = 1 TO 4 DO : FOR j = i + 1 TO 5   DO   PRINT i, j : NEXT j : NEXT i

b) Develop programs for solving the following problems. Generalize them if possible.

    b1) Add to a chosen number step by step 12 times 3. The progress has to be displayed.

    b2) Add the odd numbers from 5 to 31. The progress has to be diplayed.

    b3) Determine the product of the first natural numbers from 1 to a chosen number.

    b4) Calculate the powers of 3 and display the powers with an even exponent.

    b5) We choose an arbitrary number x and calculate its square, after that the square of the square and so on: that are x, x^2, $(x^2)^2$,... Is the power after squaring it 8 times greater than three halves if x is chosen greater than 1?

The following problems have been taken from combinatorial analysis.

1) The number of arrangements (permutations) of n different objects is n! The term n! has been concluded in a direct and in a recursive way. The following problem is suitable for practice.

We consider all permutations of numbers 1, 2, 3, 4, 5 and treat each permutation as a number with 5 digits. We assume now that all these numbers are ordered in a natural way, to begin with the smallest. What number has the place of 23154 in the sequence and what number is at place with number 76?

2) Students conclude through consideration of several examples that there are (m + n)!:m!:n! different arrangements of m white and n black spheres. It was proved by students that AABCDE has 6!:2! different permutations.

3) The number of combinations of n objects taken k at a time is equal to n!:k!:(n-k)!. First, that has been confirmed by considering some examples. Students have found out a way to write down all selections for small numbers n and k systematically. The teacher has shown how this can be proved by a one to one assignment. We consider 1, 2, 3, …, n and we make a tick below each element we want to choose and make a cross below if we do not want to choose that element. Each selection is assigned to an arrangement of ticks and crosses and conversely.

On the basis of the following problem students are also able to learn to work systematically and further on the feasibility of using a one to one assignment.
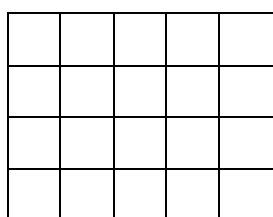
We are looking for the number of all the shortest ways from the vertex (lattice point) O which is on the top left to the vertex R which is at the bottom right. The ways have to be chosen on the lines which are displayed above.

Students have started the examination on the basis of smaller rectangular figures of size 2 times 2 and 2 times 3. Systematically they have tried to find the solution. Because of the small size of the figures they have done it successfully. The examination of bigger ones like 4 times 3 figure in a simple manner often fails, some of students have made mistakes. That is the point to suggest working systematically. The teacher gives hints by asking the right questions. For instance: "You want to get to vertex V. There are at most 4 vertices around V. Which of these vertices do you have to pass on one of the shortest ways? Imagine you know the number of the shortest ways to get to the vertices around V. How can you get the unknown number of the shortest ways to V by the use of the supposed numbers?" Student should become aware of the recursive way of finding that solution – step by step with the use of properties of predecessors. For getting practice I have asked for the number of shortest ways which include a chosen vertex W.

The connection of that problem to the number of arrangement of letters is that each way can be described by a word "rrbbrbrbbr". "r" stands for "go to the right" and "b" stands for "go to the bottom". One has to go 5 times to the right and 4 times to the bottom, altogether 9 segments. Students have to draw such a way into the figure and make clear that they can assign each word to a way and conversely. It is one-to-one. Thus we have 9!:5!:4! shortest ways.

Usually at the beginning of the introduction into the theory of probability I make students familiar with the following first problem. "Imagine, we have a box with one white and five black spheres in it. All spheres have the same size and

surface. Alternately two persons A and B draw one sphere each path without replacement. The winner is the person who drew the white sphere. Which person can take advantage of it?"

After a first short discussion students have to vote on which person they want to be. Then students play this game some times. (It is easy to simulate the game.) They have to vote again and they have to give reasons for their choice and first explanations. To decide on the problem the teacher asks the students if they can accept this as a model for that game. A and B draw until the box is empty. Each sequence of moves corresponds to an arrangement of these 6 spheres. There are 6 arrangements exactly, for instance bbwbbb, and each A and B wins the game 3 times. Therefore they have the same chance. But, what about the case if students do not trust in that model. Then we have to decide by experiments and the calculation of relative frequency whether the model describes reality right or wrong and we have alternatives to discuss the conditions and assumptions for the model.

After discussing the concepts frequency and probability Students were instructed to develop a program at home which simulates throwing dice and calculating the relative frequency. Students accepted immediately that a computer is able to choose numbers of an interval randomly, because "a computer is able to do all you want". That programme needs instruction IF-THEN-ELSE. It is the best way leaving students alone with the problem. At least one student is able to solve it. He or she shows how it works and helps the others to enter the programme. Of course you can show how the random variable "relative frequency of throwing number 6" converges to 1/6, but it is up to the teacher to do that.

Consideration about drawing spheres without replacement

We consider a box with 8 white and 12 black spheres in it and we draw 5 times without replacement. (It is easy to generalize.) Each sphere can be drawn equally likely. X is the random variable which indicates the number of white spheres which are drawn. Thus the values of X are W(X) = {0, 1, ..., 5}. I would like to display some representations of the probability of drawing 3 white spheres, that is P(X = 3).

$$(1) \quad P(X = 3) = \binom{8}{3} \cdot \binom{12}{2} : \binom{20}{5} \quad (2) \quad P(X = 3) = \frac{8}{20} \cdot \frac{7}{19} \cdot \frac{6}{18} \cdot \frac{12}{17} \cdot \frac{11}{16} \cdot \frac{5!}{3!\,2!}$$

$$(3) \quad P(X = 3) = \frac{1}{20!} \cdot \frac{8!}{3!\,5!} \cdot \frac{12!}{2!\,10!} \cdot 5! \cdot 15! \quad (4) \quad P(X = 3) = \frac{1}{\frac{20!}{8!\,12!}} \cdot \frac{5!}{3!\,2!} \cdot \frac{15!}{5!\,10!}$$

These terms (1) to (4) are derived from the following models.

(1) We imagine all spheres are different (w1, w2, …, w8, b1, …, b12) , but each of it can be drawn equally likely. Therefore we have 8 over 3 = 8!:3!:5! possibilities to take 3 white spheres out of 8 at a time. (We have to notice that this is a different situation to what we have assumed before.) We get 12!:2!:10! combinations of 12 black spheres taken 2 at a time for each combination of

white spheres. Because of assuming that each selection is equally likely we can use the definition of Laplace.

(2) Conditional probability is used. The probability of drawing 3 white spheres first and 2 black spheres afterwards is multiplied by the number of arrangements of 3 white and 2 black spheres. Assumptions are made that all arrangements are equally likely and the white/black spheres are equal.

(3) We consider all arrangements of 20 different elements (w_1, w_2, …, w_8, b_1, …, b_{12}). Each arrangement corresponds to a sequence drawing until the box is empty. How many arrangements do we have and which of them have 3 white spheres at the first 5 places? We select 3 of 8 white spheres and 2 of 12 black ones and we multiply them by the number of arrangements of the 5 chosen elements and of the 15 remaining ones.

(4) The term is built on the basic of assumption that we have 8 white spheres which are equal and 12 black ones which are equal too. Furthermore it is assumed that all arrangements of these spheres are equally likely if we draw until the box is empty. It remains to determine the number of arrangements which have 3 white and 2 black spheres at the first 5 places. All together we get (5!:3!:2!)*(15!:5!:10!) different arrangements, because there are 5 white and 10 black spheres at the last 15 places.

Which solution seems to be more practicable for the first time? Is it easier to follow the steps of modelling and computing or even to find it out by oneself? There are different reasons for using (4) and (2) at first. For instance students who use (1) have difficulties to react to the provocative remark: "There is only one possibility of picking 3 spheres from 8 which are equal." Furthermore working on expression (4) helps the students to become more familiar with the model.

For the examination of the underlying model of (4) I have decided to create a program together with my students which simulates drawing without replacement. We got diverse possibilities for consolidation and practice of underlying ideas and proceedings while working out the program together. At this point students have got a better understanding by having achieved more clarity and a greater knowledge about coherences. Writing a programme requires the student's deeper familiarity with the model and with the basic knowledge of the theory of probability. The computer is a means to an end. Students must understand the basic of the algorithm.

The programme: drawing without replacement

At first I asked for all choices of k elements out of n different ones on basis of 3 out of 5 and a method to write down these choices in an ordered way. Example: Students looked for all subsets with 3 elements of {1, 2, 3, 4, 5}. The subsets which have 1 as an element are {1, 2, 3}, {1, 2, 4}, {1, 2, 5}, {1, 3, 4}, {1, 3, 5}, {1, 4, 5}. Three of the subsets which have 2 as an element are found. The remaining subsets with 2 in it are {2, 3, 4}, {2, 3, 5}, {2, 4, 5}. And in the end: {3, 4, 5}. Usually students find all subsets. "But, have we actually found all

subsets? Explain!" and "Write a program which prints all subsets! Use command FOR TO!" are tasks which can be solved not only by gifted ones because all students have examined a similar example (a3) in a lesson before.

The following program prints all subsets with 3 elements. At the beginning we assign value 0 to variable a. Variable a stands for "number of printed ordered subsets" and variable n is the number of elements of the given set {1, 2, …, n}.

FOR i = 1 TO (n – 2) DO : FOR j = i + 1 TO (n – 1) DO : FOR k = j + 1 TO n DO a:= a + 1 : PRINT{i, j, k}

(in the next programme: IF THEN order; if condition is true, then b:= b + 1)

NEXT k : NEXT j : NEXT i

Now the teacher explains the coherence between "selection of 3 out of 5 " and "drawing without replacement out of a box with content wwwbb what means that 3 white and 2 black spheres are in it". Each complete draw without replacement of 5 spheres corresponds to an arrangement of these spheres. The elements of a subset with 3 elements mark the place of white spheres in an arrangement. We have a bijection between (set of) subsets and (set of) places of white spheres. In classroom teaching I have chosen for drawing 3 spheres without replacement examples for the calculation of P(X = 2), this is the probability of drawing 2 white spheres exactly. For the first example we have had 5 spheres in the box, that is n = 5 (and for practice n = 6 and n = 10). We have been able to evaluate probability by counting arrangements which have 2 white spheres on the first 3 places. We have written all subsets and arrangements (n = 5) on the black board and tried to find a criterion that the computer can count. Solution: Variable b counts cases with 2 white spheres at the first 3 places. At the beginning we assign 0 to b. If j = 3 then i = 1 or i = 2 and we have X =2. Furthermore all cases with j = 2 and k > 3 counts. The order we looked for is:

IF j = 3 or (j = 2 and k > 3) THEN b := b + 1. That is all, very simple.

I hope that the methods described above have led to a better and deeper understanding, to get a better overview of the coherences and the basic of the theory to my students. I feel confirmed. And there is an extra bonus: The students and teacher have enjoyed their lessons.

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Building capacity: developing a course for mathematics and science teacher educators -

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Abstract

We report the background, conceptualisation, design and initial stage of a distance learning Masters course for mathematics and science teacher educators. The course coordinates research, experience, and reflective practice for the educators, of whom some are school-based, others in universities and others in systemic roles. It has been developed in the UK and is informed by local and global changes and developments in subject teacher education, drawing on international research and local and global experience. The development process included outline planning of course units and their interrelatedness, and the development of a storyline that connects course content with participants' development as teacher educators. The students work in the main as communities of critical professional practitioners in a distance learning online context as well as with some face-to-face experience. The experience and geo-location of the course participants are widely varied and this has presented both challenges and opportunities for course development and design; the initial planning for and handling of diversity in the induction unit, which is face-to-face, is described. The paper relates to theme 1 because the aim of the course is to scale up high quality mathematics and science teacher education. However, this will not be achieved through networking or cascading, but through developing the capacity of individual teacher educators to work effectively, and in a research informed manner, in their own face-to-face contexts.

1 Background

The University of Oxford Department of Education has a tradition of research-based approaches to teacher education, particularly in mathematics and science. In the 1980s we pioneered a pre-service course which integrated school-based experience with systematic input and reflection in the University context (McIntyre and Hagger 1993). This established an approach to professional learning through research informed reflection, which we have maintained and developed over 30 years. The national and global shortage of mathematics and science teacher educators has led us into providing input and guidance globally, often because these subjects are taught through the English language in non-English speaking countries. During the last two decades there has been a rapid increase in international research into mathematics and science teacher education (e.g. Even and Ball, 2008; Loughran, Mulhall and Berry, 2008), with significant contributions from University of Oxford (e.g. Childs and McNicholl, 2007a), and also comparative studies of systems and practices (Tatto and Ingvarson, 2008), as well as an

increase in policy and practice sharing (Appleton et al., 2013). These strands of development led us into an altruistic desire to contribute to global capacity in teacher education through developing cohorts of educators who have studied together in a sustained, coherent, knowledgeable and research informed manner. We believe this to be more valuable than to develop our own commercial and consultancy activities.

We realised that we are well placed to develop a high quality course of international standing in which people involved in mathematics and science teacher education in a wide range of contexts could develop the capacity to engage critically with the task, and hence be shapers of policy and practice in their own contexts. The need for teacher educators to have an informed view of the task is evident in the expansion of literature about teacher education and also from our own knowledge of the backgrounds of teacher educators. The desirable qualities of the teacher educator might include: personal subject knowledge; pedagogical experience; pedagogical knowledge; didactical knowledge; knowledge about professional learning; and, if they are working in the University context, they also need to be developing academic and scholarly propensities. In many models of teacher education several of these qualities are unattainable. To become a teacher educator therefore requires personal professional learning, and our course therefore aims to develop habits of critical comparison of structures and practices; informed reflection on personal practice; development of research as a tool to develop knowledge and practice; the development of the international community of reflective research informed practitioners; induction into mathematics or science education as a field of scholarship.

2   Course design

The key principle underpinning the course is building the capacity of mathematics and science teacher educators, whether involved in pre-service or in-service education, to provide relevant, research-informed professional learning in their context. Unlike courses that draw people out of their context, participants remain in their own context. Rather than using a train the trainer model we scale up professional development in mathematics and science education by building on the expertise of participants through online collaboration and discussion of their own experiences in the light of key literature. The course thus ties together existing trends, successful models, helpful experiences, needs and visions to create sustainable change in the participants' own contexts.

The initial cohort is drawn from a range of backgrounds and geo-locations, including Papua New Guinea, South Africa, the Middle East, the USA and the United Kingdom. All participants are teacher educators, employed at least in part in the education of mathematics or science subject teachers. Their involvement in teacher education encompasses university-based content or pedagogy-related teaching for prospective teachers; school-based pre-service and in-service courses; professional leadership in school settings or systems;

provision of professional development materials; mentoring and coaching;, and so on. We therefore have to coordinate the needs of teacher educators who may themselves have never taught, or who may have limited subject knowledge, or who may have little experience of teacher development. The formation of the cohort as a learning community through face-to-face residentials and various online forms of communication enables learning that is informed by comparison of knowledge and roles, and will be shaped and structured by research and professional literature.

Assessment will recognise the working contexts of the participants, and will be soundly based in the production of reports about practice-based activities that include elements of action research and collaborative work with workplace colleagues and with other course participants. Each assessment has a practical context-based component, with analysis informed by key readings from the literature. For example, Assessment Task 1 requires participants to observe and interview a teacher with whom they are working, and to discuss how this teacher's beliefs about the nature of the discipline and of learning are reflected in his or her practice and reflections on a lesson. Assessment Task 2 investigates the dynamic nature of teachers' content and pedagogical content knowledge (Shulman, 1994) as revealed in practice. All reports will be written to a Masters standard so that participants are well-prepared for future study and future academic work.

The course design therefore includes all the usual challenges for e-learning professional courses, and also the challenge of having an extremely varied knowledge and experience base among the participants. We see the latter as providing rich opportunities for learning through critical comparison.

3   Content design and course narrative

While the knowledge base for teachers of mathematics and science has been studied extensively (e.g. Rowland and Ruthven, 2011; Loughran, Berry and Mulhall, 2006), little is known about the knowledge base for teacher educators in mathematics and science (Goos, 2009). Our own experiences in becoming mathematics and science teacher educators was very much one of learning-on-the-job through reflection on our careers as teachers in schools. In developing this course we have therefore been living inside the question: 'what is the knowledge base for mathematics or science teacher education and how can this knowledge base be developed?' (e.g. Goos, 2013; Childs and McNicholl, 2007b).

Answers to this question will always be based on perspectives about professional learning. A procedural view could be that the teacher educator needs to know ways of teaching particular topics; needs to present these clearly to teachers; teachers need to apply these in their classroom, and hence children will learn. This model is behind many commercial packages for professional development and textbooks for pre-service teachers. A more nuanced view could be that the teacher educator needs to understand the

complexities of teacher knowledge; teach the necessary teacher knowledge; and the teacher applies this knowledge in teaching. This view, while being attractive for policy purposes, does not take into account how successful teachers acquire complex knowledge (Shulman 1994). Our experience leads us towards the development of the mindset of teacher education, which focuses on processes rather than knowledge (e.g. Davis & Simmt 2006; Mulholland & Wallace 2005). In addition, we draw on the developing strand of knowledge about the work of teacher educators (Zeichner 2005; Ellis et al. 2011). Thus we address questions about: the nature of our subjects; how children learn our subjects; what can be said about teaching and learning in other subjects; teacher learning in our subjects. Broadly, the course units address: introduction to critical analysis of the work of teacher educators; use of English as the medium of instruction; establishment of critical study groups; teachers' subject knowledge in mathematics and science; research in subject pedagogy; teacher learning; designing teacher education; researching own practice in teacher education.

The overall aims and objectives of the course are:

- To develop familiarity with research and professional debates associated with teacher education in mathematics and science;
- To learn about pedagogy for teacher education in these subjects in a variety of settings;
- To acquire a repertoire of methods for transforming the subject knowledge of teachers and educators for teaching purposes;
- To introduce participants to the quality assurance and research standards and methods that characterise the research fields of subject education; and
- To equip participants to continue professional and academic dialogue with others in the field.

We have tried to capture these aspects of course design in a narrative that shows how the course moves from a focus on the teacher-in-context to the teacher educator-in-context.

Unit 1 asks what is science/mathematics and what it means to learn/do science/mathematics? Personal views are challenged and we then look at these areas through the eyes of a teacher educator. In considering these areas participants begin to consider the knowledge base that they, as teacher educators, need to acquire in order to develop in-service and pre-service teachers' understanding of the nature of their subject and of learning in science and mathematics (aim 3). Research and professional literature is introduced to develop understanding of key debates in teacher education associated with the nature of the subject and subject learning.

Unit 2 asks what does it mean to teach the subject and what knowledge does a subject teacher need? Using a framework of the Knowledge Quartet (Turner & Rowland, 2011) we look at teachers' foundation, transformation, connection and contingency knowledge in action. Participants begin by analysing the

teaching of specific concepts in science and mathematics and observing teachers teaching these concepts in order to look at the issues and challenges the teaching of these concepts present in context. The insights gained from these observations are then extended to consider the knowledge science and mathematics teachers need to develop in order to teach their subject.

Unit 3 moves the focus to how teachers learn and how we can design an effective teacher education course. Participants begin by considering how, as teacher educators, they can contribute to developing the beliefs and knowledge base discussed in units 1 and 2. This is done in three ways: firstly the unit begins by considering the research on teachers' learning in general and will then focus on issues of teacher learning specific to science and mathematics; secondly, the practice-based tasks will look at teachers' perceptions of their own learning in your context and examine the different ways teacher education in the particular context facilitates and constrains teacher learning; thirdly, the unit looks at different models of teacher education and the rationale for each different model/design. Finally, these three strands are brought together, and participants consider the implications for teacher education in their own context in order to identify key areas of strength and key areas for development in science and mathematics teacher education.

Unit 4 moves the focus back to the individual teacher educator by addressing the critical issue of the knowledge base needed by a teacher educator and how teacher educators design their teaching. Through a detailed consideration of the professional and academic literature, participants develop their understanding of the role of teacher educators, their knowledge base and the design of teaching on teacher education courses in science and mathematics. Practice-based tasks will ask participants to explore their current role, their own knowledge base and how they currently design their own teaching.

Together these four units shape a proposal for a research study and dissertation that makes up the second year of the two-year course. The exploration of the professional and academic literature and practice-based tasks will be brought together and used to suggest areas of knowledge and pedagogy in science and mathematics teacher education that participants, as teacher educators, want to explore and develop in their own context.

4 Some early reflections

Participants are selected via an online application process, followed by an interview with a Science tutor and a Mathematics tutor, usually via Skype. The selection criteria include:

– Practising science or mathematics teacher educator
– Understanding of their context
– Views of teacher education
– Challenges of teacher education and what they wanted to learn
– What is unique about teaching and learning mathematics/science?

The course participants came together in late August 2014 for a one-week intensive induction, which was intended to: introduce participants to each other and to get to know something of the varied contexts in which they were working; develop skills in critical reading and professional writing, and; introduce some key ideas relating to the nature of mathematics and science. We reflect on each of these aspects in turn.

We commended by asking each participant to give a 5 to 10-minute presentation on teacher education in their context. The diversity of experiences, which included being head of department in a very conservative school, being a consultant in a system that is resistant to change, working with school-based pre-service teachers and teaching a first-year university mathematics course intended to model quality teaching to other members of the faculty, made this a vibrant and enlightening experience. Yet we were surprised that, even though the contexts were diverse and superficially disparate, the issues confronted in each context were remarkably similar. Each participant identified with issues such as teachers' resistance to change, the need to comply with the demands of the system that made it hard to consider innovative ways of teaching mathematics or science, the lack of time teachers have for professional learning, the difficulty in changing teachers' belief systems, or the difficulties of recruiting qualified teachers. The discussions were marked by a spirit of genuine engagement and respect, setting the scene for what we hoped would be a collaborative and supportive online learning community throughout the course.

To develop skills in critical reading and academic writing each participant was asked to read a paper relating to the nature of mathematics or science and to write a 1000-word critique. The course leaders modelled this process through a critique of a controversial article in mathematics education (Kaminsky, Sloutsky & Heckler, 2008). We chose this article because it was relatively short, it was published in a prominent journal, it crossed the boundaries of mathematics and science, and it created significant controversy by arguing that transfer of learning is more likely to occur if concepts are learned initially in an abstract rather than concrete context. We (Childs and Thornton) each independently read and critiqued the paper, presenting participants with both a structured summary of the paper and a fleshed-out 1000-word critique. Participants then wrote their own critique and were given both individual and group feedback. Participants focused on several issues in their critiques. These included:

- The clarity of diagrams/figures in the paper;
- The clarity of writing in the paper;
- Challenging authors' definitions of words from their own contextual knowledge. The participants' own professional/contextual/cultural knowledge added to the richness of the review;
- Examining the language used by the author e.g. use of positive adjectives to support the author's point of view or negative adjectives to describe alternative viewpoints;

- The use of repetition in some papers;
- Counting the number of references for and against a particular position to identify bias;
- Noticing and commenting on extensive self-referencing in some papers; and
- Commenting on the uncritical use of strings of references as a tool to suggest widespread agreement with a position.

It was clear that the participants engaged critically with the papers, and were able to identify and describe strengths and weaknesses. We maintain that the capacity to critically analyse literature is crucial in coming to be a teacher educator, as it enables the teacher educator to evaluate the relative merits of the large volume of research in the field as well as to be critical of initiatives introduced, often with little basis in research, by schools or systems.

In introducing key ideas relating to the nature of mathematics and science we presented participants with an initial activity that engaged them in collaborative investigation or problem solving. For example, in mathematics we presented a problem that asked participants to change five coins, initially all showing heads, by flipping any two at a time until they all showed tails. After considerable investigation and discussion, the participants decided that it was impossible. What ensued was a lively discussion on why it was impossible, and more particularly on what would constitute a convincing proof. This introduced some key aspects of mathematics as a dynamic activity, but one in which the dynamic nature of mathematical discovery is often obscured by carefully prepared and well-synthesised results. The idea of mathematics as simultaneously dynamic and static was one that continued throughout the discussions and readings in the first unit of the course.

5 Future developments and research

There is a steep learning curve for us, as course developers and leaders. Although we communicate regularly via Skype and email, as one of us (Thornton) is based in Australia and the other (Childs) in Oxford, we miss the sense of collegiality generated by being onsite. The course development process is ongoing, with much of the work being done "on-the-run". We are also continuing to find effective ways to communicate with the course participants and to encourage regular collaboration and discussion. Each of the participants is employed full-time, and each is very busy in his or her own context. This places great demands on their time and capacity to engage fully with all aspects of the course design. We have wrestled with identifying what are reasonable expectations with regard to professional reading, and whether to expect tasks and reflections to be completed on a weekly basis or at less regular intervals. However we have been encouraged by the feedback of the participants, their insistence that as adults they do not need to be "spoon-fed" and the way in which they have embraced the variety of readings presented. As a design principle for future units we therefore seek to find an appropriate

balance between ensuring that participants have a clearly identified set of core activities and allowing the academic freedom that is characteristic of teacher educators.

We have a research agenda attached to the course that we hope to report on more fully in future. The key questions for us are:

- What is the knowledge base of teacher educators? Is it different to the knowledge base of teachers?
- How can such a knowledge base be developed?
- What is the balance between theory and practice in developing teacher educators?
- What might be a useful theoretical framework for examining the development of teacher educators?

Little is known about how a teacher, or recent PhD graduate, becomes a teacher educator. Little is known about how such people develop a capacity to research their own practice and hence improve the experience of pre-service or in-service teachers. The Oxford course is unique in focusing on the development of teacher educators in science and mathematics; as the course continues to develop in response to our experiences and the needs of new cohorts of students we hope to shed light on some of these questions.

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PRIMAS Multiplier Concept Implementation in Slovakian Context -

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Introduction

The article presents the PRIMAS multiplier concept implementation in the Slovak Republic in three main perspectives – organisational, processional, and multiplier self-reflective. The introducing part briefly describes the overall PRIMAS dissemination in Slovakian context. Next, the main focus is brought on the process of preparing courses of professional development at Faculty of Natural Sciences, Constantine the Philosopher University in Nitra. This part covers approaching schools and in-service teachers, CPD accreditation process, and training multipliers. Consecutively, the contribution comprises self-reflection of multipliers, who further develop their skills analysing their own practical experience as educators in CPDs. This results in a summary of several relevant recommendations for prospective multipliers.

1 Courses of Professional Development policy and Slovak PRIMAS team strategy

The PRIMAS project team was formed at Faculty of Natural Sciences Constantine the Philosopher University in Nitra. PRIMAS project team had to consider national strategy (Ministry of Education, Science, Research and Sport of the Slovak Republic) and also Faculty of Natural Sciences strategy in courses of professional development (CPD) preparation and multipliers training. The new Law of Pedagogues came to force in June 2009 and has got the new version from November 2011 in Slovakia and issues of CPD have been included within this law. Ministry of Education of Slovak republic established the special committee for accreditation process for any CPD. SK PRIMAS team was in contact with three members of this committee, two of them were PRIMAS NCP members and one colleague worked as an external evaluator of CPD in mathematics.

The application of CPD for accreditation was very complex. It required detailed study plan, materials for handing in to trained teachers; assessment requirements; evidence of trainers' (multipliers') competences (diplomas, certificates). The faculty has the right to run the accredited CPD for five years if the accreditation is approved.

Teachers are awarded by credits after successful completion of the course(s). Credits allow them to increase their monthly incomes of about 6%.

The strategy of faculty and PRIMAS team was focused on CPDs of mathematics and sciences: biology, chemistry, physics and environmental multidisciplinary subjects. Target group consisted of practicing teachers in upper primary and secondary schools. In order to attract the attention of practicing teachers to the course, the content of the particular course tracked

the curriculum, or main part of it, of the subject in question. Within year 2012 eight CPDs have been successfully accredited:

Chemistry: Chemistry in real life

Physics: Physic of microspace and environmental physics

Biology: Increasing professional teachers competences in work with gifted pupils with respect to out of school activities

Mathematics and science: Innovation of methods and forms of mathematical and natural sciences education at the primary level of education

Mathematics: Innovation of methods and forms of geometry, combinatorics, probability and statistics education

Mathematics: IBL in mathematics on secondary school

Sciences: Modern methods in GIS education at upper secondary schools

Sciences: Innovations in education practicing teachers

Altogether 114 teachers of mathematics and sciences from all level of schools (elementary, primary and secondary) participated in eight PRIMAS CPDs. They worked with their PRIMAS multipliers, regularly since October 2012 until July 2013. Three CPD introductory meetings were organized at two external places, High Tatras and Mojmirovce. External place was crucial for team-building activities. Participated teachers created working groups with high level of work efficiency.

The number of meetings was 84, some meeting were half-days (four 45-minute lessons), but teachers mostly preferred full day meeting (eight 45-minute lesson). The total number of lesson hours was about 400. Teachers preferred Fridays and afternoons for short meetings, and Saturdays and holiday days for full day meetings. It means that the majority of teachers attended the course in out-of school time, in their free time. They wanted to avoid their absence on their regular lessons.

Each course was supported by e-learning course. Teachers were offered PRIMAS inquiry-based learning (IBL) pedagogies materials and other subject content knowledge materials, which support their teaching at schools. Many lessons were videotaped; as well as some lessons of teachers at their schools were videotaped.

Each course was finished by final presentation day. Teachers presented their experience in IBL pedagogies and their new skills and competences in front of the committee of three lecturers, experts PRIMAS multipliers. Heads of five departments (mathematics, physics, biology, chemistry, ecology) participated in teachers' final presentations.

Teachers were awarded by PRIMAS diploma and university certificate on the PRIMAS final conference on July 2, 2013.

2 Multiplier example: CPD Sciences / Multiplier perspective (Imrich Jakab)

Multiplier IJ was in charge of CPD *Modernisation of education with use of geographic information system tools in secondary education* primarily intended for teachers of secondary education level teaching pupils aged from 10 to 19. The course, realised in period February – July 2013, consisted of 56 presence lessons and 54 distance lessons, and was attended by five primary school teachers, two comprehensive school teachers, and one vocational school teacher.

The multiplier designed his course as a complex of three main parts – education about IBL, education by means of IBL, and education for IBL – which he based on multiplier training and consultations about IBL. The first part was covered in the initial lessons when the multiplier provided the course participants with basic information about project PRIMAS and introduced seven PRIMAS IBL modules. Throughout the whole course the multiplier presented and approached geographic information systems (GIS) as both IBL tool and the subject content (Fig. 1).
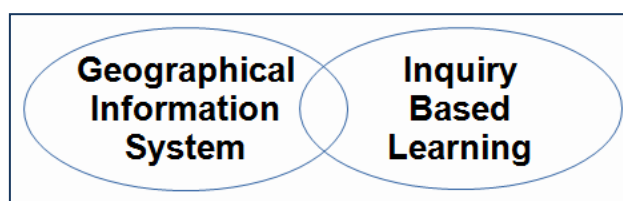
Figure 1: GIS and IBL intersection

When planning the course, the multiplier presumed that a satisfied teacher, who would have taken part in the course based on GIS and IBL, would become better prepared for their implementation in his/her teaching practice. Thus, his main objective was to prepare a course, which would motivate teachers to implement IBL and GIS in their own teaching practice.

IBL was implemented into both the course content and the process of education. As for IBL in the course content, it formed the 'education for IBL' part. During the course wide spectrum of GIS use possibilities was presented. Teachers did not have to master all of the presented GIS uses. They focused on those mobile, web and desktop GIS applications, which had the highest potential for teaching their subjects. As for IBL in the education process of the course, it formed the 'education by means of IBL' part. The practical part of the course was lead in form of practical tasks, which resulted in the course participants' projects. Project topics showed the applicability of the obtained knowledge and skills in secondary education. IBL and World of Work (WoW) principles were implemented almost into the whole course.

Teachers proved their ability to implement GIS and IBL into their own teaching at final exams. To pass the course teachers had to make a lesson plan implementing IBL and GIS, then teach a lesson following the plan to examine

its applicability, write a final thesis about the lesson plan and its effectiveness, and present the thesis in front of three committee members at final exams.

The multiplier keeps active contact with the teachers who attended his course. Nowadays seven teachers out of eight use GIS actively in their teaching practice, six of them use GIS tools by means of IBL, one teacher in a rather traditional education. Moreover, four of the teachers registered the outcomes of their pupils in the First Pupils Scientific Conference, which is to be held on April 22, 2015. All in all, the knowledge they obtained in the course seems to be sustainable.

There were several benefits for multipliers participating in project PRIMAS. Besides acquirement of theoretical background in IBL, multipliers enriched their practical experience in IBL use in education process, i. e. they practically verified model of education with use of IBL. Furthermore, active dialogue and cooperation between educational researchers and in-service teachers has been built up, which for this particular multiplier means a lot of inspiration in modernization and increasing efficiency of content and form of environmental education in university teacher training programmes.

3   Slovak PRIMAS multipliers feedback

After having completed PRIMAS IBL modules translation into the Slovak language in October 2011, the training of PRIMAS multipliers started. Simultaneously, the process of CPDs preparation was in progress. Multipliers were experienced university teachers, dominantly performing teacher education, didactics disciplines and observing teacher trainees. Regular contact of these multipliers with practicing teachers and everyday school practice turned out to be an advantage for better adjusting the content of the course and promoting the course. Several multipliers were PhD students in theory of mathematics education. The pure theoretical background of PhD students as multipliers was very welcome by the target group as the new and fresh approach encouraged practicing teachers (courses participants) to experiment.

The total number of multipliers was 23. During the initial phase of the training (October 2011 – September 2012) multipliers were exposed to PRIMAS IBL pedagogies modules, they adjusted the modules to the particular courses and subjects, and discussed IBL pedagogy vocabulary in the Slovak language.

Multiplier support phase lasted from September 2012 to December 2013. It was an intense period of the eight accredited CPDs implementation.

We consider the multiplier role of crucial importance in this process. In order to understand better the needs and requirements of PRIMAS multipliers in Slovakia, which must not be ignored, we asked seven of Slovak PRIMAS multipliers seven questions. In the following paragraphs we summarize their responses, which, hopefully, will improve further multiplier concept implementation.

3.1 What difficulties did multipliers face when planning and preparing the courses, choosing the course content?

According to multiplier MS, overcoming the teachers' barriers and prejudice towards innovative educational approaches was one of the most difficult issues. In general, Slovak teachers believe that education system in Slovakia forces them to keep on using only traditional teaching methods. Multipliers faced an exhausting task to awaken teachers' interest in new methods, and also persuade them to implement these methods.

Multiplier BL states it was quite challenging to fit together interesting up-to-date knowledge and discoveries with upper secondary education level curriculum.

Multiplier GP recalls being focused on complementing the requirements, which arose from the Slovak education system reform, and on providing teachers with useful teaching material and inspiring ideas.

Multiplier IJ was aware of the demands on the classroom, technological tools and equipment, i. e. the course required a classroom with sufficient number of computers for the participants, the Internet connection, GIS software installed in the computers in advance, GPS devices, training data (e. g. map layers), and study material. The course ran during the school term, at the time when both the participants and the multiplier had also many other duties to take care of. Therefore they agreed to combine two course forms – presence form and distance form (e-learning). The e-learning form partially disburdened the spatial demands, as well as those 24 lessons which took place in an external environment, i. e. three-day intensive education in Mojmírovce Castle with a nearby park, successfully used for practical activities with mobile GIS devices. Yet, multipliers recall how difficult it was to prepare such meetings in external environment, mainly because of the official administration requirements.

Multiplier JS considers creating a complex concept of the particular activities to be the biggest difficulty of the preparation and planning phase, since the course was aimed to develop both the mathematics content knowledge (MCK) and the mathematics pedagogical content knowledge (MPCK) of the participants, enriched by the inquiry based learning principles (Shulman, 1986; Ball, Thames, Phelps, 2008). Therefore, it was necessary to identify not only their actual MCK, but also their MPCK and teaching approaches. There was a strong need to use a complex concept which would enable the multipliers to question the in-service teachers' approaches repeatedly and systematically, and at the same time elicit the participants' own self-reflection. Multipliers made use of PRIMAS professional development modules, i. e. asking questions that promote IBL, formative self and peer assessment, students working collaboratively etc.

Multiplier JM recalls how she got aware that in-service teachers rarely read scientific publications and articles presenting modern research in education due to the great amount of work they have to deal with in their everyday

professional life. That is why she immediately planned to turn their attention to late research conducted in combinatorics education, as she considers studying such material to be one of her job duties. This corresponds to the assumption that "researchers are expected to contribute to the improvement of mathematics teaching not only by writing papers confined to descriptions and interpretations but also by working in teacher education" (Krainer, 2005, p. 77). Such face-to-face confrontation of scientific research with in-service teachers' daily experience might be a useful way of observing and identifying the differences between "the *status quo* of a situation and the desired *target* situation, for example the difference between the prevailing way of teaching and the intended way of teaching" (ibid, p. 78).

3.2 What changes did multipliers have to make with regards to their initial plans about the course content and procedural steps? Why?

Multiplier IJ notes the necessity to reduce the course content parts about GIS spatial analysis, since some of the participants required a more detailed explanations and more time for exercises and practical activities.

Multipliers JM and JS mention regular adaptations of the course content in order to meet the participants' needs. Multipliers changed the course content, the activities, tasks and topics in correspondence with what the participating in-service teachers were teaching their pupils those days. Furthermore, multipliers chose tasks, problems and activities, which would elicit the participants' discussions and reflections.

Similarly, multipliers BL and GP recall regular time adaptations in order to meet the course participants' possibilities, and also the participants' high interest in experimental activities, though at the expense of improving their theoretical background.

3.3 What objections did the course participants raise against the suggested changes and activities in their teaching approaches? How did multipliers response? Were the course participants constructive in discussions?

When asking multipliers this question, we had in mind the assumption that "...critical alignment and inquiry (necessarily) bring uncertainty and risk, and foster tensions within the teachers' practice and between the practices of teachers and didacticians" (Goodchild et. al., 2013, p. 1).

Multiplier IJ did not recognize any significant objections, and considers the course participants agreeable and constructive enough.

Multiplier JM states that most objectives were raised in the first session, for the participants claimed the presented tasks and problems to be inadequate for their learners. However, participants did not express any negative opinions on the recommended changes in their teaching approaches.

Multipliers MS and BL remember participants expressing their opinions on IBL time demands, doubts about its viability in real school conditions, and concerns about learners' interest in the suggested activities.

Multiplier JS declared that objections were raised when the activities were more general and focused on MPCK. He thinks this was because participants did not have sufficient abilities of self-reflection and meta-cognition. To deal with such situations multipliers responded in two ways. Firstly, they modelled the activity itself and tried to establish and maintain positive atmosphere. The two collaborating multipliers think they were successful thanks to the unique concord between themselves, and sensible division of tasks, i. e. one of them focused on MCK field, the other one on MPCK field. Secondly, if a problem arose in any of those fields, they dealt with it from both perspectives. The simultaneous work of the two multipliers was the integral part of the course. Multipliers questioned each other in front of the participants, sometimes it seemed as if they were having an argument. Yet, this was to model inquiry processes in their self-reflection and meta-cognition in order to naturally elicit similar processes in the participants' consciousness. By the end of the course multipliers felt the participants accepted that approach, and earlier formal discussions turned into inquiry-based debates. In addition, seeking to develop participants' self-reflective abilities, multipliers provided them with several activities video-recorded in their sessions.

3.4 Slovak teachers are not used to CPDs. How did multipliers approach them in order to overcome this barrier and to ensure stress-free and creative environment during the courses?

Multipliers emphasize the importance of choosing attractive tasks and activities, informing about interesting knowledge contests (e. g. Mathematics B-Day), implementing activating teaching methods, such as projects and discussion, providing participants with quality materials and stimulating aids, and linking the course contents to the in-service teachers' professional demands and working conditions. For instance, participants appreciated that multipliers used aids which are easily available, cheap or free, undemanding to prepare, such as plastic bottle caps, dices, coins, colourful strings, wooden sticks, plasticine etc.

The activity and creativity level of the participants also depends on their professional focus. For instance, the CPD led by multiplier GP was intended for teachers at primary educational level; therefore the participants were naturally active and creative.

Also, multipliers consider a few sessions in an informal environment to be the best way to overcome initial interpersonal barriers. This corresponds to Goodchild's (2013) records from the developmental research project *Learning Communities in Mathematics* in Norway. The two following quotations aptly describe both the teacher educators' and teachers' need for such informal meetings:

"The meeting closed with a request by the teachers to come to the university to meet with didacticians for further informal planning away from the pressures of school" (Goodchild et. al., 2013, p. 9).

"...meeting between didacticians and teachers... at Eli's home. It was hoped the location would be more conducive to informal discussion than in a school or university environment" (Goodchild et. al., 2013, p. 13).

Last but not least, multipliers pointed out the must to approach course participants in positive and collegial way. One of the multipliers promotes the Thomas Isaacs' (Stanford University) attitude that to be successful when persuading public, we must not think that it is us who know everything, and that it is our task to tell that to public, and if they do not get it, we should repeat it and even louder; it simply does not work this way.

3.5 What was the biggest challenge for multipliers?

For multiplier GP it was very challenging to put teachers in pupils' position, i. e. make them *learn* instead of *teach*. This involved also finding the right methods which would make them explore and discover facts that the multipliers were supposed to teach them, plus reminding them that in real school conditions they would be back in the teachers' position.

Generally, interviewed multipliers admit that their role is quite demanding. Teaching teachers how they should teach their learners sounds ridiculous, since in-service teachers usually have much more teaching experience than multipliers do. Therefore, the way multipliers communicated with the course participants was very important. Showing respect and appreciation turned out to be a successful way of approaching them and gaining their trust. Consecutively, multipliers faced even more difficult task – not to lose their trust, provide them with adequate activities, and keep on being supportive. Drawing the participants' attention to new teaching ways and aids, and showing them the importance of self-reflection and professional meta-cognition was also very challenging.

3.6 What was the most positive / negative feedback for multipliers?

All the multipliers were pleased by the participants' final presentations in which they presented what they learned during the course. That was the evidence they are able to apply different teaching approaches than they used to. Multipliers also felt very glad when they could see that participants got involved in the activities in the courses, they were eager to try new methods, and after all, they could enjoy feeling of their own satisfaction. A positive step forward was when participants let multipliers question their teaching approaches, and then they themselves were able to think of many creative ideas of improvement, based on their self-reflection. This also was a strong impulse which inspired many of the course participants to further develop their own professional knowledge and skills.

On the other hand, changes in the participants' approaches were slightly unstable, e. g. later on multipliers found out that some of the participants returned back to their former teaching styles and teach combinatorics using only formulas. That could be due to the environment and requirements of their schools. This factor must be taken into account in the future courses.

Most of the course participants who were led by multiplier GP were satisfied with the course content and even expressed their intentions to use their final works in their following attestation. On the other hand, unpleasant problems occurred when some of the school headmasters rejected to reward the successful course participants, although those teachers officially gained credits for their effort.

3.7 Would multipliers recommend anything to other multipliers (what should be better avoided, what is attractive for in-service teachers…)?

Multiplier IJ suggests organizing the course in various levels, i. e. divide the participants according to their computer skills and level of their geography and computer sciences content knowledge.

In general, multipliers recommend not wasting the participants' time dealing with boring and pro forma activities. Preparing adequate activities and tasks is a never-ending story. Course participants appreciate simple experiments with precisely described procedure steps, applets, presentations and ready-made materials, which they could use in their own lessons without any significant changes.

Also, multipliers find it very useful to observe a few participants' lessons in their working environment, and after such observations make a reflective interview with them. It is necessary to provide the participating teachers with support and constructive feedback. In connection with this, multipliers suggest working on their diagnostics of teachers, which would in turn enable them to improve their approach to participants.

According to multiplier GP it is inevitable to set fixed requirements on the course participants in the very beginning. As for the course content, the CPD should always meet real school conditions. It is handy when multipliers have more ready-for-use materials, since it is often the case, the more course participants there are, the less predictable their work pace is. Last but not least, it is desirable to remain undaunted by negative acceptance or misunderstandings.

Conclusions

The project PRIMAS multiplier concept implementation in Slovakian context could be considered as successful. Multipliers had to experience at least three levels of their competences concerning to new national concept of CPD: organizational (course preparation to accreditation process), processional (course implementation) and self-reflective level during and after the course

set-up. PRIMAS courses offered multipliers a huge amount of raw research materials for further analysis and some of them are strongly motivated to follow-up their research in the field of teaching teachers or educating the educators (Melusova et. al., 2014).

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Project Primas Homepage: www.primas-project.eu

Professionalizing teachers in a Teacher Design Team -
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1 Introduction

Different arrangements for Professional Learning Communities emerge in literature (Stoll, Bolam et al. 2006; Lumpe 2007; Voogt, Westbroek et al. 2011; Verhoef, Tall et al. 2013). In this contribution the focus is on teacher design teams (TDT) consisting of high school subject teachers from different schools under the supervision of a subject teacher trainer. Our first TDT was set up to develop student learning material suitable for science focusing on a context concept approach (Gilbert 2006; Parchmann, Gräsel et al. 2006). Although the purpose of this TDT was to develop student learning material, our research showed that the three teachers in this TDT learned a lot, especially with respect to their Pedagogical Content Knowledge (PCK) (Coenders, Terlouw et al. 2010). As developing student learning material from scratch proved very time consuming, and therefore expensive, we decided in 2010 to start TDT's in which teachers *redesign* existing learning materials. The objectives of these TDT's is on teacher professionalization, the development of student learning material is instrumental for this. These TDT's used the following work sequence: redesign of student learning material through repetitive cycles of discussion and redesign, implementation of the materials in own class, and finally exchange and discussion of the outcomes. In the next section a model to visualize teacher professionalization is presented, and then specific TDT issues are discussed.

2 A model for Teacher Learning

Teachers from different schools who in a TDT, under supervision of a teacher trainer, (re)design student learning material professionalize (Coenders 2010). Instrumental in this are two consecutive phases the participants go through: the *development phase* and the *class enactment* phase (Coenders and Terlouw 2012). The model shown in Figure 1 is based on the Interconnected Model of Professional Growth from Clarke & Hollingsworth (2002), in which the domains involved in the learning process of a teacher are visualized. The *development phase* in the model of Figure 1 consists of the Personal Domain, the External Domain and the Developed Material Domain. The Personal Domain holds a teachers' knowledge, attitudes and beliefs, and the objective of a professionalization program is for teachers to expand this domain. All input from outside a teachers' world is situated in the External Domain. The redesigned materials are located in the Developed Materials Domain. The *class enactment* phase consists of the Domain of Practice (e.g. class use), the Domain of Consequence (students learning outcomes) and the Personal Domain. The different domains are connected through processes of reflection and enactment.
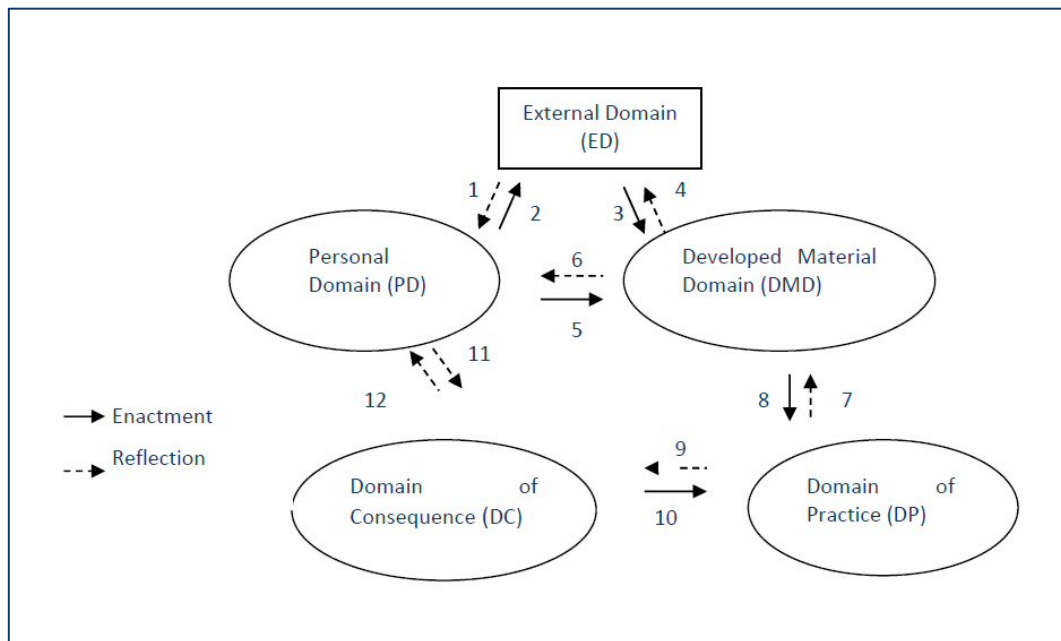
Figure 1: Extended Interconnected Model of Teacher Professional Growth (EIMPG)

Professionalization starts from the External Domain in the *development phase* where first of all experiences the different participants have with a specific topic or pedagogy are exchanged. Then new practices, ideas and views are looked for in literature or from other external sources. These new aspect are then incorporated in the materials under redesign and these new materials are again discussed and adapted until participants consider the materials ready for class use. This interplay leads not only to teacher growth in what Clarke and Hollingsworth called "change sequences", but it concurrently prepares the teachers for class use. However teacher growth is still fragile as teachers have not yet experienced how students are going to react to it. The *class enactment* phase serves to provide these experiences: how are students responding to the materials and how do these contribute to student learning? The interplay between the domains in the class enactment phase leads to "growth networks". Teacher learning proves to be highly idiosyncratic.

The External Domain plays a crucial role in what teachers learn as here the "teacher learning material" is situated. In the next section important organizational issues are highlighted, and finally drawing on experience and own research the roles of the different stakeholders are discussed.

3 A Teacher Design Team (TDT)

3.1 Organisation

From literature, and from own research and experience, the following essential aspects for a TDT emerged (Garet, Porter et al. 2001; Fullan 2007; Penuel, Fishman et al. 2007; Coenders, Terlouw et al. 2010; Avalos 2011; Desimone

2011; Schneider and Plasman 2011): (a) the content of a TDT should focus on subject matter and pedagogy, (b) active involvement of the participants in the activities within the TDT, (c) a TDT should encompass a reasonable period in time with sufficient face-to-face opportunities, (d) coherence between the different activities of the TDT, (e) the inclusion of class enactment of developed learning material and pedagogy. This resulted in our situation in a TDT structure in which we asked teachers and schools to reserve 60 hours of professionalization time per teacher per annum, half of which is for face-to-face meetings scheduled once a month for 3 hours each at the end of a workday, a total of 10 meetings per year. Our TDT consisted of subject teachers from different schools plus a teacher educator (facilitator) from a teacher training institution. Potential innovative learning material developed by others is used as a start in the redesign cycle.

3.2 The schools

Schools need to assist teachers in terms of facilities, time, a time table permitting to attend all meetings, and opportunities to class enactment the designed material. Schools of course also need to pay for the TDT program. In order to make sure schools understand the objectives and the way of operation of TDT's, representatives of our teacher training institution meet the management of all schools in our region to explain the TDT setting and how participation can be beneficial to teachers and schools. These conversations also serve to find out in what other areas schools would like to cooperate with the institution.

3.3 The participating teachers

Teachers need a time table enabling them to attend the TDT meetings. They need managerial support to enact innovative learning material and to use the ICT classrooms or the labs when this is necessary for class enactment of redesigned learning material. This requires flexibility in the schools.

Teachers will only participate when they share the TDT objectives, and therefore these objectives need to be clear but also somehow flexible as teachers should be the owners of the TDT process and the content. The first meeting will require discussion about the topics for which learning material will be redesigned. Sufficient time and having opportunities to experiment in class, are important variables. Time is required for the meetings, but as the results of the discussions need to be incorporated in the material there will also be activities that need to be done after the meetings (homework!). Concurrent with the redesign process, teachers and their school technicians can organize the necessary materials (chemicals, equipment, materials) to enable smooth class enactment.

3.4 The facilitator

Looking at the model in Figure 1 it surfaces that the External Domain is crucial for teacher learning. This External Domain is situated outside teachers daily practice and therefore the participating teachers will meet new ideas, insights, practices, materials, pedagogy's in this domain. One of the crucial roles of the facilitator therefore is to make sure this External Domain is properly filled with sources such as learning materials and opportunities to exchange experiences and views. This means that the facilitator needs to be well acquainted with the subject, and knowledgeable about new developments within the subject, both with respect to the content as with ICT and emerging pedagogies. The facilitator is also responsible for the day-to-day aspects of a TDT: organizing the meetings and the drinks, inviting the members, setting the agenda, and writing of the report. A facilitator also needs to be able to organize and lead the discussions within the TDT and to support the design process of the student learning material. To do this, the facilitator needs access to the literature and preferably has experience with designing student learning material. Teachers are trained to prepare and enact classes, not to develop curricula or specific learning material. The facilitator needs to provide this support, or to organize it for example though inviting experts on specific fields.

When asked, teachers who had participated two years in a TDT said to have learned particularly from: (a) experiences from and discussions with their TDT colleagues, (b) specific literature that was selected by the facilitator or by a colleague, on content, contexts or materials or ICT developments, (c) selected student learning material developed by others, (d) content experts, for example researchers from a university who explained specific content or shared research areas, (e) conference participation (we asked our participants to prepare and hold a workshop related to the TDT outcomes).

3.5 The teacher training institution

The teacher training institution is responsible for the overall program and as such for the facilitator, the space to meet, the finances, a digital working environment for all products and reports, internet access during face-to-face meetings and access to relevant literature in the (digital) library. It is advisable to engage teacher trainers as facilitators as they know the subject and the educational arena, and have the necessary contacts with experts that could be invited for their input.

As school management and teachers want to know what the expected outcomes of participation will be, a clear description of the TDT, and particularly the objectives and the way of working, is crucial.

4 To conclude

Setting up and sustaining a TDT is a complex endeavour. Each of the different stakeholders (teachers, schools, facilitators, institutions) plays an important role. The Extended Model of Teacher Professional Growth can be helpful to set up a TDT and to predict and understand teacher learning.

Professionalizing teachers in a TDT requires the use of small groups of teachers. When the group is too large (> 10) it is no longer possible to use teachers input and this is essential for the discourse process. The bottleneck for upscaling will be having sufficient numbers adequate facilitators.

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Long-term Teacher Professional Development: Lessons learnt from PRIMAS -

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1 Introduction

The aim of this paper is to present lessons learnt from the experience of providing long-term professional development (PD) to a group of Maltese teachers who participated in the FP7 project aimed at promoting inquiry in Mathematics and Science classrooms across Europe, PRIMAS. The main focus will be the model of professional development adopted and the experience of the participants, with emphasis on the experience of the PD facilitators[1]. The paper will attempt to answer the following questions: What lessons were learnt about the model of PD adopted? What was the experience of the PD facilitators who were involved? What do PD facilitators need in order to be able to fulfil their role?

1.1 The PRIMAS project

PRIMAS (Promoting Inquiry in Mathematics And Science) was an international project within the Seventh Framework Program of the European Union. Fourteen universities from twelve different countries worked together over four years (2010-2013) to promote the implementation and use of inquiry-based learning (IBL) in mathematics and science. The work involved development of materials for use in class; development of materials for PD of teachers; professional development activities and courses for teachers; as well as work with policymakers, school management teams and parents to help create a supportive environment for IBL (PRIMAS, n.d [a]).

1.2 Inquiry-based learning

IBL is a term that has been used to describe a number of student-centred activities or approaches in which students take on an active role in their learning. A widely-accepted definition of IBL is that proposed by Linn et al. (2004): 'the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments' (p. 4). This definition clearly shows a shift in the understanding of what teaching and learning entails from a process in which the teacher transmits a body of knowledge to students to one in which students ask questions, seek answers, hypothesize, observe, measure, debate and communicate ideas in a collaborative environment with their peers. In the PRIMAS vision, IBL also involves a teaching and learning culture with particular characteristics related to students' and teachers' roles, type of problems used and classroom atmosphere (Maaß et al., 2011). IBL is seen as

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a means of ensuring that students acquire skills and competences needed by 21st century citizens such as reasoning, critical thinking, deeper learning, creativity and problem solving as well as soft skills. IBL is also considered to be a way of addressing students' lack of interest and negative attitudes towards science and mathematics (Rocard et al. 2007). Several studies in fact report positive influences including long-term positive effects of IBL on students' attitudes and engagement (e.g. Gibson et al., 2002; Berg et al., 2003).

Changing the way students learn, what they learn as well as the quality of what they learn depends on a change in what teachers do. As Harwell (2003, p.2) points out: 'we cannot expect students to change what they do if we are content for teachers to continue doing what they have always done'. The change from teacher-centred traditional classrooms to student-centred learning in which students are given some responsibilities and are encouraged to think, reason and decide is an ambitious change and like many other education reforms ultimately depends on teachers. Teachers need content and procedural knowledge (Shedletzky et al., 2005); and a good understanding of what inquiry entails in its different aspects, in order to be able to plan, structure, support and vary teaching and learning experiences according to their students' needs (Martin-Hansen, 2002). This extent of change in classroom practice will require considerable learning on the part of teachers and will be difficult to achieve in practice without providing guidance, support and professional development (Borko, 2004).

1.3 Professional Development

Several definitions and models of PD have been offered. For example, Eraut (1977) defines teacher development as: 'The natural process of professional growth in which a teacher gradually acquires confidence, gains new perspectives, increases in knowledge, discovers new methods and takes on new roles' (p.10). Joyce et al. (1980) recommend a combination of techniques for effective PD: presentation of theory; modelling or demonstration; practice under simulated conditions; feedback upon observation of practice; and direct coaching on how to apply new skills to their teaching situations. Similarly Bubb et al. (2010) suggest PD programmes that involve 'discussing, coaching, mentoring, observing and developing others' (p.27) for effective PD. PD programmes may vary widely in type and content however they all aim to bring about change in understanding, attitudes, beliefs and practice. While many programmes aim at changing understanding, attitudes and beliefs assuming that this will result in the desired change in practice, Guskey (2002) believes that 'significant change in teachers' attitudes and beliefs occur primarily after they gain evidence of improvements in student learning' (p.383). King (2014) observed that: 'teachers' beliefs, values and attitudes were instrumental in the sustainability of the practice and that changes are iterative and can begin with a change in teacher beliefs leading to a change in practice or can begin with a change in practice leading to a change in beliefs' (p.104). Guskey (2002)

points out that changing teachers' practice is both slow and difficult, requiring extra effort, possibly involves an increase in workload and in addition places teachers in an uncertain position. All this suggests that in order to achieve a permanent change in practice, teachers require PD opportunities that not only provide them with knowledge and skills but also provide opportunities to try out IBL, supporting them along the way.

2 Methods

2.1 Organization of the PD course

In Malta the project involved collaboration and co-operation between the University Project Team (UPT), the directorates of Education, a group of 10 PD facilitators, 50 teachers and their students. Fifty mathematics and science teachers from five state schools participated on a voluntary basis in PD sessions that were provided regularly over two scholastic years. In each school a group of five mathematics teachers met a mathematics facilitator and a group of five science teachers met a science facilitator. The meetings took place every two weeks during school hours within the school. The teachers who participated were given a reduced teaching load to enable them to attend the PD sessions, prepare new lessons and resources, and reflect on their practice. The school administration also made arrangements to ensure that the participating teachers had a common time during the week when they all did not have classes in order to allow them to meet as a group. This arrangement greatly facilitated the organization and ensured that teachers could dedicate time to the meetings, prepare new or modified lessons and reflect on their performance and practice. All the teachers participating in PRIMAS were required to keep a reflective diary in which they reflected on the implementation of IBL in their lessons.

During the meetings the PD facilitators discussed together with teachers issues and practices related to IBL and about how inquiry may be encouraged and promoted. They also worked on exercises and activities intended to help them reflect on their practice and on their students. These activities were part of PD modules developed for the PRIMAS project (PRIMAS, n.d. [b]) and dealt with topics such as the use of questioning techniques to promote student thinking and helping students with collaborative learning among others. During the meetings teachers were also assigned tasks that they were required to try out in class by the following PD session. There was also time for sharing experiences especially those related to their attempts to implement IBL.

In preparation for the PD sessions in schools, there were regular (fortnightly) two-hour meetings between the UPT and the PD facilitators. The sessions were held in a friendly and comfortable atmosphere, appreciative of the contribution and expertise of all those present. The way the sessions were organized and handled was intended as a model of how the meetings between the PD facilitators and teachers in schools could be held, promoting an

environment and attitude that all were there to learn from one another. On a number of occasions, PRIMAS PD modules were covered, working out tasks and activities from the PRIMAS PD modules. The sessions also involved discussing ways of adapting the tasks, activities and modules to the local needs. Teacher difficulties and concerns were discussed. The different backgrounds of the participants enabled the group to 'predict' possible teacher concerns and difficulties and how these can be addressed. On other occasions, the meeting or part of the meeting was used to gather feedback about what was happening in the schools, challenges encountered, tasks being used and so on. Together, the group reflected on ways of overcoming the difficulties. Occasionally videos of work attempted locally as part of the project were shared and discussed.

2.2 Data collection and analysis

Data were collected from a number of sources via different methods including reflective journals kept by teachers, interviews with teachers and PD facilitators and observation of lessons and PD sessions. The different sources provided a means of triangulation, to obtain 'a more comprehensive perspective' and to 'validate and cross-check findings' (Patton, 1990 p. 244). Through the use of multiple sources it was also possible to 'build on the strengths of each type of data collection while minimizing the weaknesses of any single approach' (Patton, 1990 p. 245). The journal entries were written by teachers throughout the duration of the PD course. Interviews were semi structured and sought to obtain information about participants' beliefs and views and about the experience of the PD sessions from the participants' (teacher or PD facilitator) view point. They were audio-recorded and transcribed soon after the interview. Observations were non-participant, intended only to observe and collect field notes. Through these observations it was possible to see directly what was taking place 'in situ' (Cohen et al., 2007) rather than rely only on what the participants said during interviews. Detailed field notes were taken which included descriptions of what was being observed as well as quotations from conversations/statements.

All data were qualitative in nature and analysis involved making sense of the data by reading and re-reading in order to identify major categories and themes (Bowen, 2009). Through different levels of analysis the data were given descriptive codes as well as less specific and more general codes. Data analysis resulted in a number of themes that were common across the different sources.

3 Results

Borko (2004) lists four interrelated elements of a PD system: the *PD programme*, the *teachers* who are the learners in the context of PD; the *facilitators* who accompany, guide and support teachers; and the context in

which PD occurs. Pertinent feedback related to these elements and their interaction in this particular context will be presented in turn.

3.1 The context

In Malta the education system and school culture are rather examination-oriented. There are yearly national examinations for all state schools. School based tests and examinations tend to dominate in secondary schools especially during the last two years of compulsory education which prepare students for the Secondary Education Certificate Examinations. These high stakes examinations determine progression into post-secondary institutions. This examination-oriented school culture is accompanied by rather traditional classrooms where teacher-centred instruction and transmission are the predominant method of instruction (Pace, 2000; Gatt, 2011 and Borg, 2013).

Between 2010 and 2013, the author and colleagues from the Faculty of Education of the University of Malta participated in PRIMAS. The main aim of the project was promoting IBL in Mathematics and Science classrooms by providing long-term PD to teachers as a means of support during the introduction and implementation of IBL.

3.2 The Teachers

The 50 teachers who participated, did so on a voluntary basis. They met in small groups with their PD facilitator within their school. They started off the PD course with different views, expectations, beliefs and understanding. Many teachers who participated, found the project to be a positive and worthwhile experience and claimed that they would continue to participate in the PD sessions if the project were to be continued beyond the two years of its lifetime. One of the most valued benefits was the experience of the community of practice formed with other colleagues engaged in the learning process. Teachers faced a number of challenges as they tried to implement IBL in the classrooms. Some of these challenges were school specific challenges while others were more general difficulties. The challenges and difficulties can be classified as systemic challenges, teacher-related challenges and challenges that were student-related.

3.2.1 Systemic challenges

Student-centred teaching methods tend to be more time-consuming than teacher-directed ones. Lengthy, content-laden syllabi and lack of time were a constant source of concern for teachers. Transmission of knowledge was considered to be more time-efficient, giving teachers more control over the amount of material they could cover in each lesson than student centred-activities. As a result teachers felt that they could not afford more than an occasional inquiry activity. Teachers often wrote or stated positive comments about the experience of using IBL with their students but these statements

tended to end with phrases such as "however they take too long to do..". Examinations especially high stakes examinations and the culture of frequent testing often led to learning for the examination. IBL and other student-centred activities were often seen as a waste of time or as taking precious time that teachers can ill afford: time that can be spent doing activities/tasks that are more closely related to the examination. This concern was not a source of anxiety only for teachers. Students were apprehensive about these factors, especially high achievers who were anxious about waste of time, activities that were taking too long, not having time to work out more examples and so on. These systemic challenges proved to be a great barrier for implementation of IBL. It is clear that through PD teachers needed to find support and encouragement as well as suggestions about how IBL can be integrated in the current syllabus. It was also clear that introducing IBL needed to be supported by other changes such as policies related to assessment and examinations.

3.2.2 Teacher-related difficulties

Some difficulties were related to teachers' beliefs such as beliefs about what teaching and learning entails or their views of the nature of science or mathematics. Other barriers to making progress in the use of IBL seemed to be related to their understanding and interpretation of what IBL entails. For a number of teachers adopting IBL meant an improvement in their teaching and moving away from lecturing and transmission. However some of their interpretations showed a limited understanding/application. For a number of teachers doing IBL meant asking many questions in class and eliciting from students rather than 'telling' them. For other teachers, assigning any hands-on work was doing IBL. These interpretations were evident in some of the descriptions given in the teachers' journals as well as through interviews. A similar observation was reported in a study by Brincat (2014) who observed lessons indicated by teachers to be 'inquiry' lessons but finding that they simply involved hands-on work or the use of questioning in class. Other teachers' views and perceptions about IBL included the perception that IBL was suitable only for high ability students. A number of teachers started off with this view but were surprised by lower achieving students who were highly engaged in inquiry activities that were of an appropriate level of difficulty. Other teachers thought that the use of IBL necessarily involved long projects and long investigations that took a number of lessons to complete. Other teachers thought that IBL involves students working completely on their own with no guidance at all, as in open discovery learning. It was clear that teachers needed help to understand what IBL entails. These observations also point towards the need to give teachers opportunities to talk and share experiences about their attempts, leading to discussion and feedback about their interpretations. While many of these views changed with time, other teachers seemed to have remained set in their ways.

Apart from difficulties that were a result of teachers' views there were also difficulties related to the new role that teachers were expected to hold in the

inquiry classroom, with a less central position in class and encouraging students to take a more central position. Finding ways of encouraging all students to think and participate created some difficulties. For example some of the difficulties reported were related to dealing with and controlling overenthusiastic students who usually dominated class discussions. On the other hand another issue was related to how to motivate passive students and encourage them to become more active learners. There were some cases of challenging behaviour and class management difficulties. A major difficulty evident in the teachers' journals was related to knowing when not to 'tell' students and knowing how and when to intervene. The following excerpt from a teacher's journal illustrates this difficulty: "there were moments when a few students got stuck and were about to lose interest and start wasting time. So at that point I had to go next to them and guide them to the notes. Maybe this is not proper IBL behaviour but it was necessary at the time". Finding the right level of challenge and providing the right amount and type of scaffolding was another evident difficulty. As was the issue of how to decide when IBL is the appropriate pedagogy and when it is less appropriate. It is clear that teachers need guidance, help and support as they develop the confidence and skills to deal with these issues and difficulties. The PD facilitator as well as other colleagues working together in a small community of practice can be of great help.

3.2.3 Student-related difficulties

It was also challenging for the students to get used to the new classroom environment and to IBL challenges. In the traditional, examination-oriented classroom, the environment tended to be competitive but now students were introduced to a more co-operative environment. Students who were quick thinkers, and were used to getting instantaneous reward for their answers, were being asked to wait and let other students think and have a go. The examination-oriented culture emphasized giving correct answers and not making mistakes whereas in inquiry the focus and emphasis was on the process and learning from mistakes. For these students it meant a change in how they perceived learning: from being an individual activity they were now invited to learn collaboratively. The biggest change of all was perhaps from being totally teacher-dependent to learning to become more autonomous. One of the teachers describes an activity in which students were asked to work together in groups on a task: "some students were completely at a loss and could not concentrate without my presence … some asked me to stay around in order to check whether they were on the right track". These were rather drastic and undesired changes for some students, especially high achievers for whom the traditional classroom worked perfectly well. As a result there were reports of initial resistance or difficulty. Teachers may be discouraged when they encounter this resistance and the student difficulties.

3.2.4 Feelings reported

Teachers described several feelings related to the experience. Expressions of surprise, amazement and disbelief at what their students managed to achieve were common. Some teachers wrote about how much they enjoyed a particular lesson and about how pleased they were by the outcome. Some teachers, especially early in the PD course, wrote about fear, anxiety and lack of self-confidence. These teachers tended to be hesitant and not very adventurous in their attempts. Unsuccessful attempts resulted in teachers commenting that they were ready to give up and some of these teachers rarely used IBL. On the other hand, successful attempts encouraged teachers to use other IBL processes. Teachers observed a number of benefits for their students such as ownership of knowledge, improved learning, better retention and students taking control of their own learning. Another advantage that was greatly appreciated by teachers was the fact that students were thinking rather than accepting information, in fact some students were asking questions about more advanced ideas than those they were expected to learn at their level.

The teachers' experience clearly shows that the first stages in the process of adopting IBL are not easy and involve teachers finding their feet in the new role. Making mistakes such as in finding the appropriate task, level of difficulty and scaffolding is inevitable. This puts the teacher in an uncertain position, add to it student resistance and systemic pressures and the teacher is very likely to revert back to traditional teaching by transmission. This is why short courses are unlikely to lead to successful long-term adoption of IBL. Short-term courses are likely to inform teachers about IBL and some teachers who are willing to try out new things may try out IBL in class but the initial uncertainty is likely to outweigh the initial enthusiasm. This is where the PD facilitator and the community of practice come in useful: as a source of support and a source of ideas. As one of the teachers said:

"What I liked best was the contact with other teachers – usually we really lack the opportunity … the fact that every fortnight we were able to meet and talk about our difficulties and discovering that we were experiencing similar problems, helped a lot … in working against isolation. … working on your own you think that certain difficulties are only being experienced by you – and perhaps at that point you can't see a solution, when you discuss them with others, first of all you say: ah so it's not just me … and from other people you may get an idea of how they are tackling a particular situation which you can learn…"

3.3 The PD facilitators

The nature of the change expected and the difficulties that teachers were facing implied that the work of the PD facilitators was a lot more than imparting information to teachers about IBL. They were expected to introduce teachers to IBL but they were also required to deal with teachers' anxieties, answer questions and encourage those who were giving up. What was the facilitators'

experience? What preparation do they need? What are the required characteristics and skills of the PD facilitator?

3.3.1 Who were the PD facilitators?

The PD facilitators were all experienced teachers who were either still teaching and were Heads of Department for their subject or were former teachers working as Education Officers for their particular subject. This meant that not all of the facilitators had access to a class and hence some were unable to try out IBL activities with their own students. However they were all very familiar with the local context and appreciated the teachers' concerns about the constraints and challenges that they had to face. It was beneficial to have Education Officers involved as PD facilitators as they were in a good position to influence or advocate changes in policy, syllabi and assessment as a result of their first-hand experience with IBL in PRIMAS. Having Education Officers as facilitators also meant having leaders who were in a position to support teachers in the use IBL and train others after the project ended. In practice, however, this was considered to be a disadvantage by the PD facilitators themselves. The facilitators who had an administrative role explained that this was because they had no first-hand experience of working with IBL in a class themselves. They felt that they were not "practising what they preached". As one of the facilitators pointed out, "the teachers talked about discipline problems and pointed out this difficulty when I introduced tasks to the teachers. Sometimes I felt that the message was that it is easy to talk about something which you are not doing". Not being part of the school itself was considered as a disadvantage as it would have been "easier to understand the dynamics at that particular school" had they been teachers teaching in the same school. Another difficulty encountered in the case of an education officer who was one of the PD facilitators was a merging or blurring of roles. This Education Officer pointed out that some teachers were not seeing her as a support but as an assessor due to her dual role: "Apart from the fact that I was not school-based, my role as Education Officer was a hindrance as I had the confirmation of the appointment of two newly qualified teachers taking part in the project coming up. So I was mostly seen as an assessor and not a support. It was difficult for them to distinguish between the two different roles even though I tried to explain the reason of every school visit."

On the other hand being practising teachers as well as PD facilitators was seen as an advantage because they were able to try out the tasks and activities themselves with their own classes and then take back the experience as well as evidence to use with the teachers during the PD sessions. Being a practising teacher in the same school was considered to be particularly advantageous: "as you can identify more with the context ... with their difficulties and concerns. Working in the same school also meant that we did not need to wait for the meeting to share ideas or concerns" and "working with my colleagues made the PD meetings less formal and encouraged more participation from their side". However, this lack of formality could also be a

disadvantage, as one facilitator pointed out: "sometimes I felt the need to be firm with the teachers involved and ask them to be more committed to the project. The teachers were experiencing difficulties in participating fully due to behaviour issues prevailing in our school. Being their colleague, they expected me to understand their situation and excuse their lack of commitment."

3.3.2 The preparatory meetings

The facilitators appreciated these meetings and the collaboration between the UPT and the facilitators. They found the meetings to be very useful, especially going through the PD modules and sharing their experience and feedback from schools. The meetings served as a source of ideas for facilitators as well as support in overcoming and dealing with challenges. They found discussions on issues that were not applicable for their school to be less useful and on the other hand would have liked to have more videos involving local work.

As a result of the way the PD process was organized, with regular preparatory meetings, the facilitators felt well-prepared for introducing teachers to inquiry and for answering teachers' questions: "I felt quite well-prepared since some of the questions were also raised and discussed during the preparatory meeting at University". Another facilitator commented that: "being a teacher at the time helped as I could try out the IBL techniques and discuss any problems I faced during the University meetings". The facilitators also felt well-prepared to deal with certain difficulties that teachers encountered, and they found the experience of other facilitators to be very useful. It seems that the preparatory meetings for facilitators were a means of support for facilitators in the same way that the school PD meetings were a source of support for teachers. The facilitators observed that one particularly difficult challenge was dealing with teachers' beliefs especially in the case of teachers who were not open to change. Over time, they observed changes in teachers' views and beliefs and one PD facilitator pointed out that her own understanding changed with time through the preparatory meetings and the whole PRIMAS experience. This was not the only change in views reported by the PD facilitators. In fact they mentioned several points related to how their own beliefs changed and how they became more convinced about the importance and benefit of IBL, how their understanding developed and how they became more aware of the challenges that teachers were experiencing. The experience also improved the facilitators' skills: "PRIMAS helped me adopt a more systematic and effective approach to the use of IBL techniques in my own classroom and gave me the necessary confidence to be able to observe the practice of other teachers and mentor them in the use of IBL". As in the case of teachers, the positive experiences encouraged PD facilitators and changed their beliefs too: "I actually implemented more strategies in my teaching. The feedback of my teachers and the experiences of the other facilitators and their teachers helped me believe more and more in the benefits of IBL on students' learning."

3.3.3 The PD sessions in schools

In general these sessions involved the use of PRIMAS PD modules dealing with a number of IBL related issues. The groups worked on activities. Teachers were encouraged to try out some classroom-related activity or task by the following meeting. There was also time for discussion about concerns, the assigned tasks and about their attempts to use IBL in class. All facilitators used these components, but to different extents. They all came with different ideas, attitudes, levels of enthusiasm and preferences. Likewise, the groups of teachers were made up of individuals with different beliefs, attitudes and motivation. The groups worked and developed in different ways and to different extents. For example facilitator A was a mathematics teacher teaching in the same school. During the school meetings he often referred to his experience and shared materials including videos with his group of teachers. He also invited the teachers to go into his classroom and observe his lessons. On the other hand facilitator B was a former science teacher who was in an administrative position at that point. Part of the PD session was always dedicated to teachers' sharing of ideas, concerns and experiences. The group developed into a community that supported each other very much. They often planned and prepared activities together and in fact their journals often referred to similar lessons/activities done with their respective students.

In general the PD facilitators were able to conclude that their work was successful but it was not always easy. One of the facilitators described the situation as: "an experience of moving forward and backward and then forward again. It was slow but enjoyable work which enriched my professional experience of teaching and learning". The degree of success depended, to some extent, on teachers' starting point: some had a positive attitude while others started off with a more sceptic attitude. This resulted in different outcomes and levels of success: "The outcome was in general positive especially with teachers who had a positive attitude towards classroom innovation and were daring enough to risk changes in their classrooms. Less confident teachers were more cautious about using IBL and so had less opportunity of experiencing success." However there were also some reluctant teachers: "there were a couple of teachers who did not take much from this experience as they only gave the minimum possible".

3.3.4 Preparing facilitators

The PD facilitators provided a number of suggestions about how facilitators may be prepared for their role. The regular preparatory meetings seem to have been greatly appreciated. In fact they recommended that there should be regular, continuous meetings with the other facilitators. They suggested the use of small-group discussions during the preparatory meetings to increase participation, the sharing of ideas and experiences as well as the use of videos of IBL lessons, preferably local ones, since these can lead to good discussions. According to one of the facilitators, the meetings: "should always be considered to be workshops between equal partners who bring different but

valid experiences to the discussion." Other facilitators recommended more hands-on practice such that the PD facilitators themselves experienced IBL. Providing reading material prior to the preparatory meetings could also help the facilitators to be better prepared.

The PD facilitators felt that the role has particular requirements. Some of the requirements they suggested were personal characteristics of the facilitator: leadership, enthusiasm, belief in the effectiveness of IBL, commitment to support teachers, commitment for preparation, ability to communicate ideas to others, to be approachable as well as confident. They also gave a number of professional competences and skills: a good understanding of IBL, very good knowledge of the school subject, teaching experience in different situations, some experience of using IBL, reflection on personal experiences. The last group of requirements may be described as logistic and practical in nature although their importance is beyond the practical: the facilitator should be based in the school and support from school administration is very important. These requirements identified by the facilitators mirror the characteristics of influential PD facilitators outlined by teachers in a study reported in Linder (2011) that include: personality, management, motivation, support, knowledge, experience, evidence and professionalism.

4 Discussion and Conclusion

The PRIMAS PD experience has been a learning experience for all those involved. Among the lessons learnt are five that were closely related to the PD organization and its effectiveness.

4.1 Need for observation and feedback

Regular observations were not part of the PD model. However, classroom observations carried out for research purposes as part of the PRIMAS evaluation showed instances of gaps between what teachers say and what they practice as well as instances when the teachers' understanding or interpretation or application of what IBL entails appears to be limited. Similar observations were reported in Brincat (2014). It is evident that teachers need feedback on their practice. This can be based on what they write in their reflective journals or through discussions. A better way to achieve this is by incorporating observations of lessons and discussions about the lessons observed as part of the PD programme. The lesson may be observed by the PD facilitator or one of the other teachers who then takes up the role of a critical friend. Teachers appreciated having the possibility to meet and discuss the experiences with their colleagues. Perhaps it is time to take up Borko's (2004) suggestion to go a step further through critical examination of teaching. This requires the PD facilitator to establish trust and develop communication.

4.2 The impact of the facilitator

Just as teachers' enthusiasm, love for the subject, values and so on are communicated to their students, likewise the facilitator's enthusiasm or lack of it, belief in IBL among other things are communicated to the teachers. Differences in the enthusiasm and outcomes achieved by different groups of teachers appear to be linked to the facilitators' enthusiasm, beliefs and values. Linder (2011) reports that teachers participating in her study mention the facilitator's motivation and enthusiasm as one of the characteristics of an influential facilitator. Harland and Kinder (1997) observed that where values of those attending a course were compatible with the values and intentions of the course leaders, there was an increased likelihood of impact on classroom practice. Otherwise it is likely that only outcomes such as new awareness or new knowledge and skills are achieved. This may be a problem when attempting to 'cascade' since this difficulty is likely to be more pronounced when another level of cascading is added.

4.3 Flexibility vs Fidelity

Linked to the first two lessons described above, is the issue of flexibility versus fidelity. While it is generally agreed that no new programme or innovation can be implemented uniformly due to different situations and contexts and that an attempt to implement innovations uniformly is very likely to lead to failure (Guskey, 2002), on the other hand while adaptation is necessary it is also important to safeguard fidelity. An appropriate balance must be struck through close collaboration between developers/researchers, PD facilitators and teachers. This is by no means an attempt to stifle creativity but to avoid, for example, having teachers who decide to interpret IBL as simply the use of oral questions in class. Regular meetings or preparatory sessions for PD facilitators are required to ensure that values and meanings are shared and will help strike a balance between adapting programmes/materials to suit particular contexts and not losing the aims of the originators. Through communication one can ensure that this is maximized.

4.4 Success results in change in attitude

The PD model described in this paper enabled and encouraged teachers to try out inquiry activities as part of the PD course. Experiencing success and observing improved learning outcomes as well as improved motivation and increased student engagement encouraged and convinced teachers. This confirms Guskey's (2002) proposal that it is the experience of successful implementation that changes teachers' attitudes and beliefs (p. 383). Teachers will believe that IBL works when they see it work and that experience shapes their attitudes and beliefs. This is different from many other PD models where it is assumed that teachers will change their practice after they change their attitudes and beliefs. Figure 1 shows an alternative approach to teacher change proposed by Guskey (2002). The experience of PRIMAS supports this

proposal. It is more likely to result in the use of IBL beyond the lifetime of the PD course such that teaching through IBL becomes normal practice.
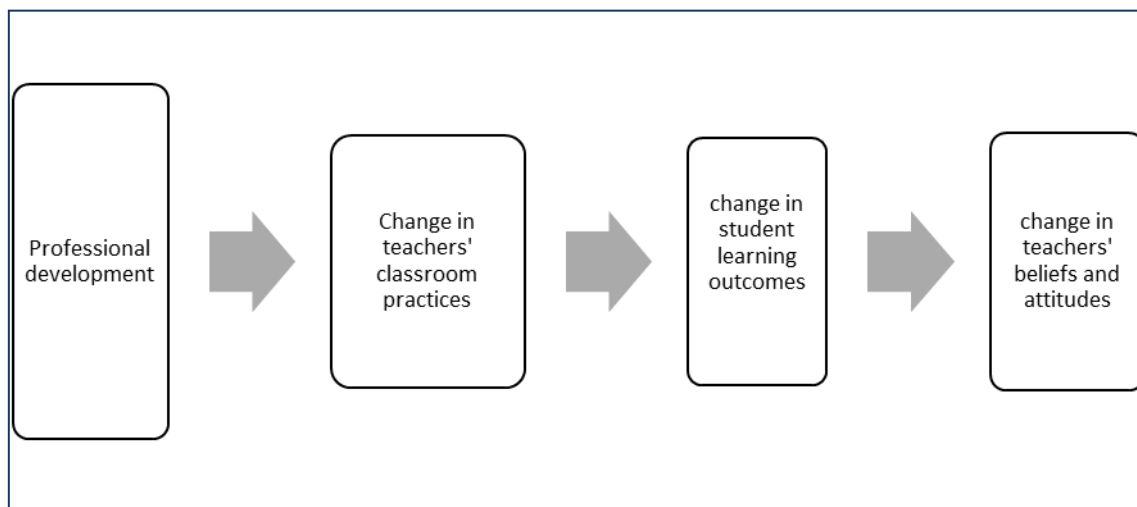
Figure 1: Alternative approach to teacher change proposed by Guskey (2002) p. 383

4.5 Professional Development

Based on this experience and in this context, an effective PD experience is one that must be seen as a process and not an event (Loucks-Horsley et al., 2010). In order to be successful, long-term PD preferably over three years is recommended, in which teachers are actively involved. On-going and on-site help and support and the possibility of teachers working as a school team and forming a community of practice. Ideally it should provide teachers with the possibility to observe one another's lessons, reflecting and discussing lessons with a critical friend. This is necessary to encourage teacher learning which involves more than acquisition of knowledge or new skills; to encourage change in attitudes, beliefs and personal theories; to provide new experiences and at the same time support the anxieties which result. Support is necessary to help the participants to overcome the anxiety of occasional failures and to encourage and motivate teachers to persist (Guskey, 2002). Guskey also refers to the need for continued follow-up and pressure that is needed to start off and maintain change. This is more likely to be successful and to ensure that teachers start using IBL out of habit.

Endnote

In this paper the term PD facilitator refers to the person leading the PD sessions, assisting and supporting teachers in the learning experience leading to professional growth. In the PRIMAS project PD facilitators were referred to as multipliers.

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KeyCoMath - Multipliers Concept for the Urban Network of Primary Schools -

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1 KeyCoMath – Multipliers Concept for the Urban Network of Primary Schools

The Chair of Mathematics and Didactic of Mathematics at the University of Bayreuth, Germany, developed a practice-based multipliers concept for an urban network of primary schools with the aim to develop mathematics education and to support pupils' competences. The idea is implemented on a local scale and addresses primary school teachers of a city. More specifically, the concept is realised within the framework of the European project "KeyCoMath – Developing Key Competences by Mathematics Education" in Augsburg. 28 primary schools are taking part in this face-to-face professional development.

1.1 Involved Parties

On the urban scale, the Chair of Mathematics and Didactic of Mathematics at the University of Bayreuth coordinates, organises and supervises activities for the professional training of primary school teachers. It works directly with a group of qualified maths teachers as coaches for teachers' professional development. These teachers with their advisory function form a link between university and school, between science and practice, because they are responsible for appointed mathematical tutors from primary schools in the entire city.

1.2 Organisation
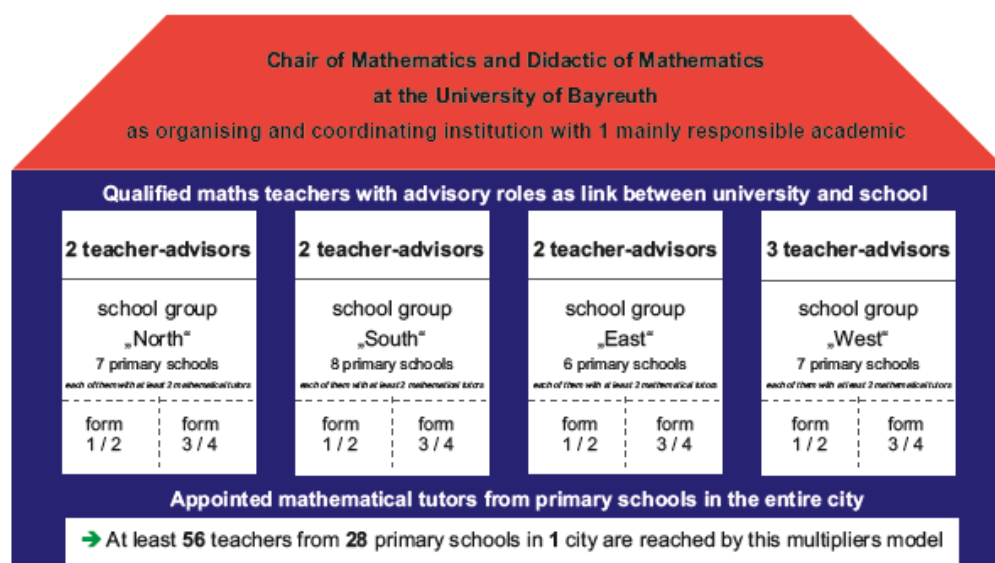
Figure 1: Organisation

For this structure the Chair of Mathematics and Didactic of Mathematics delegates one mainly responsible academic. This person is primarily in contact with the local education authority and with nine dedicated teachers who were assigned by the responsible academic to become advisors due to their high professional expertise and their innovation capacity. Groups of two or three teacher-advisors guide 28 primary schools in the entire city. Therefore, a classification into four school groups according to the location (north, south, east and west) has been assigned. Every primary school appoints at least two mathematical tutors – one responsible for the first and second form, the other for the third and fourth form. Hence, one school group consists of a minimum of twelve mathematical tutors, who will further introduce/present newly gained acquaintances to their local colleagues.

1.3 Functions

The contributor of the chair has several duties: She keeps in touch and makes all arrangements with the local education authority. Teacher-advisors are appointed and meetings are summoned by her. She provides an academic support for schools and makes funds as well as learning and teaching materials available. Above all, she operates a hosting platform for the information and material exchange (www.fibonacci-augsburg.de). The nine mathematical teacher-advisors meet their contact person at the university regularly and organise and guide school group meetings. There, they assist the mathematical tutors in planning teaching units. The tutors take an active part in the meetings in their assigned school group. They prepare and realise planned mathematical lessons and document teaching approaches.

1.4 Activities

Once a year, a major event for all involved primary teachers takes place at the university. Such a meeting consists of a lecture to a superordinate topic such as developing key competences by mathematics education. The attending teachers receive theoretical input and adopt it afterwards in workshops. The inclusion of pupils' utterances and solution processes conditioned by the study of pupils' written exercises, call logs or video shots demonstrates how children operate in a certain lesson's sequence. In addition, every local primary school has the possibility to book in-house advanced training courses for its teaching staff according to requirements. Normally, four school group meetings per school year are organised by the teacher-advisors. For these meetings, the mathematical tutors have to prepare the following: They previously realise a teaching unit in their own class and collect pupils' approaches. Above all, the members of a school group organise joint visits to classes, compare their varying approaches of teaching on the same specific mathematical topic, together reflect on one's own work and exchange their ready-made experiences, whereby mathematics education can be refined. The focus is not

solely set on spreading teaching materials and on giving recommendations for lessons. The objective of the project lies to a great degree on developing the level of inner convictions and beliefs teachers have of their subject, on teaching and learning processes, and their role in the lessons. These play a major role for the planning, implementation and implementation of lessons (see Blömeke et al. 2010; Kunter et al. 2011).

1.5 Experience

This multipliers concept for the urban network of primary schools has proven itself over five years and will be continued in future.

The professional responsible academic Petra Ihn-Huber says: *"It is encouraging to witness how mathematics education progresses at many primary schools in Augsburg, how teachers set out together to develop good mathematical assignments and how they bring teaching concepts of the common retrospect into question and thus improve them. By observing the children, I recognized their growing interest for mathematical issues, their creative dealing with numbers, patterns and structures, a greater openness for mathematical observations of everyday life and an increasingly safer handling with basic mathematical skills and abilities. The cooperation with school administration (education authority, administration) is successful because of good personal contacts."*

The involved primary teachers work as multipliers during their leisure time, including extra effort in their daily workload, which is unfortunately neither compensated nor squared with class hour reduction, but which demonstrates the commitment of the participating teachers - since *"Staying still means taking a step back."* (Teacher advisor)

Concerning the observation of lessons, it is not always easy to find a volunteer who shows the own teaching approach to colleagues. However, this risk is effectively prevented by the offer of a joint preparation of classes. But: *"I can work through exciting new ideas and discuss problems with motivated colleagues. Instead of sitting alone in my room I have many like-minded people around me."* (Teacher, participant in the school group) and *"at the moment it's the only opportunity to get a direct look at the work of my colleagues. I can challenge myself in the implementation of the curriculum and at the same time receive inspiration through the teachers and their contact with students. Everyone learns from each other in a relaxed atmosphere without the pressure of being judged."* (Teacher who is on parental leave)

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Sustainable Training in Mathematics -
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1   Starting point and objectives

A team working at the Centre for Didactics deals intensively with developing a sustainable concept for in-service teacher training in mathematics. Based on research findings on the topic of (in-service) teacher training and the professional development of teachers as well as on current research findings concerning "competence-oriented maths teaching", a training concept has been developed. This concept focuses on the teaching of competences in mathematics (pupils aged between 6 and 18) and shall attract various target groups at schools.

For the poster presentation we decided on two training concepts: 1st the training series for elementary school teachers on a regional level and 2nd the training of high school teachers at the national level.

2   Competence-oriented Teaching with a View to the New Standardised Final Examination (Neue Reifeprüfung)

2.1 Target group

The working group leaders for mathematics and the professional group of high school teachers from all parts of Austria, who

- are eager to design their mathematics classes competence-oriented based on state-of-the-art research results
- are interested in working as multipliers at their schools or in their province
- intend to work as an expert in teaching development

2.2 Structure and Contents

The course consists of four complementary, consecutive modules (20 units each) and phases of in-depth self-study. While in the three compulsory modules, the contents was given, the participants could choose various subjects in the fourth module. Different educational backgrounds and experience levels were taken into account. Since 2012 follow-up seminars and workshops have been provided every year relating to current problems and results from feedbacks of the participants. Approx. 55 teachers have completed this course and currently continue to participate in the annual events.

Module 1:

- Interpretation and determination of substantial basic mathematical skills
- Reflection on one's own classroom instruction and teaching in relation to the basic mathematical skills
- Joint planning of (in-service) teacher training (concerning both contents and structure)

Module 2:

- Basic mathematical skills as an integral part of one's own classroom instruction (impact on one's own teaching; task development and questions; competence-oriented test examples)
- Evaluation of the conducted training seminars (collection of open questions; analysing concerns; consolidation of the results of training seminars)

Module 3:

- Reflecting one's own classroom instruction and teaching in relation to all the individual basic competences
- Developing additional tasks and assignments
- Developing processes for the conducted training seminars
- Collecting ideas and proposals concerning topics to be provided in the course of the 4th module

In between the individual modules the participants work on individual and self-selected assignments in the domain of their own maths teaching and offer training courses held at their own schools or at partner schools. They form regional peer groups, which meet in the periods between modules, in order to work on and plan individual topics and to exchange views on certain issues.

2.3 Characteristics of the Concept

- Discussing the theoretical background knowledge of teachers and discussing different perspectives on teaching practice
- Providing support and advice from external academic experts and practitioners
- Offering training cycles, in which teachers can engage with their own learning and work context specific
- Collaborating with peers within the large group as well as collaborating in peer groups, perusing joint objectives
- Collecting different learning needs
- Duration (2 years), learning how to distinguish between subjective assumptions/theories & existing practice and desired practice in order to change practice
- Commitment to participate in all modules

- Alternating phases of discussion and reflection in order to deal with one's own practice as well as with new ways of thinking and patterns of action
- Target group oriented

2.4 Support Systems

Current teaching of mathematics is not only based on knowledge of facts and arithmetic operations, but focuses on problem solving skills, understanding and thought processes. This new alignment of teaching mathematics is also reflected in the new final examination in mathematics, which will become mandatory for each high school student by 2015. Through the training course and the training of multipliers, it is possible to prepare teachers early on this change. Thanks to the provision of resources and the support of both the Ministry and the Bifie as well as to the good cooperation with the provincial school boards and the universities this series of continuing training courses could have been developed and be made accessible to many teachers.

3 Training Course - Competence-oriented Teaching Focussing on Educational Standards at Primary School

3.1 Objectives

Primary school teachers shall:

- gain knowledge of basic theoretical concepts of competence-oriented maths teaching in relation to the educational standards.
- get to know ways of individual learning assessments (Lernstandserhebungen) and providing supportive feedback.
- reflect on their own classroom instruction in accordance with competence-oriented learning and teaching.
- be enabled to design their maths lessons competence-oriented
- act as multipliers and disseminators at their schools.

3.2 Target Group

It is a series of training seminars for primary school teachers. On the one hand the whole series can be attained as one complete course, on the other hand individual modules can be attained by all interested teachers. The individual course modules were held in three regions in order to ensure a comprehensive implementation of the competence-oriented teaching of mathematics in Tyrolean primary schools. In parallel to the subject-specific modules a pilot project was launched in two districts. In each of these districts the support of project groups is offered. Within these groups further development tasks can be supervised and discussed. 40% of the primary schools have already taken advantage of this special offer for themselves.

3.3 Structure & Contents

The whole course consists of six interlinked, sequential modules, which are supplemented by phases of deepening self-study.

The relatively high proportion of self-study results from

- the dialogical and interactive form of the modules - knowledge is not merely taught, but developed in a dialogic process among the students.
- the structure of the individual modules - phases of presence and self-study with collegial exchange alternate.

Contents examples for each module:

- competence model of education standards in mathematics for the 4th grade.
- mathematical tasks and assignments.
- analysing the competence potential of assignments.
- development and application of diagnostic tools.
- Feedback.
- development of support frameworks.
- dealing with mistakes in learning situations and settings in mathematics.

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Scaling up professional development: Changes and challenges –
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1 Introduction

In a plenary presentation at ICME 10 in 2004, a team of researchers (Adler et al. 2005) presented an analysis of papers on mathematics teacher education in leading journals and proceedings throughout 1998-2003. Their meta-study indicates that small-scale qualitative research predominates: More than two thirds of studies with an empirical claim had less than N=20 (participants being in the focus of research). Thus, ten years ago, small numbers in teacher education research were relatively common, and this makes sense regarding different context factors (Krainer 2015). However, Adler et al. (2005, p. 376) claim also a need for scaling up, and stress:

We know little about what happens when programs spread to multiple sites. We have also done less of studying what it means to scale up or what it means to extend a program that has worked in one setting to another setting – what works, what goes wrong, what do designers need to know and think about.

Another claim of this meta-study is that most research in teacher education is conducted by teacher educators studying the teachers with whom they are working (90% of JMTE articles, 82% of PME, and 72% of JRME articles were of this type). Adler et al. (2005, p. 375) regard this as not surprising in teacher education research:

A person designs a program and wants to show that it works. It is not so surprising that research aimed at showing effectiveness of particular approaches predominate. This is how innovative ideas are shared, substantiated, and thus gain currency.

It is not by chance that the meta-study is titled 'Reflections on an emerging field: Researching mathematics teacher education'. Teacher education research was and still is an emerging field of research, the need for scaling is an ongoing challenge. However, the ZDM special issue 'Evidence-based CPD: Scaling up sustainable interventions' (see e.g., introduction by Roesken-Winter, Hoyles & Blömeke 2015), and this conference on international approaches to scaling-up professional development in maths and science education, head-titled 'Educating the Educators' are indicators of progress.

2 WHAT does scaling up (with multipliers) mean?

Scaling up professional development (PD) is a means to reach many or even all teachers (of a region, state, etc.). One prominent model for scaling up PD is the Cascade model (see e.g., Maaß & Artigue 2013). In this model, experienced teacher educators provide PD for future teacher educators (mostly experienced teachers), who in turn provide PD for teachers, and so on.

One usual name for providers of such PD is 'multipliers'. This term stresses the 'multiplying' feature of scaling up: For example, in order to reach 8,000 teachers, and following a simple multiplication model, 20 × 20 'multipliers' are needed if each PD educates 20 participants. Of course, several challenges of this scaling-up strategy should be taken into account. For example, it is obvious that in each step the PD participants can hardly reach the knowledge of the PD providers. In addition, it is likely that the interest of PD participants decreases in each cascade, whereas their scepticism (e.g., towards the reform ideas) increases[2].

Large-scale PD design and research is a complex endeavour. It has at least three dimensions that afford critical consideration: PD design, research design, and time & number (see Figure 1).
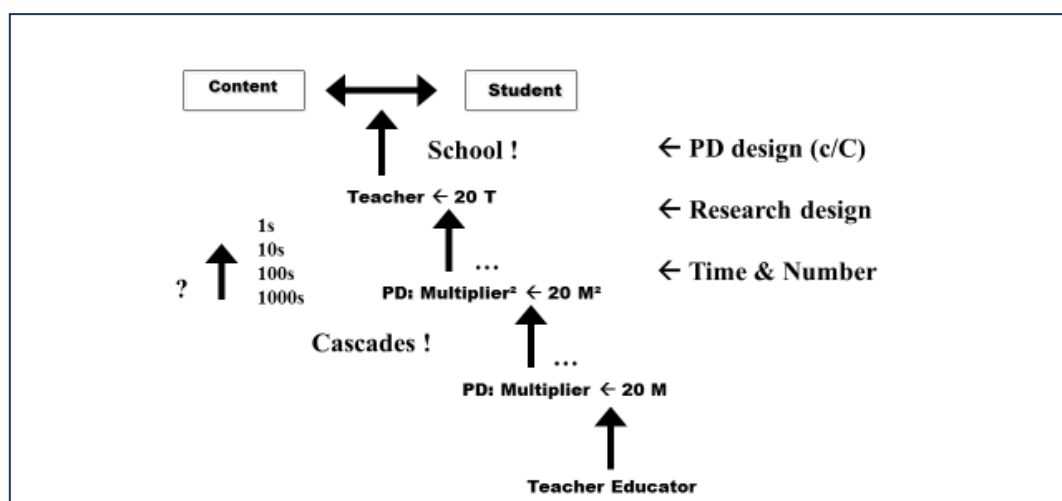
Figure 1: Large-scale PD design and research

The PD design includes several cascades. However, in order to aim at an impact on all students, at least the last cascade needs to deal with practising teachers. These teachers have the challenge to cope both with the PD idea, and the complexity of their classroom (sketched as a triangle comprising the teacher, the student/s, and the content/s). The PD can be designed in various forms regarding the content. To sketch only two very different forms: a) All cascades are dedicated to a specific mathematical content (big C), like fractions (e.g., referring to grades 5-6); here, the challenge is that only a part of all teachers (those teaching in grades 5-6) are reached, and also regarding these teachers the question remains how they get support in further developing their teaching in all other mathematical areas and grades. b) The content of the cascades is varying, which means that no specific content is

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[2] Due to these challenges of disseminating knowledge in a top-down-manner, other approaches follow bottom-up (or mixed) strategies where the starting point of innovations are teachers' own ideas for improving their teaching, supported by "critical friends" (e.g., colleagues or university staff). For example, in Japan, the lesson study approach has a long tradition, meanwhile widespread all over the world, recently more often combined with the learning study approach. There is an increasing claim to regard teachers as relevant stakeholders in research (see e.g., Kieran, Krainer & Shaughnessy 2013).

treated deeply in the cascades (small c); here the challenge is that many teachers can be involved, but it is not easy to investigate the impact from the content point of view.

Another challenge is that with the increasing numbers of involved classrooms and teachers, different interest groups (at different levels) come into play (see Figure 2). For example, dealing with hundreds or even thousands of classrooms (macro level and $macro^2$ level), district leaders and policy makers involved in states or nations are relevant stakeholders (and eventually also mathematics teachers or researchers from larger organizations like unions). In contrast, dealing with some teachers or tens of classrooms (micro and meso level), students, parents, colleagues (teachers of mathematics or other subjects), (mathematics) teacher leaders (at schools or in districts) are relevant environments to deal with (see more detailed in Krainer 2008).

Levels	Classrooms/Teachers	Focus
Micro	1s <-> Students, Parents, Ms	Individuals, Teams
Meso	10s <-> (Math) Leaders, Ms	Networks, Schools
Macro	100s <-> District Leaders, Ms	Districts, Regions
$Macro^2$	1000s <-> Policy makers, Ms	States, Nations

Figure 2: Number of Classrooms/Teachers

3 WHY is scaling up (NOW) so important?

Scaling up PD (although it means efforts from many people and considerable resources like time and money) became a real issue in mathematics education in the last decade. This increasing attention can be regarded as a reaction to interests by educational policy (see more detailed in Krainer 2015). Policy needs to deal with increasing results of data from national and international testing (e.g., in the context of educational standards or studies like PISA and TIMSS with regard to students' achievement, or TALIS related to teachers' working context, or TEDS-M on teachers' competences). This testing is partially caused by changes from input- to output-steering of educational systems (being the case, e.g., in Austria and Germany, whereas Great Britain and the USA have a longer tradition of testing and thus more experiences with its challenges). Thus, a new approach to steering educational systems strengthens international comparative testing; with the involvement of new participating countries, the focus on comparing increases; new data become visible and attractive; they bring into light new challenges, or underline old ones; the challenges evoke reactions by educational policy; if the challenge is

considered strong enough (e.g., a very bad ranking of a country), it is likely that it becomes the starting point of a (new) reform.

Of course, developing new curricula, textbooks, or other educational material can support reform movements; however, most experts regard teachers as a key for achieving sustainable change. Since modifications in pre-service teacher education take a long time to be implemented, often PD is chosen as a quite more direct and quick intervention into the field of teaching. It is taken for granted that offering only a small number of short-term PD activities are not sufficient in fostering change in all classrooms. PD seems to be direct and quick way, and easy to scale up.

There are several critical issues to consider when scaling up PD (see Krainer 2015). One of these decisive issues is the role of multipliers. In most cases, multipliers started as teachers, but by getting more contact with teacher educators and research and by providing PD for "normal" teachers themselves, they change their role and are increasingly detached from being (regarded as) "normal" teachers. Moreover, if they, for example, work (part-time) at a university or at an educational administration, their role and perception changes essentially: they no longer belong to only one group (namely teachers), but need to build up a new identity. In addition, multipliers often stay part-time as teachers at their school, and this causes a structural challenge, too. For example, it is assumable that their principal is interested to use the human resource at his/her own school, surely in the area of mathematics teaching, but probably also for fostering innovations in other areas. Thus, also the bridge between PD and school development is a crucial issue. If scaling up PD should reach all teachers, designing adequate school development processes are necessary. Another challenge is the (potential) contrast or difference between the current practice (at schools) and the reform practice (as intended by those financing and/or providing PDs or other kinds of initiatives). This leads back to the question of multipliers' identity: is the multiplier someone who fully represents the reform practice, or is he or she rather a mediating person (broker, bridge-builder etc.) between current practice and reform practice, critically reflecting both practices, including the search for finding viable steps towards change? Is the multiplier a transmitter of knowledge from outside teaching practice to teaching practice only? Or is he or she intended to be an autonomous facilitator that helps teachers to critically reflect their practice (e.g., by using viable stimuli from research), and to negotiate norms (see Krainer 2005a), for example, by jointly finding meaningful and reachable compromises between the current practice and the intended reform practice? The latter approach is in stark contrast to a transmitter-of-knowledge stance. This stance apparently makes multipliers' identity and work difficult, and thus makes the success of pure scaling up cascades questionable.

4 Scaling up as "knowledge transfer"? Three approaches

A naïve approach to cope with the question of bringing about change in an education system, is the following: only teachers have to change, there is no need to involve much of research, there is only a need for (some) professional development, of high importance are central regulations through curricula, decrees, etc. from educational administration. Following the wording of *"Technical Rationality"* (see below), such a view could be called *"Naïve rationality"*. It overvalues steering by decree, not taking serious the voices of practitioners and researchers, indirectly expressing mistrust to their contribution. This view is not held officially and surely not put into practice in a pure way, however, (worldwide) critique is raised that such a thinking is present, although only partially and hidden.

In order to criticize the knowledge transmission view, Schön (1983) introduced the term *"Technical Rationality"*. It follows three basic assumptions:

- There are general solutions to practical problems.
- These solutions can be developed outside practical situations (in research or administrative centres).
- The solutions can be translated into practitioners' actions by means of publications, training, administrative orders, etc.

Teachers have merely to apply what has been predefined in the academic and administrative power structure above them. Thus, technical Rationality causes a *hierarchy of credibility*, expressing a genuine *mistrust* of practitioners. In turn, this evokes *resistance* by teachers, opposition against reform, and a genuine mistrust of researchers, and of education policy and administration people. It is a *vicious circle*, and it causes a challenging role for multipliers (see the discussion on their identity above).

In contrast to Technical Rationality, *"Reflective Rationality"* (see e.g., Altrichter, Feldman, Posch & Somekh 2008, p. 270) follows three very different assumptions:

- Complex practical problems require particular solutions.
- These solutions can only be developed inside the context in which the problem arises and in which the practitioner is a crucial and determining element.
- The solutions can only rarely be successfully applied to other contexts, but they can be made accessible to other practitioners as hypotheses to be tested in practice.

These assumptions imply *new types of communication* among practitioners and new types of communication between practitioners and researchers (see a more detailed discussion in Krainer 2014). If teachers are regarded as important producers of knowledge and "practical theories", the *production of "local knowledge"* could be seen as equally important as *"general knowledge."*

This could make the situation of multipliers more acceptable, desirable and manageable, and they would gain a more *autonomous position*, which is a good precondition for *sustainability.*

5 Some remarks on sustainability

Sustainability can be defined as the lasting continuation of achieved benefits and effects of a programme or initiative beyond its termination (see e.g, DEZA 2002 in Zehetmeier 2008 and 2015). Short-term effects are necessary "to build trust with the public or shareholders for longer-term investments", but long-term effects need to be considered as well, otherwise the result could be to "win the battle, [but] lose the war" (Fullan 2006, p. 120). Similarly, Hargreaves and Fink (2003, p. 3) state that sustainable improvement requires "investment in building long term capacity for improvement, such as the development of teachers' skills, which will stay with them forever, long after the project money has gone".

At least three aspects (3 Co's) need to be considered when aiming at sustainable scaling up:

- Content: It makes a huge difference regarding the design of scaling up and the link between PD and school development whether the content of PD is rather specific, or rather general (see discussion in section 2).
- Community: It is essential to reflect whether the communication is directed to individuals, teams, communities, networks, or institutions. When scaling up PD and involving a variety of stakeholders, the issues of negotiating goals, interests, researcher-teacher-multiplier-relationships, identities, are essential.
- Context: It is decisive whether a PD relates to the micro, meso, or macro level (see discussion in section 2).

In the following, experiences from two programmes running in Austria since 1982 (PFL) and 1998 (IMST) are sketched.

6 Experiences from PFL

In 1982, two-year PD courses for secondary teachers in Austria were launched, in reaction to a considerable lack of subject-didactics in teacher education. The courses (first established for English, German language, history, and mathematics) were called Pedagogy and subject didactics for teachers (Pädagogik und Fachdidaktik für Lehrerinnen und Lehrer, PFL). In 1984, about 100 teachers finished PFL, in 1985 new courses started (on average leading to 25 graduates in each course), Since then, in general every third year, several courses (for single subjects or combinations) started and made PFL a long-run PD programme. Till the end of 2014, about 1000 teachers finished PFL (40 ECTS; all school levels, since 2012 focus on competence-oriented teaching). Each course consists of a variety of formats, in particular three one-week seminars, five one and a half-day regional group

meetings and individual practical work. The teachers are required to write case studies on innovations introduced in their schools, and pay a small course fee. After conclusion, participants receive a university certificate with a description of their achievements during the course.

In the following, a short view on the eight design principles of PFL (see e.g., Krainer and Posch 1996, pp. 10-12) is done, and compared with those of DZLM (2013).

- PFL: Integration of pedagogy and subject didactics (interdisciplinarity); DZLM: (Partially covered by) Various instruction formats
- PFL: Starting from teachers' experiences, strengths and questions; DZLM: Participant-orientation; case-relatedness (ideas based on practical experiences and specific student results)
- PFL: Teacher as researcher (action and reflection); DZLM: Fostering (self-)reflection
- PFL: Connecting theory and practice; DZLM: Competence-orientation (competence framework)
- PFL: Professional exchange of teacher knowledge; DZLM: Participant-orientation
- PFL: Building a „learning community" (autonomy and networking); DZLM: Stimulating cooperation
- PFL: Self-initiated learning processes; DZLM: Case-relatedness (e.g., practical experiences as PD providers)
- PFL: Teachers take responsibility for their learning (important for acting as facilitators); DZLM: Participant-orientation, competence-orientation

This shows that there is some overlapping, and that both bundles of design principles aim at bridging theory and practice. However, both have their specific emphasis: PFL is closer to starting from teachers' (individual) practice; DZLM is closer to starting from a (general) theoretical framework.

Putting an emphasis on continuous PD, PFL is an exception of the (PD) rule in Austria. PFL courses are led by a team of about five members (educationalists, subject-matter specialists, practitioners) who are responsible for the preparation and realization of the course and for follow-up activities (e.g., evaluation, publication). This means three years of intensive theoretical and practical work. Besides being a contribution to the further education of teachers, PFL is also an experience in interdisciplinary cooperation and university didactics. So far, three books (in German) have been published (Fischer, Krainer, Malle, Posch, & Zenkl 1985; Krainer & Posch 1996; Prammer-Semmler, Prexl-Krausz, & Soukup-Altrichter 2006), and several publications (in English e.g., Krainer 1994; Zehetmeier, Erlacher, Andreitz, & Rauch, 2015).

PFL evaluations and research show – regarding the question of impact – many positive aspects (e.g., reports on individual teachers' learning and satisfaction; many teachers became visible innovators, some got new got roles in teacher education or positions in educational management; teachers' feedback was

used for continuous adaptation of design). However, it was disappointing to realize (by the end of 80-ies) that although many teachers improved their own teaching, there was little impact on other teachers or even on school development.

Based on the assumption that a link between PD and school development is needed, the team reacted at several levels. For example, by integrating reflection on the challenge of spreading innovations into PFL, by integrating reflection on school development into PFL, by attending a two-year-course in organisational development (and multiplying the knowledge to other team members), by launching pilot-projects, or by offering an extension from PFL to ProFiL (including issues of school development; Master of Education with 120 ECTS).

This investment into school development brought additional knowledge to PFL and was the starting point for new projects with schools or its departments, focusing on general issues at schools (e.g., Brunner, Hruska, Krainer, Piber, Posch, & Racher 1997), or on subject-related further developments (e.g., Krainer, Krainz-Dürr, Piber, Posch, & Rauch 1998; Krainer 2001; later Rauch & Kreis 2007). Studies show impact with regard to many levels (e.g., reports on individual school's further development and satisfaction; individual teacher groups and schools became visible in their region). However, it was disappointing to realize (by the end of 90-ies) that although many schools improved, there was little impact on other schools, on their region, or even at the national level. The experiences brought an "existence-proof" of success at the individual and organizational level (including improvement for practice, and new knowledge about design and research of PD), but also the insight that also regional and national efforts as well as structural innovations are needed. Thus, a next step (after focussing on the learning of individuals, and then on the learning of organizations) seems to be important to do: looking at the learning of districts, regions, or the whole country when focussing on classrooms and teachers.

7 Experiences from IMST

Looking back, it was good luck that Austria had bad results in TIMSS 1995 related to upper secondary schools. The responsible ministry looked for explanations and for measures, thinking primarily into the direction of professional development for teachers. Since PFL and other activities (by the institute organizing PFL, recently called IUS[3]) had reached some visibility, the IUS was asked to analyse the TIMSS results. The ministry commissioned a research project (1998-99) to analyse the situation of mathematics and science teaching in Austria, and to formulate suggestions for improving the

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[3] IUS is a German abbreviation for the Institute of Instructional and School Development at the Alpen-Adria-University Klagenfurt in the south of Austria.

situation. This gave birth to IMST as a project[4]. The research project (like the following projects, too) was carried out in collaboration with partners throughout Austria (see e.g., Krainer & Kronfellner, 2000; Krainer 2003).

The research project led to an Austrian-wide development project IMST (2000-2004). This project (see e.g., Krainer, Dörfler, Jungwirth, Kühnelt, Rauch, & Stern 2002; Krainer 2005b) focused on the upper secondary school level only. The two main goals of IMST (2000-2004) were

- to initiate, promote and make innovations visible, to analyse and to disseminate innovations, with the emphasis on generating ''good practice'' concepts and on supporting teachers in further developing their teaching;
- to take part in setting up a support system for the further development of school practice in MINT subjects, in particular by encouraging practice-oriented, scientifically grounded subject didactics.

Due to the success of IMST regarding these two goals, the responsible ministry decided to continue the project, based on the support system suggested by IMST (see e.g., Krainer, 2005c). IMST was carried out 2004-2006, then prolonged to 2007-2009, 2010-2012, and up to now 2013-2015. The initiative was adopted several times. For example, it was enlarged to all school levels and types, and further subjects like German language were added. The support system comprises seven measures focusing on various levels of the educational system: local, regional, and national. A particular focus is laid on evaluation and research, and on gender & diversity, which are integrated into all measures.

In the following, the seven measures (M1–M7) and their present status quo are sketched briefly, using a focus on structures, to which IMST aimed at contributing.

a) Multiplier- & interface structures (M1 and M2): In order to support teachers in disseminating innovations, in building bridges between innovations in practice, new results in science, and new demands from educational policy, the school system needs at the local and the regional level a subject-related middle management (MINDT[5] multipliers). This means upgrading the role of local subject coordinators (M1) at schools, and upgrading the role of regional subject coordinators (M2) in all federal states (regarding M2 as educated educators who in their turn educate and support M1, etc.). By the middle of 2015, M1 has been repeatedly included in government plans; however, it still awaits implementation (mostly due to budget problems). Regarding M2, a pilot PD programme (40 ECTS) started in 2006-2008 with about 90 M2-expert teachers graduating the programme (see e.g., Krainer & Müller 2007). The

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[4] IMST = originally, Innovations in Mathematics and Science Teaching (1998–1999); later, Innovations in Mathematics, Science, and Technology Teaching (2000–2009); since 2010—motivated by adding German studies as one more subject— the name is Innovations Make Schools Top

[5] MINT is the German equivalent for STEM. Since in IMST, in addition to mathematics, computer science, natural sciences, and technology, the subject of German language was integrated in 2010, the term MINT was enlarged to MINDT.

M2-idea was extended and combined with the PFL programme, having started in 2012 with more than 150 teachers. M2-programmes were/are not direct parts of the IMST initiative, but they have mutually influenced each other, and in many cases the same educators and researchers are involved. In particular, PFL courses (including those for mathematics and science, both for primary and secondary teachers) show a great synergy with IMST.

b) Qualification- & research structures (M3, M5, and M7): In order to have the adequate academic basis for educating prospective teachers, for delivering PD for practicing teachers and expert teachers like M2, etc., sufficient teacher educators and researchers in subject didactics are needed. It was planned to launch Austrian Educational Competence Centres (AECC) for all subjects (starting in the MINDT disciplines, M5) and one AECC for instructional and school development (M7). During 2004-2006, six AECC had been established (for biology, chemistry, and physics situated at University of Vienna; for German language, mathematics, and instructional and school development at the Alpen-Adria-Universität Klagenfurt), with a certain impulse budget from the ministry. These centres were a strong impulse for research and education in subject didactics in Austria (see e.g., Krainer, Hanfstingl, Hellmuth, Hopf, Lembens, Neuweg, et al. 2012). The AECC strongly contributed to strenghtening research in these areas (e.g., by establishing professorships and other new staff, doctoral programmes, the Austrian society for subject didactics, etc.), but they had also been involved in activities that helped to improve teacher education and teaching at schools (e.g., the generation of educational standards, the new Austrian-wide final exam, activities related to IMST and M2, etc.). Whereas it is only planned having one AECC for each subject in Austrian, more regional subject didactics centres (M3) should be installed at universities and university colleges for teacher education. IMST supported the establishment of such centres and initiated the label Regional Educational Competence Centres (RECC) for M3, fulfilling specific quality criteria. In 2014, the first 13 RECC had been awarded by the responsible ministry, 7 more RECC will be added in 2015. An evaluation of MINT subject didactics in Austria showed that – in addition to AECC – also regional subject didactics centres contributed largely to the further development of the disciplines (however, still having challenges becoming stronger in research, in particular due to historic and structural reasons).

c) Support structures for practice (M6, partly M4 – see below): In order to make good practice in challenging MINDT areas visible and accessible for many teachers, and to thus contribute wide spreading the culture of innovations at schools, an adequate opportunity needs to be offered. IMST established a kind of fund (M5), structured in so-called Thematic Programmes. The design of Thematic Programmes (TP) is based on the idea of a scientific fund, adapted to the needs of teachers and schools. Each TP is selected by an independent jury (application of a theme that responds to a current challenge in MINDT teaching by a team of experts from universities, university colleges for teacher education, and practice). Each TP supports about 20 innovation

projects a year all over Austria. Like in a fund, the teachers have to apply for a project (describing e.g., challenge, innovation, goals and evaluation of the project). They get (when successfully passing the review process with a final decision and recommendations by a jury) – apart from individual support for their project and participation in several meetings with colleagues and experts – about € 1500 when finishing their project, including a written paper about their innovation which is accessible at the internet IMST-Wiki (http://www.imst.ac.at/wiki). High quality projects are presented at IMST conferences, network meetings, partially at international conferences and in the context of EU-projects (e.g., Fibonacci, KeyCoMath, and PROFILES) where IMST is involved; or these projects might become winners of the annual IMST award (currently six prizes, sponsored by state and economy). The number of financed projects had with about 200 projects per year a peak, recently, about 100 projects (covering all MINDT subjects and grades) are supported. The actual four nation-wide TP focus on competence oriented teaching in the fields of mathematics and science, writing and reading, learning with digital media, and hands-on laboratory. This is supplemented by a regional, economy-sponsored TP in Carinthia which focuses on creative teaching in computer science. Teachers carrying out innovations within TP are expected to be disseminate their knowledge, and thus become potential bridge-builders between the work in Thematic Programmes and in the Network Programme in IMST (see below).

d) Network structures (M4, enriched by some further activities): In order to broaden the programme at the regional level, the plan was to set up Regional Networks (M4) in all nine federal states in Austria. Measure M4 has been implemented fully within a few years, and even developed further ideas to strengthen the network idea. The first Regional Network was established in 2003, contracts with other federal states followed in the years 2004-2008. Since then, these contracts (e.g., including the fact that the federal state invests more resources than provided by IMST) have been prolonged till now (with an average duration of 2-3 years). Each network has a steering committee with representatives from practice, the federal state education board, and the teacher education institutions (covering all MINDT subjects). As a further development of network structures, support was provided by setting up five district networks in reaction to needs articulated by regional stakeholders like superintendents and/or bottom-up initiatives by teachers involved in M2-activities. Often, the M4-activities were the driving force for establishing the regional subject didactics centres (M3). In some smaller MINT-subjects, where no university or university teacher college in Austria was able to launch such a M3-centre (technical handicraft, nutrition, descriptive geometry), IMST helped to establish nation-wide Thematic Networks as a basis for a future regional (or even national) centre. All these initiatives are recently bundled in the so-called Network Programme. In order to exchange experiences among these networks, bi-annual meetings are organized, where also representatives of universities and university colleges for teacher education (including M3, M5, and M7) are invited, if new activities are

discussed, also representatives from the federal states' education boards and/or the ministry. The main feature of the Network Programme are the nine Regional Networks. Their task is geared to the needs of the schools in the region and to existing resources. It always includes the establishment of a platform for schools and teachers, arranging opportunities for sharing experiences and further education, supporting school development, in some networks the support of small projects (who could lead to submissions in M6), developing a pool of experts to advise on didactic and school matters, evaluation related to the goals, drafting an annual report, and interim reports on the networks' activities (see e.g., Rauch, 2013).

The example of PFL and IMST show that PD can only by one element of sustainable scaling up. Multipliers are important, but there is a need for a variety of accompanying structure-building measures. These efforts need a joint effort by practitioners, researchers, and in particular by educational administration and policy. Therefore, it makes sense to end with an appeal, formulated as a message from ministry to schools: 'Please, focus on (students') inquiry-based learning; please, continuously reflect and improve your practice; please, change experiences with colleagues and experts; and please, try your best in embedding new research results. We try inquiry-based learning ourselves and support you!'

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KOMMS: Teacher training courses fostering modelling in schools -

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1 Introduction

Within the framework of KOMMS (competence centre for mathematical modelling in STEM[1]-projects in schools) based in Kaiserslautern, Germany, teacher training courses to foster modelling in schools are conducted at a regular basis. KOMMS does not only offer teacher training courses, but combines the four fields of *school projects, teacher training courses, teacher education* and *research.* Due to this wide field of activities concerning mathematical modelling teacher training courses can be offered in an environment connecting theory and practice within schools in an optimal way. Teachers have been educated and trained to teach modelling in schools by staff of the University of Kaiserslautern for many years. Now, with the newly established competence centre KOMMS, new approaches to enhance the multiplier effect of mathematical modelling in schools are being developed and implemented. One of the main goals of KOMMS and its teacher training courses is to foster sustainability of modelling by training teachers to use and multiply their knowledge and experiences.

2 Theoretical Background

In the educational standards of the German school system for the subject mathematics six general mathematical competencies are being named by the KMK[2] (2012): *arguing mathematically, solving problems mathematically, mathematical modelling, using mathematical representations, handling symbolic, formal and technical elements of mathematics* and *communicating mathematically.* According to the curricula these competences should be encouraged and fostered on a regular basis. One of these competences is *mathematical modelling*. Blomhøj and Jensen (2003) define mathematical competence to be the ability "to autonomously and insightfully carry through all aspects of a mathematical modelling process in a certain context". A modelling process is split up into different sub-processes which can be represented in an idealized modelling cycle (e.g. Blum et al., 2009).
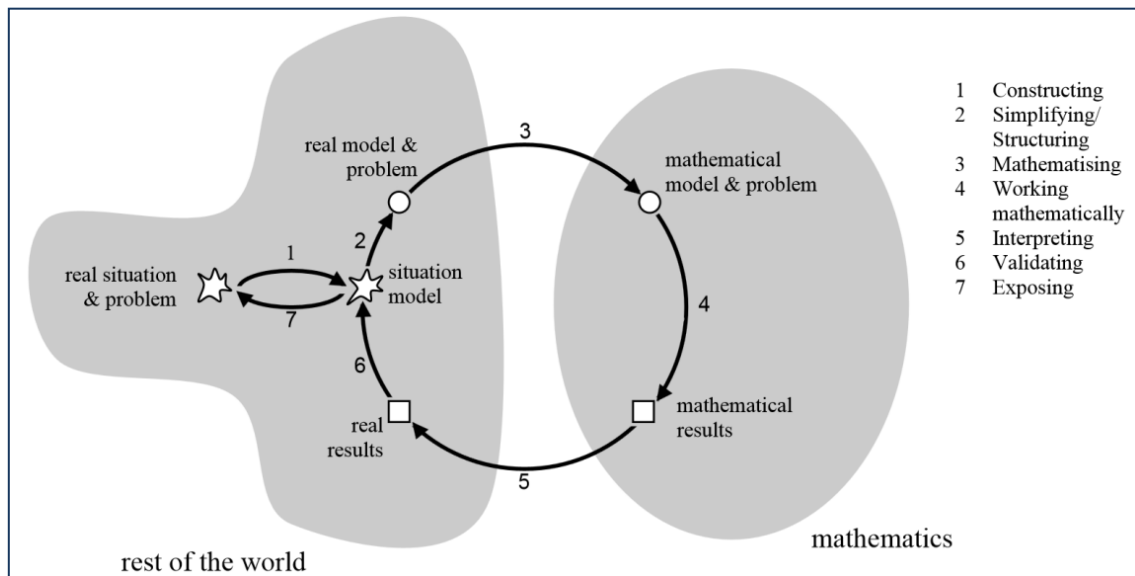
Figure 1: Modelling cycle (Blum et al., 2009)

A realistic problem formulation is given at the start. To solve this, a modelling process needs to be applied which contains different steps that need to be undertaken. These *sub-processes* include to understand the task, to simplify the problem in building a mathematical model, to solve the problem in the chosen model and, finally, to interpret and validate the solution and the model used. A modelling process is often referred to as a modelling cycle as the process usually needs to be undertaken more than once. Advantages and disadvantages of the model have to be revised iteratively to find a better solution. The *global modelling competence* is defined as the ability to undertake a full modelling process and to have the knowledge of the procedure (Kreckler, 2015) and is necessary to be able to solve applied modelling tasks on the whole.

While formulating and developing modelling tasks it is essential to keep with the four quality features of good modelling tasks named by Blomhøj & Kjeldsen (2006):

1. Comprehensibility and signification

2. Adequate challenge

3. Authentic problem

4. Open formulation

Hence, it is important that modelling problems are comprehensible and significant for the students and that they describe an adequate challenge, i.e. the tasks should neither be too easy nor too difficult. It is also important for the problems to be authentic and to use authentic data.

"An authentic problem is a problem posed by a client who wants to obtain a solution which is applicable in the issues of the client. The problem is not filtered or reduced and has full generality without any manipulations, i.e., it is posed as it is seen. A real-world or realistic problem is an authentic problem

which involves ingredients which can be accessed by the students in real life."
(Bock et al., 2012)

Another essential point about modelling problems is, that they need to be formulated widely open such that various mathematical models can be built and such that the problem can be solved with respect to different approaches.

Due to the lack of experience and many uncertainties how to implement mathematical modelling in regular school lessons or larger projects, teachers need to be trained and prepared for an efficient classroom practice. The question of how to do this efficiently has been addressed in various research projects as, for example, the project LEMA[3]. LEMA (2006-2009) was an international research project with the goal to develop a concept and materials for teacher training courses in the field of modelling and applications. Within this and other projects a *spiral model* has been proven to be efficient, meaning a continuous cycle of *analysis, implementation* and *reflection.* With each cycle the knowledge and experiences can be extended and improved. This concept of combining theory, actual implementation in the classroom and a reflection afterwards is also used in the teacher training courses carried out by KOMMS.

3 Concept of teacher training courses in the framework of KOMMS

Teacher training courses in the framework of KOMMS are based on three main concepts:

1. Additional teacher training courses for the mathematical staff of single schools.

2. Training courses to be undertaken in the three modules: Implementation, mathematical topics and software.

3. Connection of theory (training courses) and practice (implementation to classes in school).

To successfully educate teachers to become multipliers of modelling, training courses are not only offered for individual teachers from different schools, but also for the complete mathematical teaching staff of specific schools. From our experiences, this enhances the chances for actual implementation of modelling to the classroom of participating teachers as the communication with colleagues who have gone through the same learning is efficient and motivating.
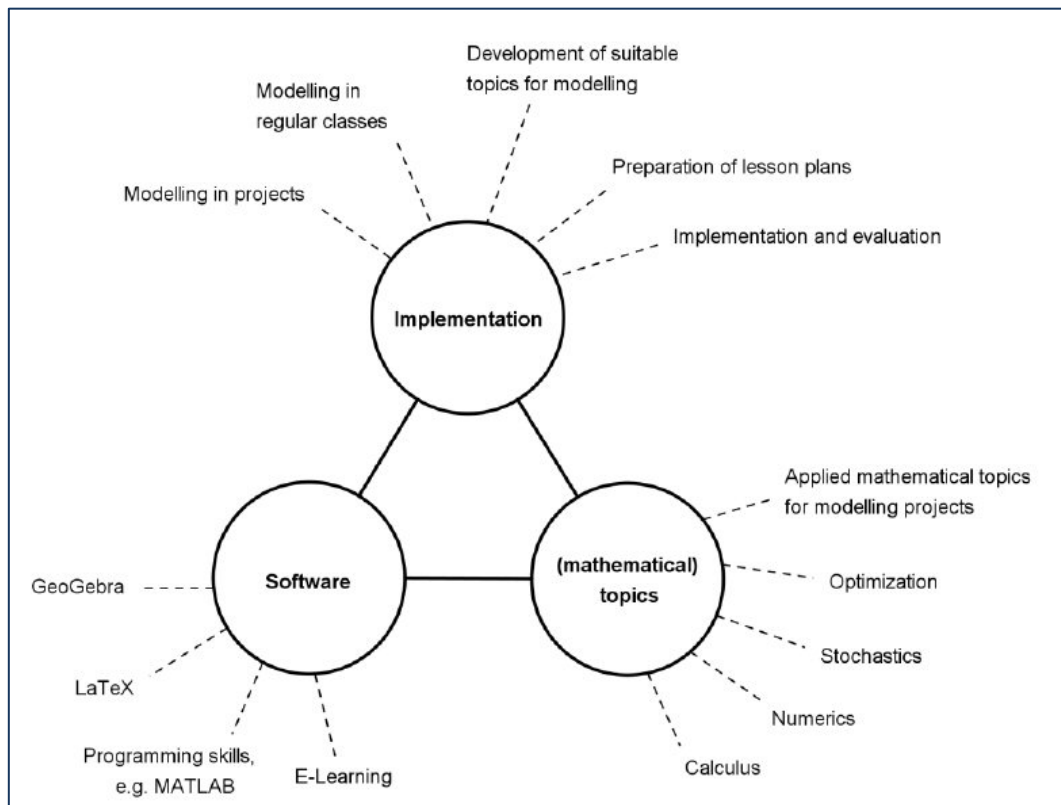
Figure 2: Three modules of teacher training courses within KOMMS

The information and experiences that teachers need in their everyday classroom practice to successfully teach mathematical modelling lie within three modules: *implementation, mathematical topics* and *software* (see Figure 2). From each of these modules teachers should complete some of the courses offered in the individual module.

The module *implementation* deals with the most important part of the teacher training. It involves courses dealing with the implementation of modelling to project work or regular schools lessons, discusses how suitable topics can be found and developed as well as the preparation of concrete lesson plans. Within the limits of these training courses, teachers can implement their knowledge to projects supervised by the staff of KOMMS, for example by participating at one of the modelling weeks or days organized in cooperation with different schools.

To integrate applied and realistic modelling topics to school lessons the teachers should also be competent in the certain subject matter chosen. To give teachers a chance to revise some mathematical fields as for example stochastics or calculus, and to show some relevant and appropriate topics with their mathematical background (see for example Hamacher et al., 2004, Kreckler, 2015), training courses are offered in the module *mathematical topics.*

The third module *software* represents another very important feature for a successful implementation of modelling. The use of computers, tablets and

smartphones in school is increasing and therefore marks an ongoing research field. Teachers must be able to effectively embed different software in their lessons. Training courses dealing with software often needed during the work on modelling projects, for example GeoGebra or MATLAB, are therefore also required.

The third concept sets value on the connection of theory and practical implementations in school. After introductive courses about implementing modelling, own projects can be realized and reflected under the supervision of KOMMS.

Altogether, after completing courses of the three modules, teachers will have learnt to do mathematical modelling, how to implement modelling to regular classes as well as projects, will have revised mathematical topics and learnt to handle different useful software.

3.1 Handling difficulties and barriers

Implementing mathematical modelling to school still raises some teacher-related difficulties. These difficulties and barriers are handled during our courses in the following way (see Table 1).

Difficulties / barriers	How to handle them in the course
Time-consuming preparation	Developing materials together
Knowledge gaps	Course topics: mathematics & software
Little experience	Teachers solving modelling tasks themselves
Little time	Course concepts also for short periods in class (4h)
Insecurity with implementation	Guided implementation to classes

Table 1: Handling difficulties

A problem often named by teachers is their lack in time to prepare and undertake modelling in class. To motivate and help the teachers, this barrier is handled by developing teaching materials together during the courses and to present and discuss didactical teaching concepts for shorter periods in class. Knowledge gaps are filled by courses in the modules *(mathematical) topics* and *software* while their insecurity with an exact implementation is discussed during courses in the module *implementation.* As teachers often feel insecure with mathematical modelling, modelling tasks have to be solved in groups of teachers during the training courses. This leads to a more secure handling when implementing modelling to school.

Combining the knowledge of all three modules enables the teachers to successfully implement modelling to school lessons, after having gained competency in mathematical topics, software to handle modelling projects and the concrete development of lesson plans.

3.2 Course example

Training courses in the module *implementation* are usually divided into three parts: Training course part 1 (preparation), the implementation to their own class and the second part of the training course (reflection). In the following, a specific course example is given to the topic "Mathematical modelling in regular classes":

Part 1 - Preparation (1 day)

9:00 – 12:00

- Introduction
- Specific mathematical topics adequate for modelling in school
- Connection of topics to curricula

13:00 – 16:30

- Theoretical background and introduction to mathematical modelling
- Experiences and difficulties
- Didactical concepts to implement modelling to school
- Development of teaching materials using discussed topics

Implementation

Guided implementation of teaching material to own classes.

Part 2 – Reflection (half day)

9:00 – 13:00

- Positive and negative experiences and observations
- Handling difficulties
- Improvement of materials (if required)

3.3 Summary

KOMMS is a competence centre for mathematical modelling in STEM[6]-projects in schools and combines the four fields of schools projects, teacher education, teacher training courses and research. Teacher training courses to foster modelling in school are based on three concepts: Training complete mathematical teaching staff of specific schools, connecting theory and practice and offering courses in the three modules implementation, mathematical topics and software. Altogether, this enables teachers to successfully implement mathematical modelling projects to their own classes.

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[6] STEM: An abbreviation for the academic fields of science, technology, engineering and mathematics.

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Inquiry based biology education in the Czech Republic: A reflection of five years dissemination -

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1   Introduction

Dissemination and implementation of IBBE (Inquiry-Based Biology Education) in the Czech Republic were initiated by European project S-TEAM in the 2009.

At the same time, Czech individual national project PTPO (Support of interest in technology and science education in the Czech Republic) supported our effort to disseminate IBBE more widely (Fig. 1).

We organised three successive weekly summer schools of IBBE (2010, 2011, and 2012) addressed to teacher educators and pre-service teachers from Czech universities. Furthermore, we guaranteed and arranged a yearlong School of IBBE for in-service teachers from the region of South Bohemia (2012). Simultaneously we were and are cooperating with different Czech institutions trying to disseminate IBBE and offer IBBE lessons and workshops to teachers. Recently, our interest is focussed on formative and summative assessment of IBBE within the scope of European project ASSIST-ME. This contribution presents (1) our reflections and experiences from dissemination and implementation of IBBE as well as (2) our observations regarding changes of teacher thinking related to IBBE gained during the course of five fore passed years.
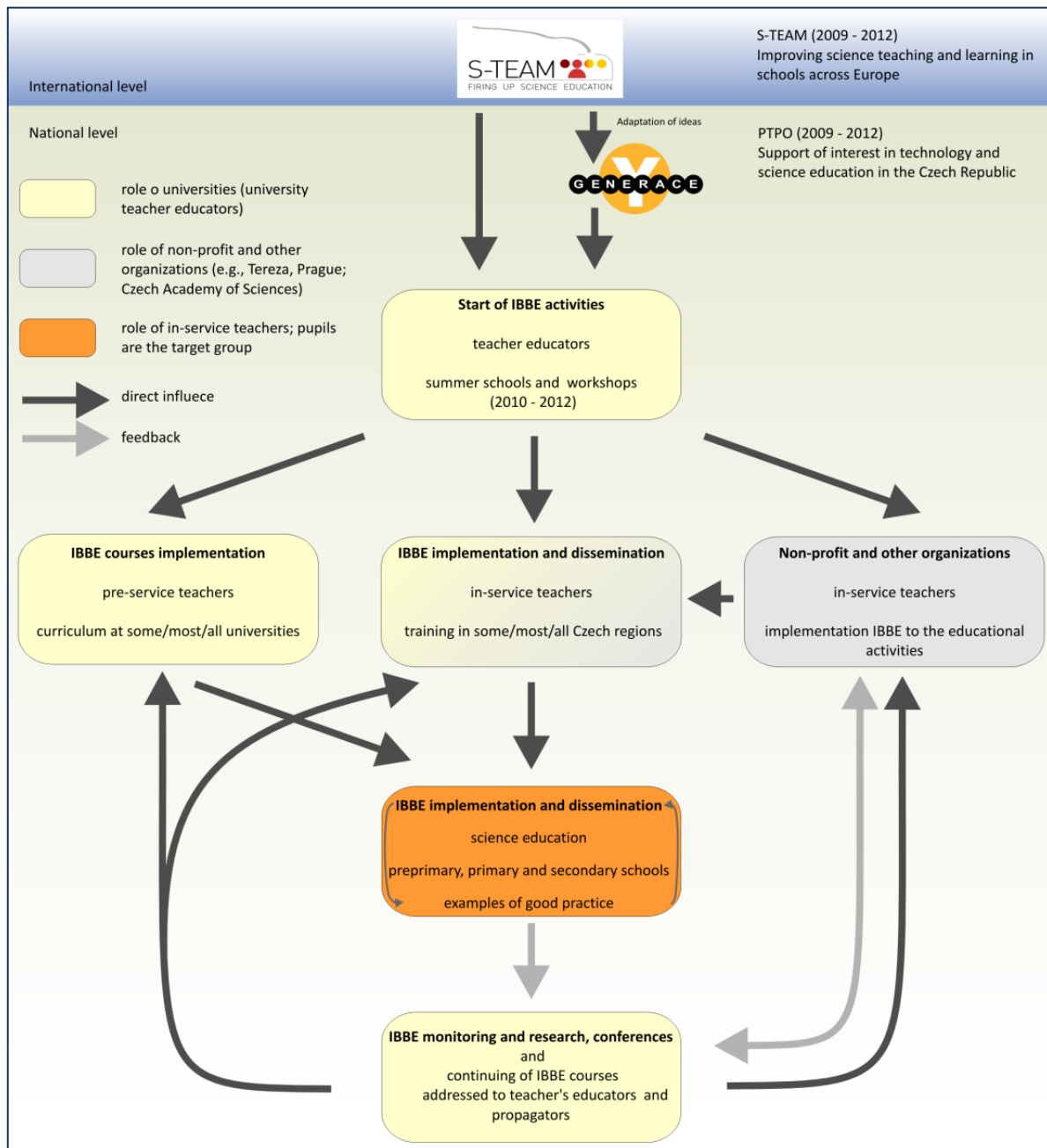
Figure 1: The model of implementation and dissemination of Inquiry-based Biology Education, used in the Czech Republic (by Papáček, 2010a, p. 158; translated from the Czech and modified)

2 Attitudes of pre- and in- service teachers to IBBE

A model of IBSE dissemination for the Czech national environment that is more or less implemented was designed by Papáček (2010a). The same author also listed and discussed barriers, necessity and chances of dissemination of IBBE in Czech schools (Papáček, 2010a, b). At the beginning of IBBE dissemination (2009, 2010) we realized a brief investigation focussed on attitudes of pre- (a set of 160 respondents from different universities) and in-service teachers (set of 36 respondents of wide age range from different

schools) to IBBE. Most of pre- and in-service teachers were not familiar with the inquiry based education due to the fact they were not systematically trained to implement this method and they perceived IBBE as too difficult and time consuming.

Our other study (2012) focused on secondary school (152 respondents) and university (169 respondents) students revealed that only 20% of students had experience with inquiry- based learning in biology at secondary school and one third of respondents had no experience with IBBE at all (Rokos at al., 2013).

However, 70% of all respondents would embrace implementation of a course dealing with IBBE into pre- and post-gradual teacher professional development programmes. Due to results and interviews of this investigation, we also state the necessity to improve teacher training through (i) tighter cooperation of pedagogy, pedagogical psychology and biology didactics, and (ii) modification and completion of biology didactics courses, (iii) offer of IBBE methodology, demonstration of examples of IBBE as well as a repertoire of tasks, lessons, tuition sequences, experiments and workshops. (Fig. 2)
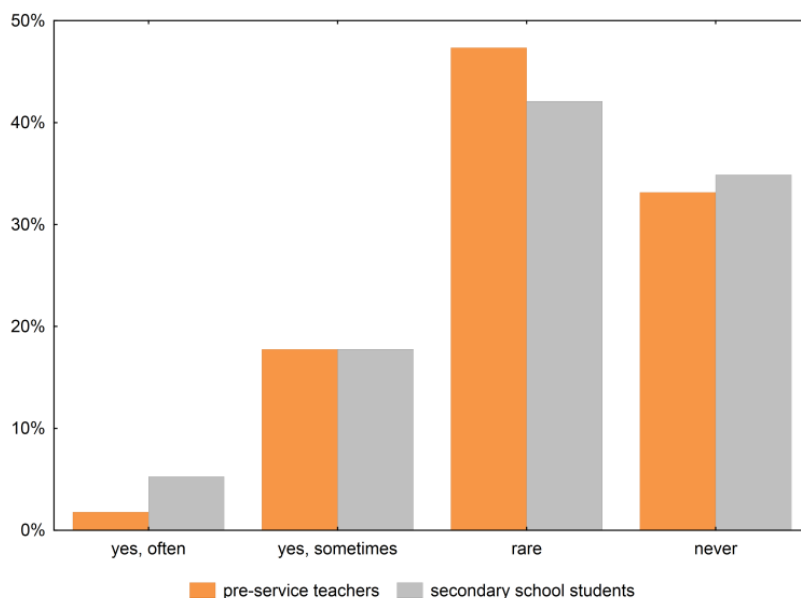
Figure 2: Experience with IBBE (by Rokos et al. 2013, modified)

3   Background and first steps of the IBBE implementation

By random search (preformed in 2011) including 160 respondents of pre-service teachers - students of two last study years of four faculties from two universities (University of South Bohemia in České Budějovice and Charles University in Prague) we found that only 34% of respondents had any awareness of pedagogical constructivism. Less than 20% percentage of informants had some intuitive awareness of IBSE and informants' facilities and availability to start to use of IBBE were much delimited.

Therefore following crucial challenges were established:

- Training of communication corresponding to IBBE teaching style (teacher - pupil(s), pupil - pupil(s)).
- To explain to all multipliers, that IBBE is not fixed „cook recipe" for unambiguous educational success every day.
- Portfolio of inquiry-based tasks, teaching units and sequences, applicable in all schools including those with poor (missing) laboratory equipment.

4 School of IBBE

Week-long Summer schools of IBBE addressed to teacher educators, in-service teachers and pre-service teachers were organised in years 2010, 2011 and 2012. Year-long course called School of IBBE addressed primarily to in-service teachers was organised in year 2012.

Two main goals of the schools were specified:

1) To offer innovative teaching approaches in biology and natural science education.

2) To create a network of primary and secondary school teachers from the region of South Bohemia.

The practical impact of the School of IBBE can be regarded as significant. Upon attending this course teachers have began using inquiry learning in their school lessons (or they use inquiry more frequently then they did before). The fact that participants of the School of IBBE have found the inquiry methods to be important can be deduced from the teacher's opinion that IBE should be implement not only in science and math but also in other educational fields at all school levels. This is important particularly regarding the fact that the world doesn't need more or better scientists or technicians (Charette, 2013), but more scientifically thinking people. On the other hand we have found that some teachers, who attended the School of IBBE workshops, had probably confused IBE with non- inquiry learning approaches such as team cooperation, search for information or verification observation/ experiments.

The participants of the School of IBBE were asked to fill the questionnaire about usage of IBBE in their school lessons three months after final session of the School of IBBE. Whereas only 44% of the teachers participating at the School of IBBE had previously known about the IBBE, 75% (out of 36 teachers who responded the questionnaire) was actually using the IBBE in their school lessons after the school of IBBE. More than half teachers (56 %) think that IBBE should be used at the primary schools, while 28% consider used at higher classes. Only 6 % of teachers think that IBBE is suitable only for the students with special interest in Science.

However we noticed that some of the participants had still inaccurate conception of the IBBE. When we offered them a variety of statements specific/nonspecific for the IBBE (Tab. 1), many of them chose (beside correct answers) also false options. Many teachers consider conducting standard

experiments, operating technical instruments, searching for new information and either individual or collaborative work as IBBE (Fig. 3). Only 20 out of 36 checked all or made one mistake when selecting correct answers. However most of them checked also some common classroom activities, not-specific for IBBE. Those teachers with one correct option unselected usually did not check "asking own questions" and "conducting self-designed research."

Considering these results, the conclusions about implementation of IBBE into the teaching process should be formulated very carefully, when they are based on teachers responds. Most probably many teachers can confirm using of IBBE while conducting common laboratory experiments with using modern technical devices.

Correct answers	Incorrect answers
Formulation of own hypothesis	Working individually
Asking own questions	Conducting experiments following given instructions
Designing of own procedure to answer questions	Operating technical instruments (microscopes, balances, etc.)
Conducting of own research according with own research design	Searching of new information in internet, books, journals, ...
Formulation of own conclusions based on performed experiments	Cooperating of students

Table 1: What is specific for IBBE? (Variety of statements specific/nonspecific for the IBBE)
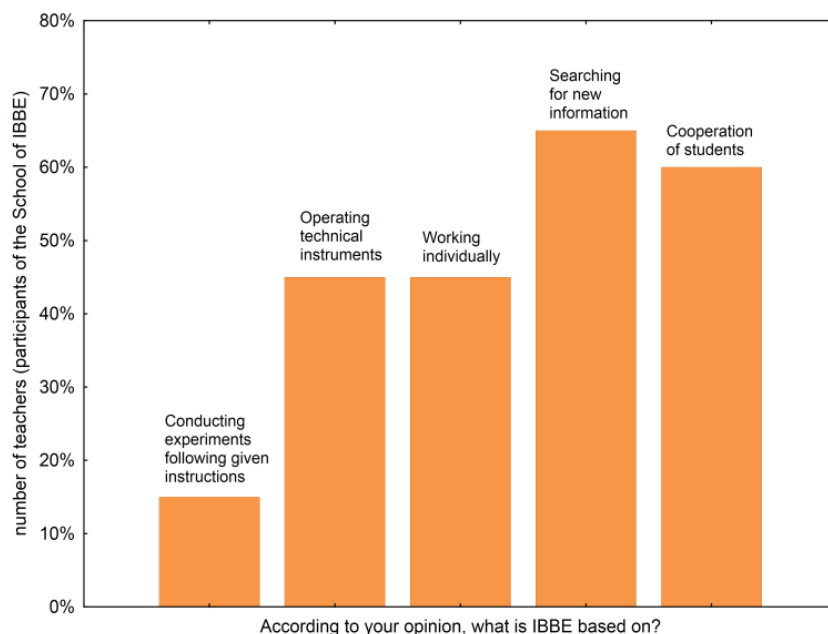
Figure 3: Opinion of teachers what is IBBE based on

Two years after the School of IBBE we asked the participants about IBBE and School of IBBE again. Out of 32 teachers, who completed the survey (63 teachers were asked to complete the survey), all consider the School of IBBE

as useful. Majority (91 %) of teachers currently use IBBE in their classes, almost half (44 %) of them implement IBBE in the form of complex lessons and 47 % use IBBE as short particular elements (questions, short exercises etc.). Two teachers (6 %) do not use IBBE in their classes because of time demands of IBBE, although they still consider IBBE as an useful style of education. (Fig. 4)
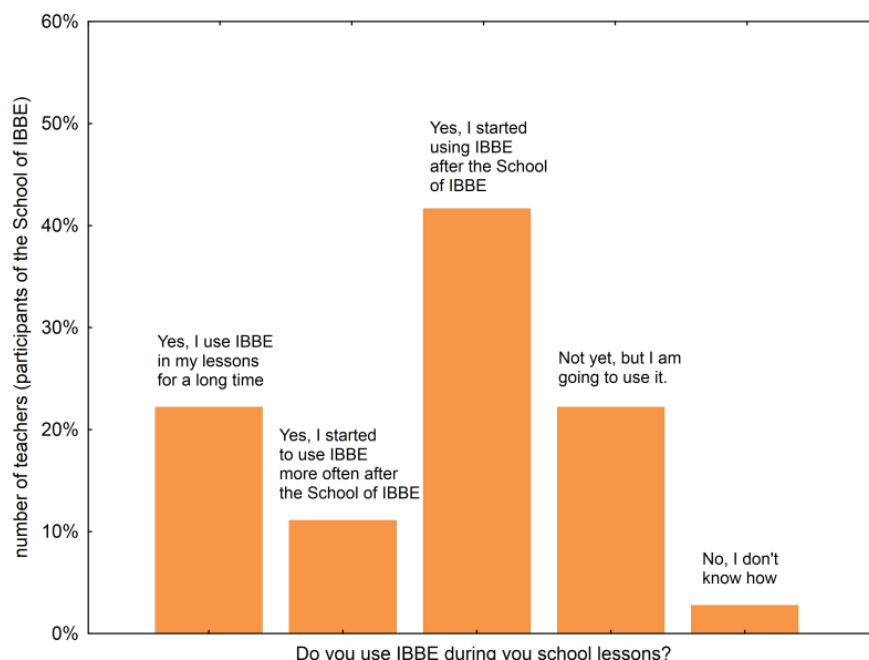
Figure 4: How teachers who participated at the School of IBBE have increased using of IBBE in their lessons.

5 Conclusions

This contribution presents (1) our reflections and experiences from dissemination and implementation of IBBE as well as (2) our observations regarding changes of teacher thinking related to IBBE gained during the course of five fore passed years. Currently the dissemination of IBBE in the Czech Republic continues successfully but there is a risk of distortion of some IBBE features if teachers, who are to train other teachers, will not comprehend exactly the principles of inquiry learning process.

The main goal and challenge for educators are:

To assure perfect understanding of IBBE by educators through innovating of biology didactics courses at faculties preparing teachers and through demonstration of proper examples of tasks, lessons and experiments. In the last five years our observations and research have been focused on critical points and failures in implementation of IBBE in the Czech Republic.

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How to determine what teachers should learn and multipliers need to know? Five steps for content specification of professional development programs and the research-based background for multipliers -

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Professional development of mathematics teachers is a topic of growing interest in the mathematics education research community. In analogy to any instructional design for students, the design of professional development (henceforth PD) programs requires a theoretical and empirical base. This need for research-based designs has fueled a growing body of empirical investigations into pedagogical features for PD programs focusing on their effectiveness. In that way, important principles could be specified for the design of PD programs (for an overview cf. Lipowsky 2010). However, these studies rarely consider the 'what-question', that is asking what contents are most crucial for PD programs and in which perspectives they should be addressed. E.g., in their survey on the state of teacher education at ICME 2004, Adler et al. (2005) do not name the specification of contents as a major issue of research, and especially remarkable is the fact, that it is not even on their list of missing issues. However, especially for the work with multipliers, the content specification is of major importance.

Considering the variety and sometimes arbitrariness of possible contents for PD programs, the talk starts from the assumption that selecting crucial competences calls for its theoretical and empirical foundation. As emphasized for mathematical contents by van den Heuvel-Panhuizen (2005), the empirical foundation is not restricted to proving effectiveness for students' learning in experimental interventions, but also other forms of empirical insights come into question that can inform the selection of content. This need for an empirical base also applies to PD courses which are conducted by multipliers who are not themselves involved in the research. Thus, this talk firstly suggests the systematic use of empirical approaches (e.g. on classroom interaction) to identify the most urgent kind of contents. Secondly, these contents need a so-called restructuring for the purposes of PD (Prediger 2005) that takes into account the theoretical foundation, empirical investigations, but also relevant perceptions and conceptions of teachers. These necessities are combined in our five step approach for content specification in research-based design of PD programs (Prediger et al. submitted):

Step 1.   Theoretical embedding: Why and how is the content relevant?

Step 2.   Empirically based specification of the concrete professional demands

Step 3.   Empirical exploration of teachers' perspectives

Step 4.   Synthesizing seeming antinomies in different perspectives for restructuring the content of the PD program

Step 5.   Iterative design of concrete PD program

After discussing alternative strategies for addressing the what-question, the talk argues that taking into account teachers' perspectives is required for restructuring the identified content and explain what restructuring means in this context. Then. a the five step approach is presented and illustrated for an exemplary content, teachers' moves that support students' participation.

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6.2 Track 2: Blended learning concepts and e-learning support

A study and research path on mathematical modelling for in-service teacher education: the challenge of an online course on SRP-TE -

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Abstract

Considering the general problem of integrating mathematical modelling and inquiry activities into current educational systems, this talk focuses on the ineluctable step of educational courses for pre-service and in-service teachers. Within the framework of the Anthropological Theory of the Didactic, it has been recently proposed to use study and research paths for teacher education (SRP-TE) as means to combine a constant practical and theoretical questioning on mathematical modelling school activities.

The research project we are presenting starts from a particular case of SRP that have been designed, locally implemented and analysed in previous research, at secondary and tertiary educational levels with face-to-face learning communities. Our aim is to explore how these SRP could be used in teacher professional development programmes. The aim is twofold: on the one hand, to identify teachers' professional questions that could lead to enrich teachers' mathematical experiences with inquiry and modelling processes; in the other hand, to move from these face-to-face educational situations to virtual learning conditions.

After presenting the rationale of our proposal, we will illustrate the framework, principles and phases for the design of a SRP-TE, together with some preliminary results with the implementation of an e-learning course for in-service secondary school teachers in CICATA (Mexico), which presents a powerful chance for collaborative, learner-centred and research-oriented means to implement SRP-TE with students, lectures and learning communities spread around Europe and South-America.

1   Study and Research Paths for Teacher Education (SRP-TE)

Considering the general problem of integrating mathematical modelling and inquiry activities into current educational systems, this paper focuses on the ineluctable step of educational courses for pre-service and in-service teachers. Within the framework of the Anthropological Theory of the Didactic, it has been recently proposed to use study and research paths for teacher education (SRP-TE) as means to combine a constant practical and theoretical questioning on mathematical modelling school activities.

There exists an extended agreement about the necessity to foster the teaching of mathematics as a modelling tool and to enrich the study of contents at

school through the development of inquiry processes. At the same time, many investigations highlight important objective difficulties that hinder any proposal of implementing modelling and inquiry as normalised activities in current educational systems (Burkhardt, 2008; Kaiser & Maaß, 2007; Doerr, 2007; among others). Many of these constraints are related to what has recently been called the 'monumentalistic' paradigm (Chevallard, 2012), which rules in many of our teaching systems, where mathematical contents tend to appear as 'works to visit' more than tools to provide answers to questions. In the spirit of moving towards the new paradigm of 'questioning the world', recent research carried out in the framework of the Anthropological Theory of the Didactic (ATD) proposes to approach this problem through a new teaching and learning device called study and research paths (SRP) based on the long-term inquiry of generating problematic questions (Barquero et al., 2008, 2013). However, designing and locally implementing new devices is not enough to ensure their long-term viability. Among many challenges, an important one is related to teachers' professional knowledge and competences, and furthermore to the mathematical and didactic infrastructures that need to be at their disposal to face this change.

The research project we are presenting starts from some particular cases of SRP that have been designed, locally implemented and analysed in previous research at preschool, primary, secondary and tertiary educational levels. Our purpose is to explore how these SRP could be used in professional development programmes for teachers, in what we call SRP for Teachers Education (SRP-TE). They consist of the following five stages:

1. The starting point of a SRP-TE is an question arising in the teaching profession related to a given piece of knowledge to be taught: for instance, how to teach proportionality, algebra, integers, linear regression, etc.? This question is initially approached searching information and available resources, including results from research, official curriculum guidelines and innovation proposals.

2. The second stage consists in carrying out a study and research path (SRP) related to the professional question approached and similar to what could exist in an ordinary classroom and is: for instance a SRP involving proportionality, algebra, integers, linear regression, etc. Teacher-students have to follow the SRP as if they were students, under the supervision of educators acting as teachers.

3. The third stage is devoted to the analysis of the teaching process just followed. Three main phases are distinguished:

(a) The mathematical analysis of the work done, including the elaboration of a reference epistemological model describing the modelling process involved (Bosch & Gascón, 2006);

(b) A didactic analysis of the process, including a description of the differences between the contract established during the SRP to manage the modelling

process, compared to the usual school didactic contract centred on the transmission of contents;

(c) A more general study of the viability of SRP, including the identification of the institutional conditions and constraints affecting the development of modelling practices in school settings.

4. The fourth stage consists in designing a SRP based on the one previously followed and analysed, adapted to a given group of students. This design should be based on the analyses of the previous stage: sequence of mathematical questions to be posed to the students; sharing of responsibilities between teacher and students to pursue the questions; teaching devices to ensure the viability of the SRP.

5. The final stage of the SRP-TE corresponds to the implementation and a posteriori analysis of the SRP designed. The same didactic tools made available at stages 3 and 4 are again supposed to play an important role: not only to provide some provisional answers to the question that was at the origin of the whole process ('How to teach …?'), but also as a means to analyse other possible alternative answers, as those found at stage 1.

The hypothesis of our research is that SRP-TE may contribute to provide teachers with tools to question the mathematical contents to be taught and, at the same time, to release teachers from the usual way of doing and teaching mathematics at school. We also consider that SRP-TE are also based on a fair contract between teachers and teacher educators in the sense that educators are not led to provide definitive answers to the initial professional questions raised (which most of the time do not exist) but help student-teachers approach them by critically accessing the available resources. Our research project wishes to explore to what extent these hypotheses can be confirmed and what changes or adaptations are suggested by different implementations of SRP-TE. We are here presenting a single case of a SRP-TE for in-service secondary school mathematical teachers. A more development description can be found in (Barquero, Bosch and Romo to appear).

2 A SRP-TE on sales forecasting for in-service teachers

In Autumn 2013 a SRP-TE was experimented in an on-line course for in-service secondary school teachers coordinated by the CICATA-IPN centre (Legaria, Mexico) as part of an on-line postgraduate programme in Mathematics Education. The course was led by a team of six teachers, three from CICATA-IPN and three from Spain, all of them researchers in mathematics education. The authors of this paper were all part of the team. In this case, the SRP-TE took as initial question the problem of teaching mathematical modelling at secondary school. It was formulated as follows:

Q0: How to analyse, adapt, develop and integrate a learning process related to mathematical modelling in our teaching practice? How to institutionally sustain a long-term learning processes based on modelling? What difficulties should be overcome? What teaching tools are needed? What new questions arise?

For four weeks these issues were approached through a SRP on sales forecasting, considering four activities corresponding to the last four SRP-TE stages introduced in the previous section. There were 15 participants, all of them in-service secondary school teachers. They were supposed to spend 80 hours on the SRP-TE for five weeks: one week for each activity and one week for the final report.

The SRP on sales forecasts that was at the basis of the SRP-TE had previously been designed and implemented at university level and also at upper-secondary level (Serrano et al., 2010). In other words, we took an already experimented SRP, with a previous mathematical and didactic a priori design and some material concerning its implementation and a posteriori analysis. Students were informed of it and were invited to review some published works in the third phase of the SRP-TE. More concretely, the first activity (Activity 1) proposed the Resolution and analysis of 'Forecast sales of Desigual' with the main aim of letting participants experiment a SRP similar to the one experimented. Participants were asked to 'live' it like mathematical learners or apprentices.

They had to act like a team of mathematical consultants and had to provide an answer to a request from Desigual (a Spanish fashion brand), which wanted to have an in-depth study on 'how to predict the evolution of several variables (see Figure 1): weekly sales in several of their shops, evolution of their benefits or of new national and international shop openings, etc.'

9) Evolución de las ventas semanales de las camisetas one-print desde el 15 de febrero de 2010 en la tienda de las Ramblas 136 (Barcelona):

Semana	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Camisetas one-print vendidas	233	112	118	130	116	151	159	173	175	230	253

10) Evolución de las ventas semanales de las camisetas one-print desde el 1 de marzo de 2010 en la tienda de la Rambla de Catalunya 140 (Barcelona):

Semana	1	2	3	4	5	6	7	8	9	10
Camisetas one-print vendidas	100	101	107	115	125	140	140	164	194	210

Figure 1: Initial worksheet of Desigual's request to the consultants

Participants were organised in five teams of three consultants each, combining individual work with group work (using the on-line forums of the CICATA virtual campus, see figure 1).
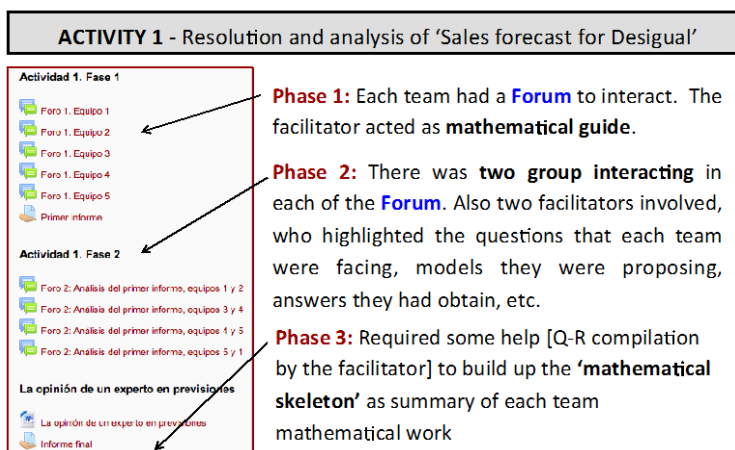
Figure 1: Elements of Activity 1

They first had to act individually and propose their own answer to the question (phase 1). They later had to share and contrast their proposals with their partners (phase 2). Finally, in phase 3, they were asked to prepare and present a final report together, providing some answers to Desigual's request and defending it as the best proposal for the project. The final answer had to be accompanied by an analysis of the process followed by the team, including the difficulties encountered.

In Activity 2, the participants were asked to prepare a 'lesson plan' based on the mathematical work previously carried out in Activity 1. The situation proposed was that they were supposed to be secondary school teachers that had planned to implement the activity of 'Forecasting Desigual sales' in their classroom. Due to a cultural trip with other students, they had to ask another teacher to replace them. They were asked to write a brief and easy to read lesson plan including all the necessary elements for the substitute teacher to carry out the lesson/s. Like in the previous activity, participants first had to prepare and individual proposal, then share their proposal with the rest of their team and agree on a final common lesson plan. This activity was supposed to provide a first spontaneous answer of the teacher to the question: 'How to teach a modelling activity based on Activity 1?' in terms of a teaching proposal designed (see figure 2).

Figure 2: Elements of activities 2 and 3

Activity 3 consisted in the experimentation of the participants' own design of the teaching activity with a group of students. The participants had to individually assume the role of the teacher and implement the initial phases of the lesson plan proposed in Activity 2. With this purpose in mind, they had to elaborate a more detailed design, a more in-depth a priori analysis (phase 1), experiment their proposal (phase 2), finish with the a posteriori analysis (phase 3) and prepare a brief 'experimentation report' (phase 4).

Finally, Activity 4 was devoted to a joint analysis and final revision of the lesson plan with the aim of proposing a new version taking into account both their own experience and the experience of their teammates. In particular, the difficulties found in the implementation of the modelling activity (a posteriori analysis) were supposed to highlight the constraints related to the normal implementation of this kind of teaching proposals and the possible ways to overcome them (see figure 3).

Figure 3. Elements of activity 4

The supervision of the teacher educators during the SRP-TE consisted of the following. By way of feedback to the team discussions in the forum and to the activities (reports, lesson plans, etc.) submitted, the course staff progressively introduced some didactic tools to support the mathematical analysis of activity 1: notions of model and system, criteria and ways to characterise the models provided, ways of comparing them, etc. At the end of activity 2, as a means to carry out the didactic analysis of the spontaneous teaching proposals, some publications about SRP were provided: Serrano et al. (2010) and Chevallard (2012). Between activities 3 and 4, the educators prepared a guideline with the main sections of the a posteriori analysis of a SRP, including some examples of its mathematical description, some criteria to describe the didactic organisation and some elements of the conditions produced, the constraints faced and the global evaluation of the teaching process. They also provided an assessment grid for the final report and a questionnaire about the development of the course to be answered individually at the very end of the course. All the material produced by the students was gathered during the course, especially the students' discussions in the forums (including the teacher educators' interventions), the students' questions raised (in the forums or by mail), the partial and final reports and their answers to the questionnaire.

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Promoting teacher trainees' inquiry skills by self-regulation and tablets -

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1 Theoretical Background

Educating the educators in science education should promote inquiry skills, which are considered to be mandatory for inquiry-based science education (NRC, 1996; NSTA, 2003; Kultusministerkonferenz, abbreviated as KMK, 2010). German standards for pre-service teacher education stipulate that science teachers should not only know about subject specific working and inquiry methods, but should also have skills in hypothesis-led investigations (KMK, 2010). The American National Science Teacher Association (NSTA, 2003, p.19) goes further by stating that science teacher preparation "require[s] inquiry-based university science courses". To meet this requirement, a concept for higher education has been developed that aims to promote the inquiry skills of biology teacher trainees. This teaching concept has two central features: first, a model of self-regulation ("Kölner Handlungskreismodell", Figure 1) emanating from the area of educational psychology is used during the course to support students in their inquiry process. This activates metacognitive processes such as planning, conducting and reflecting on the inquiry process. Second, the inquiry process is documented with tablets by preparing video journals on the inquiry process. Video journals allow reflection on the inquiry process to be made. The following theoretical considerations on inquiry skills and the two features mentioned are the basis for our research.

1.1 Inquiry skills

As the KMK requires imparting knowledge of practical and inquiry methods and furthermore, skills in hypotheses-led investigations in pre-service teacher education, but does not outline a clearer definition of what is meant by knowledge and skills on inquiry, the following research is based on a definition of inquiry skills by Mayer and Ziemek (2006). Defining inquiry skills as a part of "Scientific Thinking" ("Scientific Thinking" is linked with "Practical Skills" and "Nature of Science") one can distinguish personal and process variables of inquiry skills. Personal variables comprise content knowledge and cognitive processes (Mayer, 2007) as well as metacognition (Künsting, Kempf & Wirth, 2013). Process variables are related to activities in the inquiry process such as "Questioning, Hypothesizing, Planning, Conducting, Reflecting and Communicating". Next Generation Science Standards (NRC, 2013) support this view on inquiry skills being not only based on skills but on knowledge too. A change towards the term "Inquiry practices" (NRC, 2013) therefore emphasizes the importance of knowledge in the inquiry process. The following research always considers knowledge as a personal variable influencing inquiry skills.

1.2 Self-regulation support

Developing inquiry skills in an inquiry-based learning environment may exceed working memory capacity according to cognitive load theory and may be detrimental to learning when instructional guidance is minimal or absent (Kirschner, Sweller & Clark, 2006). Therefore, Kirschner, Sweller and Clark (2006) suggest more guided approaches.

Wichmann and Leutner (2009) showed that "advanced inquiry support", "explanation prompts" and "regulation prompts" facilitate learning in scientific discovery: whilst advanced inquiry support provides guidance in specific tasks in the inquiry process and explanation prompts engage students in scientific reasoning, regulation prompts encourage students to understand the underlying processes of inquiry. Regulating inquiry learning asks for planning, conducting and reflecting on experiments (ibid.). Therefore, the phases of the inquiry process may be parallelized to a cyclical model of self-regulation: here, the Cologne action cycle model ("Kölner Handlungskreismodell", Aschermann & Armbrüster, 2009, Armbrüster, 2013).

Inquiry-based learning requires self-regulation, so that regulation prompts promote metacognitive supervision of the inquiry process and lead to more strategic experimentation (Künsting, Kempf & Wirth, 2013). A desideratum of previous research is to transform these findings from simulation-based inquiry (ibid.) to practice-based inquiry courses at university. The combination of advanced inquiry, explanation and regulation support was even more effective in promoting the learning processes than just using the two elements of basic or advanced inquiry and explanation support (Wichmann & Leutner, 2009). Therefore, the following research on self-regulation support takes advanced inquiry and explanation support as a baseline and supplements it by regulation prompts to promote metacognition.

Figure 1. Cologne Action Cycle Model (Kölner Handlungskreismodell, Armbrüster, 2013, adapted)

1.3 Tablet support

Furthermore, Castek and Beach (2013) describe how tablets enforce reflection on scientific inquiry: apps provide students with the affordances to share their production, present inquiry in a multimodal manner and to collaborate with others when the apps are embedded in a learning environment. Video journals made by students incorporate these affordances. Producing a video using a tablet forces students to collaborate by taking on different tasks and being dependent on each other (e.g. holding the camera/tablet, being the actor or speaker). Students' productions (video journals) are multimodal representations of the inquiry process they have conducted. This back-and-forth transfer between visual or auditory representation provides possibilities not just for interpreting results and criticising them, but also for presenting them convincingly. Sharing with others facilitates reflection on the entire process of acquiring scientific knowledge, as students do not just present their data and conclusions, but also reason their planning process and document the precise realization of their experiment. Thereby they have to decide on how best to explain to and convince their audience. Thus, video journals open a window to students' inquiry processes and make each step they take transparent and reproducible.

Useful computer tools for supporting inquiry-based learning are already described by Bell et al. (2010). The authors emphasize the use of computers for enabling (i) higher learning processes in inquiry such as constructing knowledge by organizing and visualising data and (ii) self-regulated learning by opening information access through the interface. Altogether, each inquiry step (e.g. Questioning & Hypothesizing, Planning, Conducting, Reflecting & Communicating) is promoted by a computer tool (Bell et al. 2010). Similar possibilities are described by Bruckermann et al. (2013) related to tablet-use. Condensed in the outcome of a video journal, those app possibilities may facilitate inquiry learning considering both knowledge gain as wells as promoting skills.

2 Key Objectives and Hypothesis

The concept of promoting inquiry skills by self-regulation and tablet support addresses teacher trainees in biology education in Germany. The practical course presented is implemented at the University of Cologne and aims to promote teacher trainees' inquiry skills in the first and second semester. Implementation is followed by an evaluation of our concept. This evaluation aims to investigate whether inquiry skills are promoted by i) tablet-supported experiments or by ii) self-regulation through the "Kölner Handlungskreismodell" or by both, iii) tablet support as well as self-regulation. We predict that combination of tablet support and self-regulation in our blended learning concept will promote more learning of inquiry skills. Since inquiry skills do not only focus on skills but also involve knowledge (as stated by the new term "practices", NRC, 2013), the predicted effects on learning should promote knowledge gain too.

3 Methodology

In their first semester teacher trainees take part in a practical course learning basic laboratory skills such as handling a gas torch, weighing solids, setting up solutions and developing analytical reactions. In preparation for the main course students learn to document laboratory activities not only using paper and pencil but also tablets.

In their second semester the main practical course leads teacher trainees to planning, conducting and reflecting on inquiry-based experiments. A 2x2 matrix ensues three experimental and one control group (EG1=control group, EG2-4= experimental group as shown in Figure 2). All groups carry out investigations using experimental instructions, which are modified and adapted to inquiry-based learning (advanced inquiry and explanation support). Teacher trainees work collaboratively in teams of four in each experimental or control group. Therefore each team member takes on a special task such as experimenting or documenting the investigation.
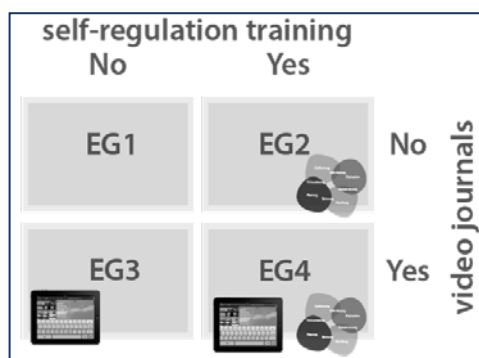
Figure 2. 2x2-factorial design (self-regulation training and video journals)

3.1 Treatment

The implementation of self-regulation and tablet support in the inquiry process promotes a blended learning environment using e-learning support and face-to-face meetings in the practical course. Practical courses are converted from a face-to-face-only setting to a blended-learning environment by using e-learning support (Figure 3): teacher trainees prepare at home for a given inquiry question online (e-learning platform) by working on the materials and then doing an online test. They meet in their teams at university to plan and conduct their investigations. The inquiry process is documented by a video journal (similar to a paper-pencil journal) produced with tablets. At the end all teams reflect on their investigation by presenting and discussing their video journals with their peers in a plenary session. Back at home, the video journals are uploaded to the e-learning platform. Peers and tutor give feedback on the journals online, having flexible access to it.
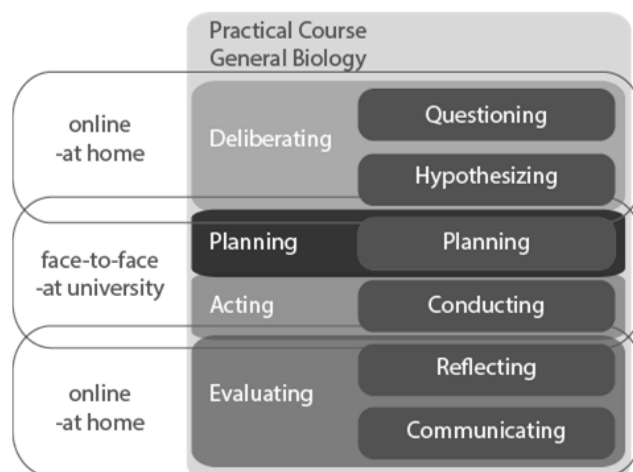
Figure 3. Blended-learning concept of Practical Courses

3.1.1 Self-regulation training

In our blended-learning environment the inquiry process is guided by a model of self-regulation, which supports teacher trainees' metacognition. The model of self-regulation "Kölner Handlungskreismodell" (Armbrüster, 2013) covers each step of the inquiry process (Questioning & Hypothesizing, Planning, Conducting, Reflecting & Communicating) with a corresponding phase (Goal setting, Planning, Acting, Evaluating, Figure 1). Teacher trainees' inquiry skills are promoted by direct and indirect support of self-regulation: A modelling of metacognitive strategy-use by the "Kölner Handlungskreismodell" introduces opportunities for scaffolding the inquiry process with metacognitive support. Prompts are short sentences given by the instructor at defined times. They remind teacher trainees to use metacognitive strategies by the "Kölner Handlungskreismodell" in order to monitor the inquiry process. Prompts should reinforce productive learning strategies indirectly by activating metacognition to regulate inquiry-based learning.

3.1.2 Video Journals

In particular, reflection on the inquiry process is forced by video journals. Tablets are used to document planning, conducting and evaluating inquiry-based experiments and to reflect on them by analysing the video journals. When carrying out an investigation, teacher trainees visualize each step and observation of their experiment. Graphical explanations of their observation enhance understanding of deduced explanation. Therefore, tablet use (here preparing video journals) as an "inquiry empowering technology" provides opportunities for communication and collaborative learning in practical courses and beyond (as reviewed in Hofstein & Lunetta, 2003). The same should be provided by our blended learning concept, which allows teacher trainees to reflect on their inquiry process on and offline.

3.2 Research Design

As the two factors in our research are i) self-regulation training and ii) video journals, a 2x2 matrix ensures there are three experimental groups (EG2-4, each n_2; n_3; n_4=16) and one control group (EG1, n_1=15). Pre-tests examine teacher trainees' inquiry skills employing performance assessment (Shavelson & Ruiz-Primo, 2005), by posing a task, recording teacher trainees while planning, conducting and reflecting their inquiry to the defined research question, and judging their activities using a scoring system. Post-tests apply for a similar outcome. In addition to the inquiry skills examined a questionnaire surveys the self-regulation and knowledge gain experienced by teacher trainees.

3.2.1 Questionnaire on general biology

As inquiry processes never take place without a context, it is important to investigate declarative knowledge of the subject (content knowledge). A questionnaire on general biology focuses on the content of the practical course in which the teacher trainees participate. The practical course comprises topics such as diffusion and osmosis, different groups of nutrients (e.g. carbohydrates, lipids, proteins), and enzymes. Therefore, 12 single choice questions took the different topics into account, each providing one correct answer and three distractors. There is a gap of three months between the pre- and post-test, so that the same questionnaire is used at both points in time, avoiding the necessity of constructing two similar questionnaires. The requirements made of the questionnaire are those of a pre-post-test design without external references.

3.2.2 Questionnaire on inquiry process

As inquiry skills are influenced by process variables as well as by knowledge of the inquiry process, the questionnaire focuses on declarative knowledge of the steps in the inquiry process. Even though no all-encompassing scientific method exists, "the process of building understanding through collecting evidence to test possible explanations and the ideas behind them in a scientific manner" (Harlen, 2012, p.5) is described as learning through scientific inquiry. Therefore, many descriptions of the inquiry process exist, but most agree on corresponding steps. However, the research presented focuses on German pre-service teacher education and takes a description of the inquiry process by a German researcher (Mayer, 2002) into account. Based on the steps of the inquiry process suggested by Mayer (2002) the questionnaire asks students to reproduce the order of the aforementioned inquiry steps. The recognition of an order of inquiry steps may be a scaffolding structure to organize the cognitive complex inquiry process, as the way experts work in their domain is not the same as novices learn in a domain (Kirschner, Sweller & Clark, 2006).

Measuring the distance of each step that was set by the student's answer to its place in the inquiry process indicates how well the structure of the inquiry process is cognitively represented (Estes, 1972 as quoted in Henson, 1996). Lower scores indicate an order that is closer to the exemplary order of the inquiry process. However, it is not a measure of cognitive flexibility in the inquiry process, because the latter measure would not be on declarative but on procedural knowledge. Procedural knowledge, however, is considered by the performance assessment.

3.2.3 Data analysis

The data collected was computed using the Statistical Packages for Social Sciences (SPSS Version 22). The results were generated by applying a repeated measures analysis of variance (RM- ANOVA) following the advice of Field (2014). Effect sizes of partial eta squared (η^2) were changed to Cohen's *d* (1988) according to a web-based computational model (Lenhard & Lenhard, 2014). The tables provide the means (*M*) and standard deviations (*SD*), while the figure provides marginal means (*MM*) and confidence intervals of 95% (*CI*).

4 Results

RM- ANOVA shows that all students gained knowledge of general biology, F_{time} (1, 49)= 10.6, *p*= .002, *d*= .93 taking the within-participant factor of time (1. pre- and 2. post-test) into account. Similar results are disclosed about knowledge of the inquiry process: F_{time} (1, 46)= 69.960, *p*= .0001, *d*= 2.46.

4.1 Effects on content knowledge of general biology

RM- ANOVA shows no significant differences in the factors of self-regulation training and video journaling on knowledge gain of general biology. However, there is a small effect on content knowledge (CK) of general biology of the within-participant factor "self-regulation" under the condition of time which is not significant: $F_{time*SR}$(1, 49)= 2.05, *p*= .16, *d*= .41. The between-participant factor "self-regulation" differs significantly at a level of p_{SR} < .05, *d*= .72 (see table 1).

Treatment on self-regulation

			No		Yes		Total	
			pre-test	post-test	pre-test	post-test	pre-test	post-test
Treatment on video journals	No	M	5.60	7.20	7.08	7.67	6.26	7.41
		SD	(.910)	(1.859)	(1.505)	(2.570)	(1.403)	(2.171)
	Yes	M	5.75	6.75	7.00	7.43	6.42	7.12
		SD	(2.137)	(1.960)	(1.414)	(.938)	(1.858)	(1.505)
	Total	M	5.67	7.00	7.04	7.54	6.34	7.26
		SD	(1.544)	(1.881)	(1.428)	(1.838)	(1.628)	(1.862)

Table 1: Means (M) and Standard Deviance (SD) on questionnaire of general biology

4.2 Effects on the content knowledge of the inquiry process

Taking a closer look at the knowledge gain considering the inquiry process, RM- ANOVA shows that there is an effect of the factor "video journaling" taking time into account (main effect: time x video journaling): $F_{time*VJ}(1, 46)= 4.83$, $p= .03$, $d= .65$. The graphs in figure 4 show a hybrid interaction of time and video journaling on the content knowledge (CK) of the inquiry process, as both graphs (VJ+ and VJ-) intersect between points of measurement. However, there are no other significant between- or within-participant effects of the factors.

Treatment on self-regulation

			No		Yes		Total	
			pre-test	post-test	pre-test	post-test	pre-test	post-test
Treatment on video journals	No	M	27.91	13.27	30.58	10.33	29.30	11.74
		SD	(13.315)	(10.864)	(6.067)	(6.035)	(10.043)	(8.609)
	Yes	M	27.77	14.62	22.86	15.64	25.22	15.15
		SD	(14.956)	(6.021)	(11.890)	(9.328)	(13.423)	(7.779)
	Total	M	27.83	14.00	26.42	13.19	27.10	13.58
		SD	(13.921)	(8.408)	(10.253)	(8.280)	(12.046)	(8.266)

Table 2: Means M and Standard Deviance (SD) on questionnaire of inquiry process
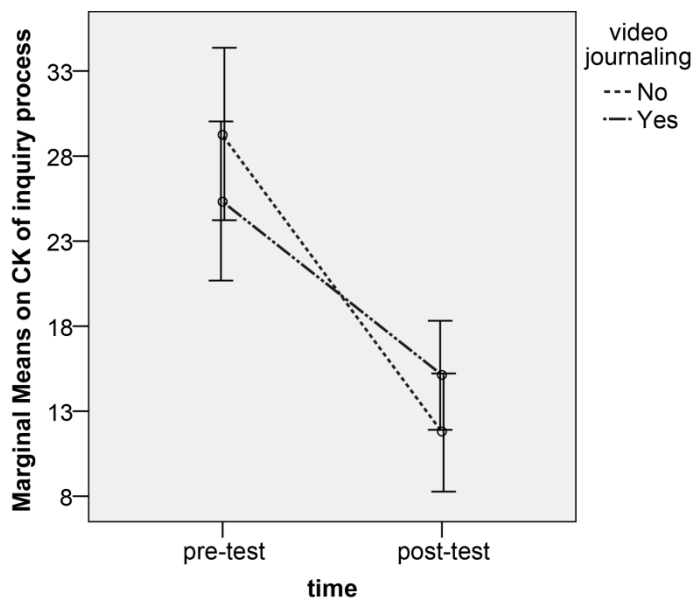
Figure 4: Interaction graph of the marginal means with confidence intervals on content knowledge of inquiry process

5 Conclusions and Discussion

The overall results show that all students increased their knowledge of general biology ($p < .01$, $d = .93$) and of the inquiry process ($p < .001$, $d = 2.46$) by the underlying concept of inquiry-based science education. Compared to the results of In Hattie's meta-meta-analyses (2013) on the effect size of inquiry-based learning ($d = .31$) the effects observed in the research presented are greater (as shown above). Nevertheless, proportions of the effect sizes on content knowledge on the subject (general biology) and the process (inquiry) are similar to the effect sizes reported by Hattie: the effects on knowledge of scientific processes are more than twice as great than on knowledge of scientific content in teacher education (Sweitzer and Anderson, 1983 as quoted by Hattie, 2013). This may be an explanation of greater effects on the knowledge of the inquiry process than on the knowledge of general biology. Some restraints have to be kept in mind as the knowledge gain of students over all experimental groups (EG 1-4) underlies the concept of inquiry-based learning but lacks comparison to a control group without promotion of inquiry skills.

Even though there was a significant difference in the prior knowledge of general biology ($p_{SR} < .05$, $d = .72$) between the self-regulation group ($M_{pre/SR+} = 7.04$, $SD = 1.43$) and the group without training in self-regulation ($M_{pre/SR-} = 5.67$, $SD = 1.54$), this difference declined with time ($M_{post/SR+} = 7.54$, $SD = 1.84$ and $M_{post/SR-} = 7.00$, $SD = 1.88$). Relating to the process of knowledge gain in general biology the promotion of self-regulation might have reduced learning. This effect of self-regulation and time is still not significant so that further research is required. Possible limitations to those interpretations are the

different starting points of both experimental groups in terms of prior knowledge (pre-test results) due to the quasi-experimental setting: it was not possible to control students' prior knowledge because they were allowed to choose the course without knowing about its treatment. The major decision-making basis for students was the time slot the course should take place.

The medium effect of video journaling and time is significant ($p<$ .05, $d=$ .65) and shows by a hybrid interaction that the main effect of video journaling may not be interpreted generally: video journaling has an effect with time but not in the intended manner. Even though the groups of video journaling (VJ+) had better results on content knowledge in the pre-test, the groups without video journaling exceeded them in knowledge in the post-test. This result shows how carefully media use has to be implemented in existing concepts. Instead of spending time on the inquiry process the task of video journaling imposed a high cognitive load. From "Multimedia Theory" we know that cognitive overload results when high processing demands are made of both visual and auditory channels by essential and incidental processes and representational holdings exceed cognitive capacity (Mayer & Moreno, 2003). As a conclusion Mayer and Moreno offer different strategies to reduce cognitive load in multimedia learning. Related to the results presented a revision of the concept of video journaling may reduce the imposed cognitive load and promote learning by considering load-reducing methods.

All in all it must be kept in mind that measuring inquiry skills is complex and that declarative knowledge is just a part of the inquiry process. Therefore, before drawing conclusions about the effectiveness of promoting inquiry skills by self-regulation training and video journaling, the results of the process variables should be considered. The aforementioned research results give a sneak preview of the effectiveness of self-regulation training and video journaling on knowledge gain when promoting inquiry skills. Further publications of results will focus on the relation between the treatment (EG1-4) and the development of meta-cognitive abilities as well as process variables of inquiry skills.

Acknowledgements

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Online training courses: Design models, addressees, effects, and outstanding issues -

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1 Introduction

Some important findings regarding the effectiveness of further training for teachers have been issued by Lipowsky (2010). Effective further training courses are normally time-consuming, extend over a longer period, and involve external expertise. It is generally agreed within professionalisation research that further training courses are oriented towards everyday teaching practice of staff and should therefore also provide opportunities for testing further training course contents with the corresponding reflection.

To conduct further training courses which would offer all this, appropriate financial resources are required which so far in the German federal states have only been provided within the scope of individual pilot projects and on a locally limited basis. For this reason, blended learning courses are preferably seen by the educational administration as a cost-saving alternative to direct and personnel-intensive face-to-face further training.

Since the end of the 1990s, the rapid development of the internet has rendered possible an increased use of web-based learning media in education and training. At the centre of such progress are the internet services which allow internet users to network across great distances.

Applications such as blogs, wikis or newsgroups convey information, whilst services such as e-mail, forum, instant messenger or chat provide their users with an opportunity to communicate with each other.

The latter services constitute the difference between computer-based training (CBT) and web-based training (WBT). A CBT describes a closed learning scenario used locally and offline on a computer. In contrast, a WBT designates the interaction between learners, trainers or teachers via appropriate internet services and taking place online.

The aim of a WBT is basically to allow persons spatially separated from each other to learn together. However, a high-quality WBT is in place only if it involves a learning scenario that is carefully processed didactically, suiting those addressed, and which stands out from a loose collection of information on a given subject.

There are, however, specific quality demands on digital learning environments at the development stage already which require specific expenditure, too (cf., for instance, Bruder & Sonnberger 2008).

Based on this requirement, the working group "Didactic of Mathematics" of the Technical University of Darmstadt has been providing online training courses for mathematics teachers at secondary levels under the direction of Regina Bruder since September 2005.

Participation in these online training courses conveys to mathematics teachers current research-based and intelligent knowledge in the sense of Weinert (1999), as well as the respective decision-making and responsibility which are necessary to set up successful and skills-orientated mathematics classes.

Along with an assessment of quality, ongoing evaluation is to highlight which aspects of online training courses actually favour the implementation of the contents of courses in professional practice, and how such implementation of the contents of courses can be further promoted. With a view to this research objective, research project WOLF (German acronym denoting Impact Analyses of Online Training Courses for Mathematics Teachers), set up for a period of three years and supported by the Ministry of Education of the Federal State of Hesse, devised a measuring instrument in the form of an online questionnaire (FEOM, Szymanski & Bruder 2012).

2 Background and description of the online training courses

The online training courses for teachers are based on experience drawn from research and development projects mostly extending over several years.

Individual course topics emerged in connection with the teacher development project "Increasing Efficiency in Mathematical and Scientific Teaching" [German acronym SINUS] with the support of the Hessian Ministry of Education [German acronym HKM], or were commissioned by the HKM directly. The development of an online training concept for mathematics teachers is thus also to be understood as a reaction to the education standards for mathematics, adopted by the Standing Conference of the Ministers of Education [German acronym KMK] in 2003.These education standards require further development of mathematics classes with the objective of promoting the development potential of weaker and stronger pupils (Collet, 2009). They are result-orientated by describing process and content related educational objectives as professional competences that have to be conveyed to learners before they leave school.

The central objective of the online training courses thus represents an increase of competency of the participating mathematics teachers by means of which the quality of mathematics classes are to be improved in a sustainable manner.

In our contribution, we should like to introduce a concept for assisted thematic online training courses for the duration of a school semester. This concept had been developed and tested within the scope of a research project supported by the DFG [German Research Foundation] on problem solving skills in mathematics instruction (cf. Collet & Bruder 2008). The objective of such course concepts is the implementation of research-based innovations for teaching in the form of modules for teaching concepts to promote certain spheres of competence at the secondary levels. On the basis of this concept, applied since 2005 and elaborated and tested for seven more topics already, we have in the meantime been able to gain multiple experiences with a total of

about 1000 course participants, which are to be discussed in an exemplary way.

The topics of the courses are as follows:

- Basics – sustainable development and elementary basic skills permanently kept awake
- Problem solving and self-regulation
- Mathematical modelling
- Internal differentiation
- Spreadsheet analysis (Excel)
- Long-term development of competence in mathematics by means of problems
- Arguing
- Competence diagnostics.

Our online course have been offered and supported nationwide via the DZLM [German Centre for Teacher Training in Mathematics] since 2013.

The majority of our courses consist of six thematic modules which are normally released consecutively on a MOODLE platform at intervals of about two to three weeks for the duration of the course of 15 weeks, and are then elaborated by the participants.

Figure 1 shows the course-structure of the course "Problem solving and self-regulation".

module 1: **Approach to problem-solving in teaching mathematics**
introduction of the topic, use of the moodle-platform and communication within the course forums

module 2: **Heuristic training in mathematics lessons**
presentation of „heurisms", that might help pupils to handle mathematical problems in a skilful way

module 3: **Practical experience with „problem-solving elements" in class**
forum for discussion and exchange of experience with other course participants

module 4: **Selfregulation with „long-term exercises"**
conditions for problem-solving in maths lessons in a meaningful way

module 5: **Creating an atmosphere stimulating problem-solving processes**
How can mathematics lessons be designed in a „pupil-friendly/orientated' manner?

module 6: **Diagnostics of problem-solving competence**
measurement of progress in problem-solving competence and consequences for further teaching

Figure 1: "Problem solving" (course structure)

Figure 2 shows the course structure of the course: "Internal differentiaton" with possibilities of choice and figure 3 shows the time schedule for this course.
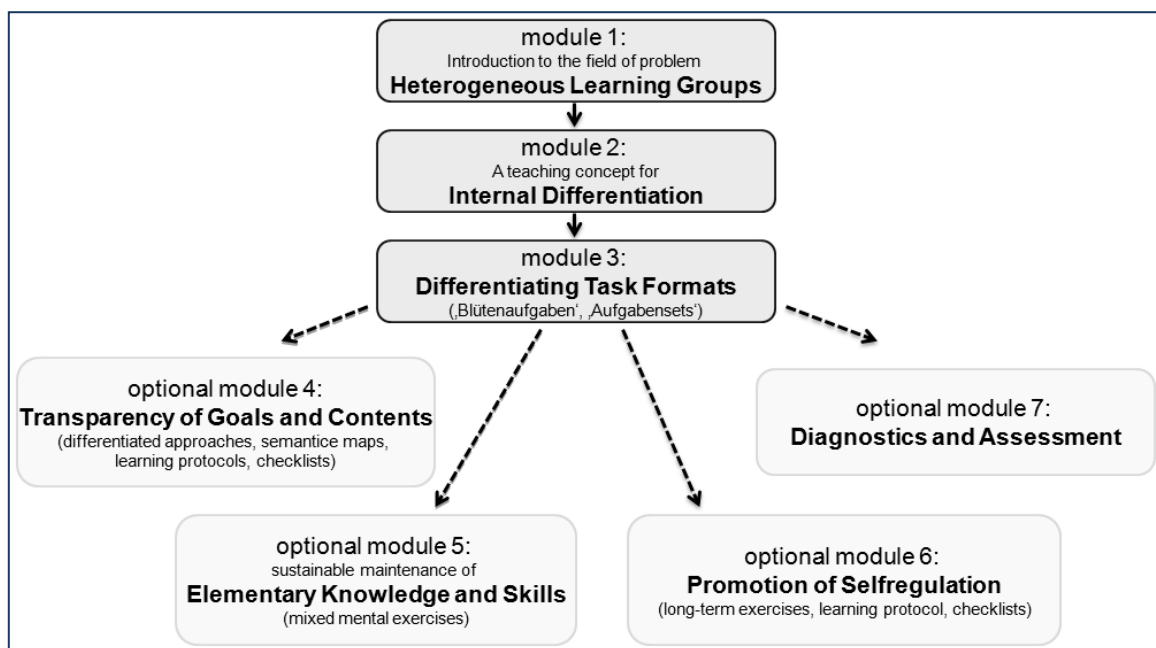
Figure 2: "Internal differentiation" (course structure)
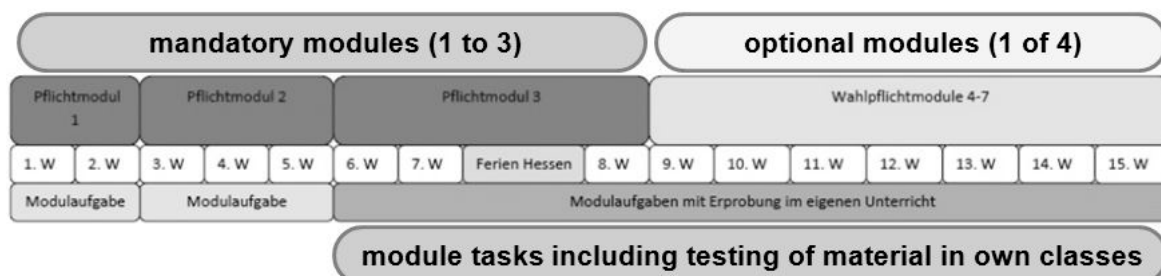
Figure 3: "Internal differentiation" (time schedule)

Nearly all modules contain each the three design elements of input, module task, and forum. Individual courses also offer moderated online chat terms. The online courses are embedded into a blended learning concept starting with a face-to-face introductory session and ideally scheduling a further meeting in the middle or at the end of the course. Currently there is a lack of skilled multipliers, who are able to run such face-to-face introductory sessions in different regions and cities. Consequently, the most participants join pure on-line sessions due to the big distance to Darmstadt where the face-to-face sessions are held.

Absolutely essential is tutorial monitoring of course participants over the duration of the six-month course including professional feedback on the submitted test reports of the participants, on moderation of the forum discussions, and suggestions on the basis of peer-to-peer feedback.

The online training courses start at the beginning of every school semester with one on-site event in the form of an introductory afternoon workshop (not

mandatory). This is followed by the online phase (12 weeks). The half-year online training courses are structured into 5-6 modules which each contain brief instructions and background information with tested examples and are built on each other. Each module starts with a theoretical part with integrated perfect examples. The course participants acquire the theoretical knowledge conveyed in the individual courses on their own by means of clear examples. At the end of each modular unit, the course participants are assigned a module task. The purpose of the module task is to test the concepts acquired.

To this end, independent tasks and materials are to be developed and the knowledge gained is to be applied in the participants' own classes. The module task contains options according to the teachers' own goals of how to develop materials and test these in their own classes. The duration of a training course is 12 weeks altogether, with two weeks' processing time provided for each module and the subsequent work task. A work load of 1-2 hours per week is assumed, depending on previous knowledge.

The course participants are supported online by trained tutors who accompany the learning process of the course participants by addressing any issues promptly and by releasing any work products and putting them up for discussion. For this purpose, a forum is provided for each modular unit. The participating teachers can exchange their views on the acquired concepts and their implementation. Moreover, the course participants are given written feedback on the teaching materials produced by themselves from their tutors. The feedback refers to theoretical models and criteria and addresses the work product of each course participant individually.

We are in a position to state that the demands on effective further training courses as known from professionalisation research can well be implemented in assisted online courses. There are, however, other factors relating to the individuality of teaching staff as well, which affect acceptance and effectiveness of blended learning courses.

The target group of our six-month courses are mathematics teachers, persons teaching mathematics without having studied it, and multipliers. The participants teach in many different types of school (primarily grammar schools and comprehensive schools), offer a wide range of second subjects, are mainly younger than 50 years, have mostly less than 10 years' professional experience, and about half of them hold leadership or coordinating positions, such as spokespersons, or heads of department (data base: survey participants in the six-month courses in 2013 and 2014).

There is thus no such thing as a "typical" online training course participant but only a very wide spectrum of participants, something which makes differentiated offers and individual support absolutely essential. Figure 4 shows how many participants worked in the online courses. For the time being there was no advertisement for these courses – they only offered in the internet: http://www.dzlm.de/fort-und-weiterbildung/suche?f%5B0%5D=field_angebots%3A248.
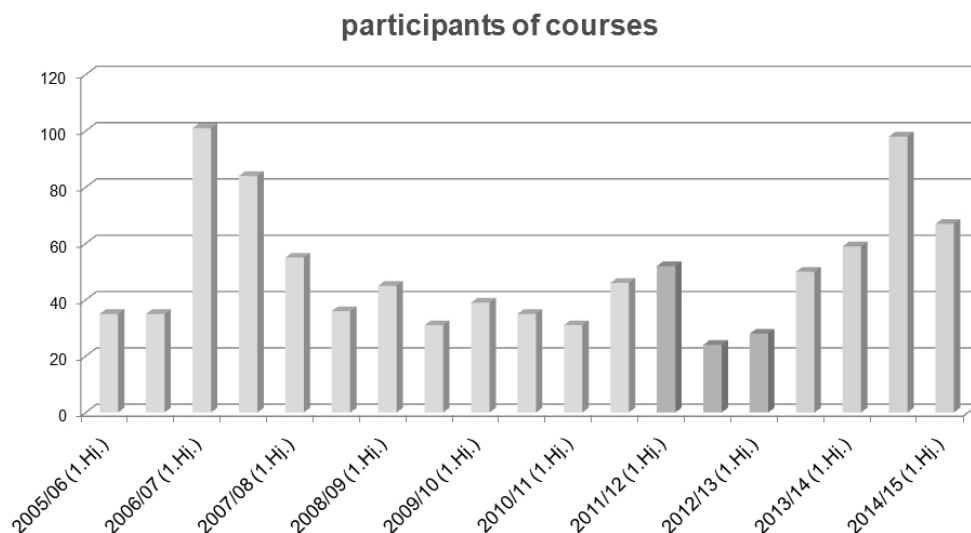
Figure 4: Course Participants (all courses)

3 Evaluation results

If it is about implementing internal innovations or pursuing development of teaching in schools in a sustainable manner, the relevant findings from work or organisational psychology should be taken into account by all means. In particular: "[… the motivation of the persons concerned, their willingness to really get involved with changes, to convert intentions into action, and to develop an attitude of responsibility" depend largely on "how their emotional state is being dealt with]." (Doppler et al. 2002). Krüger (2002) describes this desired process with the two stages of an acceptance of attitude and an acceptance of behaviour. First of all, the actors of changes must gain positive experience with an explanatory model for the relevant phenomena within their own practical knowledge. Positive balances between stimuli and contributions within an activated decision model will then lead to an acceptance of behaviour.

A study entitled "Professionalisation of teachers in the online age – conception and evaluation of online training courses for mathematics teachers" (project WOLF) was conducted over the four six-month courses in 2011 and 2012 offered by us (cf. Szymanski & Bruder 2012). There, the following aspects relating to the "four levels of evaluation" (Kirkpatrick & Kirkpatrick 2006) were examined by means of a newly developed questionnaire:

- Acceptance of courses offered
- Growth of knowledge (subjective assessment by teaching staff)
- Transfer (Testing the course contents in class? Inherent part of own teaching? Is there any intention to keep integrating the course contents into own teaching?), and
- Sustainability of courses.

The first two levels relate to an acceptance of attitude, the latter two to an acceptance of behaviour.

Research project WOLF is about developing a measuring instrument to guarantee ongoing evaluation of the online training courses by recording, along with the quality, the effect and sustainability of the online training courses for mathematics teachers. On assessing the quality of a training measure, consideration should be given to the fact that training measures have a relative quality which results from the respective circumstances and the target group.

As a result, an evaluation aimed at recording the quality of a training measure must incorporate the features of a given training measure and target group into the assessment process and be geared towards such features.

The objective of the evaluation is to establish a comprehensive assessment of the online training concept from the point of view of the participating mathematics teachers. From a user's perspective, the advantages and also disadvantages of the online concept are to be highlighted which are to establish eventually which aspects of the online training courses are connected with acceptance, learning success and implementation of the contents of courses in teachers' own classes. Moreover, an assessment of the effects by the participants themselves is to draw a first conclusion regarding sustainability of online training.

The following research question emerged from the evaluation project with the objective of assessing the quality of the online training courses from the point of view of the participating mathematics teachers: Which aspects of the online training courses particularly facilitate implementation of the contents of courses in teachers' own classes? And are these the same factors which are basically related to satisfaction with the courses?

scale	number of Items	example
„Structure and Didactics"	4	- The course was well structured.
„Relevance"	4	- I got enough clues and incitements for the preparation of my maths lessons in practice.
„Tutors"	5	- The feedback of the tutor on executed tasks was helpful to me.
„Cooperation"	3	- I took part in the forum discussions.
„Interaction"	3	- I missed the personal contact to the other participants.
„Online"	9	- Flexibility with respect to when and where I want to learn the course content.
„Learning success"	4	- I estimate my own learning increase as high.
„Transfer"	1	- I proved the content of the training course in my own math class.
„Intention"	2	- I intent to continue applying the knowledge and skills I have learned during the training course in my own math class.

Figure 5: Iterns of the scales (one example each)

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Means and standard deviation of the „scales"

Scale	Values
„Structure and Didactics"	(M= 4.21; SD= .64)
„Relevance"	(M= 3.95; SD= .77)
„Tutors"	(M= 4.06; SD= .70)
„Cooperation"	(M= 2.43; SD= 1.01)
„Interaction"	(M= 2.41; SD= 1.03)
„Online"	(M= 3.90; SD= .79)
„Learning success"	(M= 4.02; SD= .70)
„Transfer"	(M= 3.69; SD= 1.19)
„Intention"	(M= 3.90; SD= .81)

„not applicable at all" = 1, „applies completely" = 5
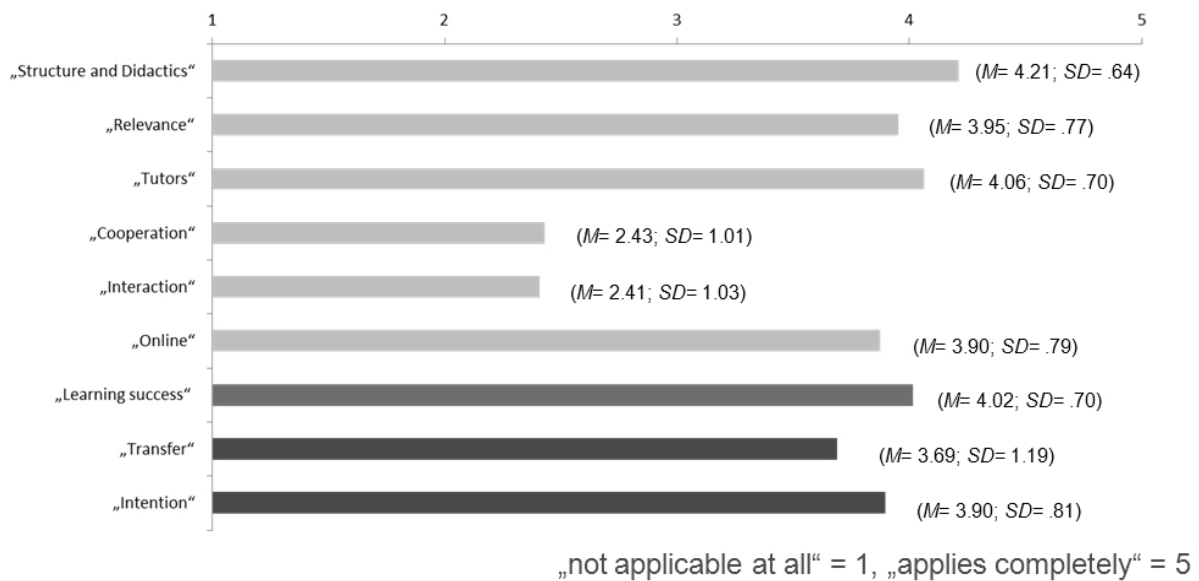
Figure 6: Course evaluation – results (scales)

In total, the participants rated the courses offered with an average mark of 1.99 (average of all courses, marking scale between 1 [highest] and 6 [lowest]). At this, high approval ratings on the scales of "Structure & didactics" and "Online" appeared particularly relevant to a good overall evaluation. The lowest impact on the overall mark came from the scales of (own) "Participation" and "Interaction" ("I should have liked to see more exchange with the other course participants.").

The results of the study, however, show a high correlation between a positive evaluation of a growth of knowledge for the participating teaching staff, and the testing of the course contents conducted in their own classes. Both the statement that the concepts conveyed had by now become inherent part of their own teaching, and the intention to keep integrating the course contents into their own teaching, also strongly correlate with practical testing conducted in their own classes.

The participants particularly liked the flexibility in terms of time, contents and location, the interlocking of theory and practical testing, the individual feedback, the material provided, and also the fact that online training courses extended over a longer period of time (in contrast, for instance, to attending just one event), see table 1.

Positive aspects	What did you like in particular about this online training courses?
timely, content-related and local flexibility	individual work management – online-course gives the possibility to work at home – flexibility of working time – Because all course material was present from the beginning, I could elaborate the module tasks well-fitting to my school classes.
theory and practical experience	combination of theory and practice – that I could test the newly learned quickly in my classes - practical experience
individual feedback	detailed and individual feedback (very important!!!) – personal und differentiated feedback
material provided	employment with the materials provided – the format/structure of the tasks given – the input text material was very good – the presentation of the „sets of problems" was very interesting
duration of course	It was very good, that the course extended over a longer period of time (e.g. in comparison to one-day-events). That allowed to gain long-term experience with the subject and prevented that it was quickly forgotten in everyday work.

Table 1: Positive Feedback

As regards any negative feedback (see table 2), for instance, the sometimes unconvincing matching of individual teaching situations (class level, contents), frequently missing time for intensive personal participation, and problems on transferring the contents from theory into practice were mentioned, and generally higher portions of practical work were desired.

Negative aspects or suggestions	What did you not like? Have you any suggestions for improvement?
even more practical experience!	It could have been even more practical experience … gives maximum benefit!
mismatch with individual situation in school	It would be helpful to take into consideration the individual situation of the course participants even more - sometimes you have only one math class at a time - not every course subject does fit to actual own classes – only suitable for better students, which you will hardly find at our school, unfortunately
problems with transfer of theory into practice	too theoretical sometimes – to apply the theory in practical work was sometimes quite difficult
not enough interaction, not enough time	There was only little interaction among the course participants. I realised on myself that it was not easy to find the time for working in the course.

Table 2: Negative Feedback and Suggestions

Even in subject-related specialised didactics, there exist different views on whether a desired behaviour by teaching staff should be trained by means of tight scripts and instructions, or not. We note there are different individual learning preferences which might also attract more interest in the future, for instance, through adaptive online offers. The fact that teaching staff, too, can be very different has so far not been taken into account in a recognisable manner, for instance, on introducing new curricula.

Outstanding issues and interesting research questions concerning the improvement of courses are:

- How to promote and expand the practical elements in online training courses?
- How to enhance communication between course participants?
- How to reach potential applicants?
- How to further ensure that the contents of courses are implemented in class on a permanent basis even after completion of the course?

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Blended learning and e-learning support within the Cornerstone Maths Project -

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1 Introduction

This paper describes the outcomes of a strand of research within the Cornerstone Maths project in England that has focused on teachers' participation in blended learning and e-learning support. Cornerstone Maths is a multi-year project that began in 2009 and adopts a design based research approach to scale the use of technology enhanced curriculum units on 'hard to teach' topics (linear functions, geometric similarity and algebraic patterns and expressions) within middle school mathematics (11-14 years). The project has developed from a set of pilots in the US and in England that have shown the efficacy of the curriculum units in a wide range of classroom contexts (Hoyles and Noss, 2013, Hegedus and Roschelle, 2013). A key element of the design of the 'at scale' professional development (PD) has been the blended approach that combines face-to-face meetings (in regional networks) with synchronous and asynchronous e-learning mediated by an online community and scheduled online webinars. We report findings from a cohort of secondary school mathematics teachers implementing the Cornerstone Maths unit on linear functions during the 2013-14 academic year.

2 Design principles

2.1 The curriculum units

Cornerstone Maths exploits the dynamic and visual nature of digital technology to stimulate mathematical thinking by:

- focusing on the 'big mathematical ideas' in middle schools mathematics (11-14 years);
- making links between key mathematical representations;
- embedding activities within realistic contexts;
- providing an environment for students to explore and solve problems within guided structured activities.

For example, the curriculum unit on linear functions focuses on the following mathematical ideas: coordinating algebraic, graphical, and tabular representations; $y= mx+c$ as a model of constant velocity motion; the meaning of m and c in the motion context; velocity as speed with direction; and average velocity. The realistic context puts the students in the role of designers of games for mobile phones where they use mathematics to analyse and create simulated motion games.

Figure 1: An activity from the Cornerstone Maths unit on Linear functions showing the dynamic linked representations

2.2 The research foundations

The Cornerstone Maths curriculum units emanated from earlier design based research projects that involved particular mathematical technologies (i.e. SimCalc, Migen eXpresser), the outcomes for which are reported elsewhere (See, Hoyles and Lagrange, 2009, Hegedus and Roschelle, 2013, Mavrikis et al., 2012). The process of making the essential design features of such resources available more widely to teachers involved a redesign whereby the software runs within a within a web-based browser. This bespoke software, alongside prescribed lesson activities and teachers' professional development form a curricular activity system (Vahey et al., 2013), which research findings have concluded to be most useful to support wider student access to technology in mathematics (Clark-Wilson et al., 2015, Hoyles et al., 2013).

Finally, in accordance with existing research, we acknowledge that transformative change in teaching practices takes time (Even and Loewenberg Ball, 2009), particularly when the dynamic mathematical technology is in the students' hands, as it challenges teachers to consider how the mathematics is different (changed representations, different modes of interactions etc.) and how their pedagogy might need to develop in response (Hoyles and Lagrange, 2009, Clark-Wilson et al., 2014).

2.3 The national context

In 2013 the UK Department of Education introduced a more aspirational national curriculum in which students meet some mathematical concepts earlier in their school experience (Department of Education, 2013). Alongside

this, successive national inspection reports document an underuse of computer software (alongside practical activities and resources),

'Carefully chosen practical activities and resources, including computer software, have two principal benefits: they aid conceptual understanding and make learning more interesting. Too few of the schools used these resources well.' (Office for Standards in Education, 2012, paragraph 62).

Alongside this, in England the political move towards increased school autonomy whereby schools decide on their own priorities and set their own budget can result in technology enhanced learning being just one of many priorities that a school might choose to address.

To date, there are 258 mathematics teachers from 124 schools across England who began to teach the CM curriculum unit on linear functions to a total of over 7000 students during the 2013-14 school year. They were organised within 6 Cornerstone Maths networks in partnership with an expanding group of PD 'multipliers'. However, within the context of an educational innovation such as CM, scaling cannot be interpreted solely on the basis of more schools and teachers. Other important quantifiable 'products' of scaling *for sustainability* include: an increase in professional networks; school-generated evidence of improved student attainment; an increase in the number of whole departments involved; wider use of materials (more classes within schools); and more teachers within departments involved. Alongside these products are the processes of scaling, which for CM included the development of: the web-based curricular activity system accessible on a range of technology platforms ; the teacher community; a localised PD offer (school clusters becoming networks); school devised evaluation approaches; a school based PD offer; localised schemes of work and the community of multipliers.

2.4 Design principles: the professional development

The CM professional development (PD) has been designed based on the following assumptions:

- teachers are not a homogenous group and 'one size' does not fit all;
- PD should be sustained over months and years – an initial one-day face-to-face event followed by synchronous and asynchronous events and ongoing online communication;
- teachers should adopt different roles within the PD process, i.e. 'teacher as learner', 'teacher as teacher', 'teacher as designer of learning', 'teacher as assessor/evaluator'.

The PD process is illustrated in Figure 2.

Before PD
- pre task – getting instrumented
- online support for pre-task (video walkthrough of software)
- optional webinar support

Face to face PD
(one-day)
- hands-on access to the technology
- deep discussion of the mathematics
- planning for classroom adaptation
- introduction to online community
- online survey (contextual data)

During teaching
- some classroom support visits
- asynchronous forum discussions
- other teachers' resources
- webinars on key themes
- online survey (implemntation decisions)

After teaching
- webinars on key themes
- online survey (evaluation)
- [...more active involvement in community]

Figure 2: The complete PD process for each CM curriculum unit - from a teacher's perspective

The e-learning elements of the CM PD include: completing a pre-PD task (email and online); 'joining' the (online) project community; participating in the (online) project community; participating in project webinars; and responding to online project surveys.

Each of these elements is now described in more detail.

2.4.1 The pre-PD task

As the CM curriculum units of work use a bespoke software environment, the main objective of the pre-PD task was to offer the teachers an opportunity to become 'pre-instrumented' with the software in their own time and at their own pace. A task was sent to them two weeks before the face-to-face PD event, which required them to access the software and be introduced to its key functionality by adopting the role of a learner. Alongside this they were provided with access to short narrated video walkthroughs, which they could choose to watch, prior to (or after) attempting the tasks for themselves. During this same 2-week period, an optional webinar was organised by one of the CM PD team at which teachers could seek help, if needed.

2.4.2 The online CM Project community

The online CM project community was facilitated via the National Centre for Excellence in Teaching Mathematics (NCETM) web portal (Gouseti et al., 2011), which offers a private space for project teachers to: read, respond to and initiate discussion threads; and upload and download related digital files.

The teachers were introduced to this community during the initial face-to-face PD event in a workshop session where they had worked in groups to complete specific CM student tasks and were then asked to feedback on their experiences. The teachers were also shown where to download the electronic copies of the teacher and student materials for each curriculum unit and how they could upload any additional resources that they created to share with the CM project community.

2.4.3 The project webinars

The project webinars were organised to offer teachers an optional point of engagement with the CM PD team to coincide with when the teachers would be planning, teaching and evaluating the CM curriculum unit. The themes of these webinars were selected to respond to aspects of the classroom implementations that the teachers' had identified as being of interest to them. These included the teacher-led adaptation of the resources to support students who had English as an additional language (EAL) and the sharing of classroom-based strategies for the formative assessment of students' learning.

2.4.4 The online project surveys

The most important methodological tool to collect data on the teachers' classroom experience of the CM curriculum units 'at scale' was three online surveys, facilitated by Survey Monkey. As indicated in Figure 2, three surveys were administered to collect contextual data, implementation decisions and post-teaching evaluatory comments. These responses aligned with the evaluation framework for the complete project (Clark-Wilson et al., 2015) and sought to elicit: the teachers' choices of technological and classroom set-up; the chosen teaching and learning pathway through the curriculum unit; the teachers' overall evaluation of the materials; and the nature of their engagements with the project community.

3 Findings

3.1 Teachers' evaluations of the initial face-to-face PD event

All teachers participating in the CM project attend at least one face-to-face PD event, which they evaluate by questionnaire at the end of the day to gather their immediate perceptions of the effectiveness of the PD event and indicate the type of further PD support that they would value. The teachers were highly positive about the initial face-to-face PD and 88% of the cohort of teachers (n=195) judging it to be 'excellent' or 'good' in terms of preparing them to teach the CM curriculum unit in their classroom. Of the 166 teachers who offered suggestions for future PD support, 58% requested support on formative assessment and 57% on adapting the materials for Special Educational Needs

and for students with English as an Additional Language (EAL). Only 8% of the cohort specifically asked for this PD support to be mediated by webinars.

3.2 The online community

An individual teacher's participation within the CM project online community could extend to some or all of the following activities:

- making a first post to the forum within an existing discussion topic, which most teachers accomplished during the face-to-face PD event;
- accessing digital resources from the Documents area within the community;
- contributing resources by uploading them to the Documents area within the community;
- beginning a new forum thread.

Despite regular posts and uploads by the LKL Project Team, the CM online project community did not become the vibrant 'teacher-owned' online community as was originally hoped. The final project survey asked teachers about their activity within the online community *following* the initial PD event to which 57% of teachers reported that they had accessed it in relation to their teaching of Unit 1 (110 teachers responded to the survey). These 63 teachers described their use of the community as shown in Table 1.

Teachers' reported uses of the online project community	% of teachers (n=63)
To keep up to date with the project news	52%
To read questions or comments by the community	83%
To post questions or comments to the community	22%
To access the electronic version of the Teacher Guide	38%
To access the electronic version of the Student Workbook	37%
To upload resources for other teachers to access	3%
To download resources created by other teachers	11%

Table 1: Teachers' reported uses of the online project community

Very few teachers initiated discussion threads within the online community forum. However, as 83% of these teachers reported that they did read other people's questions or comments, this does suggest that the online community provided an important PD resource for those who chose to access it. The 49 teachers who did not report any use of the online project community cited their most common reasons as: insufficient time; forgetting that the community existed; not feeling the need to participate; and not encountering any problems. This does suggest that, as the use of such online communities is not yet established as part of most teachers' professional practice, we do need to work to change teachers' perceptions and experiences of such communities as a useful and valuable source of PD support.

3.3 Project webinars

Only 22 teachers (less than 10%) participated in at least one of the webinars that were convened by the PD Team to respond to teachers' requests for more support on adapting the CM curriculum unit for students with EAL and to discuss pedagogical approaches to support formative assessment. However the quality of both the teachers' presentation of their ideas and the discussions that ensued validated these webinars as a PD opportunity to be continued. When the remaining teachers were questioned about why they had not participated in the webinars, the most commonly cited reasons were that they were not at a convenient time of the day for the teacher, they were too early in the term and the teacher had not started teaching the unit yet or the teacher had never joined a webinar and did not know what to do.

4 Conclusions

Whilst the traditions of face-to-face PD support is well-established in the English mathematics teacher community, our findings suggest that most teachers are yet to have a substantial PD experience that involves blended and e-learning approaches. Consequently, a cultural shift is required within the wider teaching community such that alternative PD approaches become an accepted part of teachers' professional lives. Our findings suggest that, where teachers did engage fully in the e-learning and blended PD, they were overwhelmingly positive about its contribution to their overall experience. For the PD multipliers, the mediation of such e-learning and blended PD approaches is a non-trivial activity. For example, mediating an online webinar with multiple participants in different geographical locations requires a clear plan, which takes account of both the PD aims for the session, the anticipated participant experience and it should maximise the affordances of the technology that is being used to facilitate the online meeting. These aspects are beginning to emerge from the research into the impact of synchronous online learning (Cornelius and Gordon, 2013, Kear et al., 2012, Wang and Hsu), which will inform how webinars are designed for our future work with teachers.

5 Future research

The Cornerstone Maths research team are continuing to research the impact of the various blended learning approaches adopted within the different project communities and these findings will inform the development of a more comprehensive PD Toolkit – in collaboration with multipliers. Our next phase of work, a 2-year project that is being funded by the Nuffield Foundation, will enable us to conduct deeper research into the nature of teachers' development of mathematical knowledge in the Cornerstone Maths topic areas and their associated classroom practices with dynamic mathematical technologies.

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A Virtual Mathematics Laboratory in support of educating educators in inquiry-based style -

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The paper deals with a *Virtual School Mathematics Laboratory (VirMathLab)* being developed at the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences (IMI-BAS). Various ways of using it in mathematics education are presented, with emphasis on the implementation of the Inquiry Based Learning (IBL) by means of dynamic geometry software. Strategies for integrating it with the education of educators in mathematics and information technologies are discussed. The paper deals with the specifics of seminars for teachers organized in the frames of recent European projects (InnoMathEd, Fibonacci, DynaMat, Mascil, Scientix2, KeyCoMath) the authors have been involved in for implementing the IBL in mathematics education.

1 Preparing the ground for mathematics explorations on a large scale

The idea of preparing and developing a repository of e-resources which could be used in support of inquiry based mathematics education at different levels and forms led to the establishment of a Virtual School Mathematics Laboratory (VirMathLab) at IMI-BAS (http://www.math.bas.bg/omi/cabinet/), Chehlarova et. al. (2014).

Important feature of the *VirMathLab* is that it will be dynamically enriched by resources developed within educational projects with two-way links. For instance, the dynamic *Snowflakes* file(http://www.math.bas.bg/omi/mascil/task-Snowflakes-bg.html) is linked to the scenario "Let us make a snowflake" within the *MaSciL* project which in turn refers to the *Snowflakes* file (Figure 1).
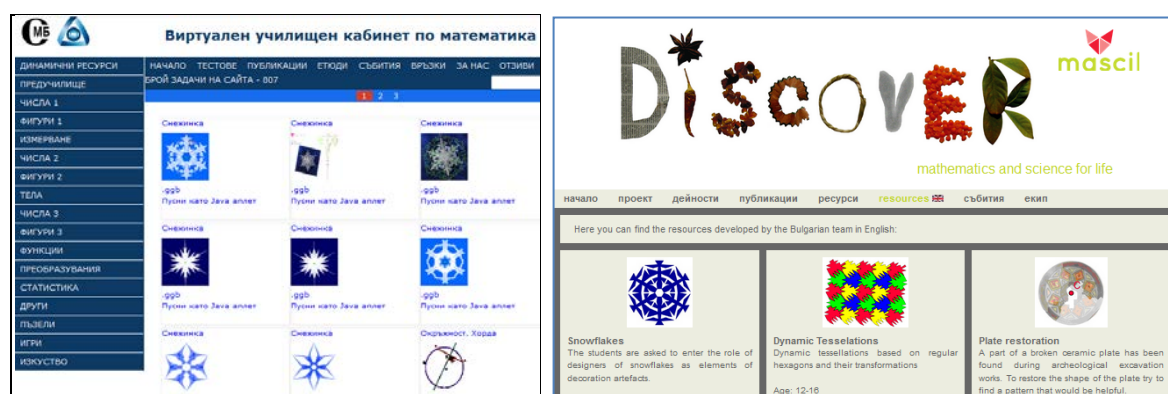

Figure 1: The sites of the VirMathLab and Mascil at IMI-BAS

Every dynamic file could be considered as a *half-baked* e-resource to be used as a means for: providing conditions for explorations, visualization of the solutions, testing and self-testing, creating and formulating mathematics

problems, preparation of didactic resources on paper, solving practical problems with a specific precision, motivation for mathematical or programming activities, acquiring skills for working with a specific software, forming of competencies for working with a text (mathematical and CS alike), development of algorithmic thinking, etc. (Figure. 2).
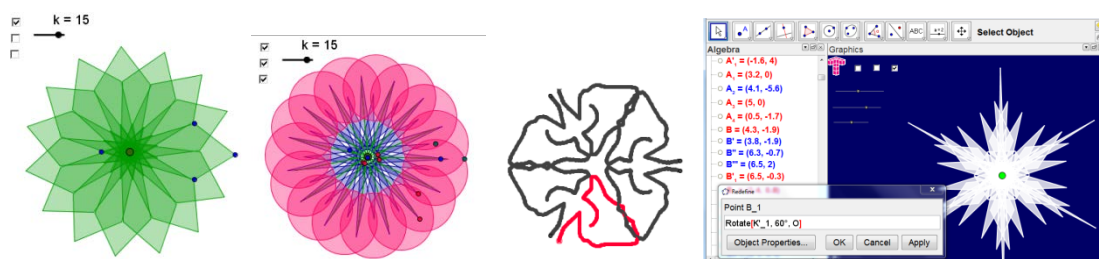
Figure 2: Examples of dynamic scenarios in VirMathLab

The dynamic files are available in three formats, the choice depending on the goals and the technical skills of the users:

http://www.math.bas.bg/omi/cabinet/content/bg/ggb/d22054.ggb

http://www.math.bas.bg/omi/cabinet/content/bg/html/d22054.html

They could be used in various ways depending on the level of preparation, as described below in the context of a specific example.

2   A 3-day seminar form

Such a seminar form proved to be very efficient, the third day being 1-2 months after the first 2, in which the teachers present their own projects (individually or as a team). During the presentation the participants discuss the project, suggest modifications and improvements. The questions posed by the teachers are targeted to their specific audience of students and the answers come from the rest of the teachers and us, the authors, in the role of teacher educators. Another important feature of these seminars is that they are **binary,** i.e. led by two people simultaneously. The dialogue type of communication among the seminar leaders is both a model to follow and usually provokes similar style of communication among the teachers. The presence of two sources of information and professional experience enables (i) different aspects of consideration of the object being studied, (ii) comparison between different points of view, and (iii) a specific analysis of a given situation. Various models of decision making and team work are demonstrated.

Our experience shows that one can work effectively in homogeneous and heterogeneous groups alike in terms of technical skills, experience in working with specific learning environments, age range, etc. What is crucial though is that there are at least two teachers per school (in mathematics and in

informatics/IT). The synergy between their competencies is a guarantee for a noticeable progress in implementing the innovation in school.

The seminars provide teachers with knowledge about a sensible use of educational software and other resources (dynamic scenarios and manipulatives) together with innovative educational strategies (e.g. inquiry based learning). It is essential that the teachers *enter the skin of researchers* so that they could implement with self-confidence the IBL in their practice. This includes leaving them to explore and find out on their own the potential of a software environment (new to them) in a limited time, to solve a specific mathematics problem in inquiry style, to solve specific didactic cases.

The crucial part of the courses is for the participants to experience different stages and levels of IBL. The teachers work on pedagogical problems related with: reformulating of math problems in IBL style so as to enhance the development of specific key competences; formulating their own math problems reflecting real-life situations, not solvable with the current math knowledge of the students but allowing for explorations by means of dynamic geometry models leading to an acceptable approximation of the solution; studying and proposing methods for tackling problems which are unstructured, or whose solutions are insufficient or redundant; solving "traditional problems" with "non-traditional" data, for which the use of a computing device is necessary; applying game-design thinking so as to engage better the students in the problem solving; formulating more relevant evaluation criteria for the students' achievements; assessment of learning resources in terms of formation and development of IBL skills and key competences; project-based work with presentation of the results.

We specify **three levels of competencies for working with dynamic constructions**: (i) using them as offered by somebody else, (ii) modifying them for a specific purpose, and (iii) creating them from scratch.

For example, the file at
http://www.math.bas.bg/omi/cabinet/content/bg/html/d14007.html or
http://www.math.bas.bg/omi/cabinet/content/bg/ggb/d14007.ggb

could be used in the given format for forming the notion of a *fraction*, when learning the basic property of the fractions, etc. (*Figure 3*).
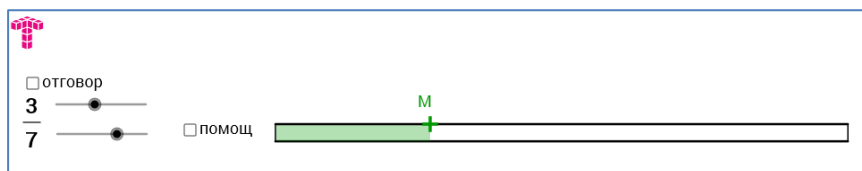
Figure 3: A dynamic model for forming the notion of a fraction

This file could support the good understanding of the nature of fractions, as well as the self-checking of corresponding knowledge and skills. The activities could take the form of a game. In a relatively short time every student can first

solve a specific problem and then create a new problem for the next participant. It is sufficient that the student moves the point M so that the green rectangle corresponds to the fraction in the condition (3/7 in the case of *Figure 4*).
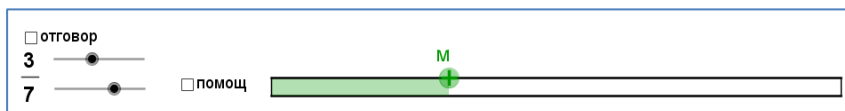
Figure 4: Locating M so that the colored part is 3/7 of the whole rectangle

If needed the students could ask the program for help (checking the box **помощ**) which leads to the division of the rectangle in the corresponding number of equal parts (7 in our case, *Figure 5*).
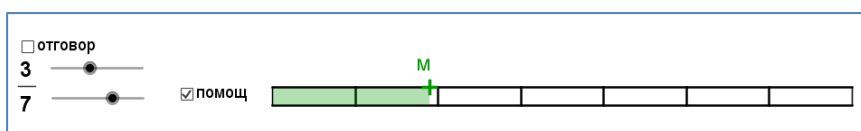
*Figure 5: Asking for help (checking the box **помощ**)*

Including an answer box (**отговор** in Bulgarian) enables the feedback (*Figure 6*).
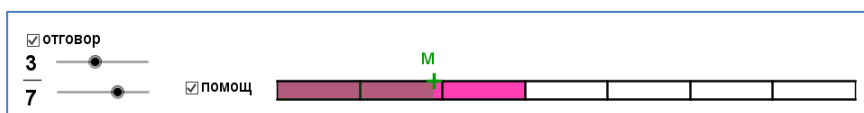
*Figure 6: Asking for the answer (checking the box **отговор**)*

To pose another problem the students should first hide the help box and the answer box (by unchecking them) and then choose new values for the numerator and denominator by means of the sliders (*Figure 7*).
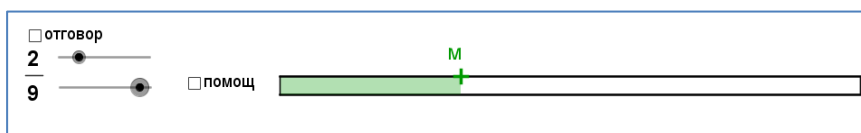
Figure 7: Posing a new problem

Thus, when working on specific examples, the teachers get familiar with elements of the software and develop their digital competence. When carrying out an experiment with teachers and students, we were surprised by the results of the teachers, especially of those working in the primary school. More

than 70% would commit essential errors when solving similar problems on a sheet of paper. It turned out that after 10 min work with the file discussed above their results were significantly better. Their abilities to form knowledge and skills for estimating the result matter even more today when the calculations are often performed by means of computing devices. This format of the files is helpful also for self-checking. In some cases, the *VirMathLab* contains a series of files with modified conditions, e.g. intervals of the admissible values of the numerator and denominator, using a circle instead of a rectangle, etc.

In most of the cases however it is appropriate for the teachers to modify the file according to specific goals. For instance, they can change the end points of the sliders in the above case from [1, 10] to [1, 20] (as shown in *Figure 8*).
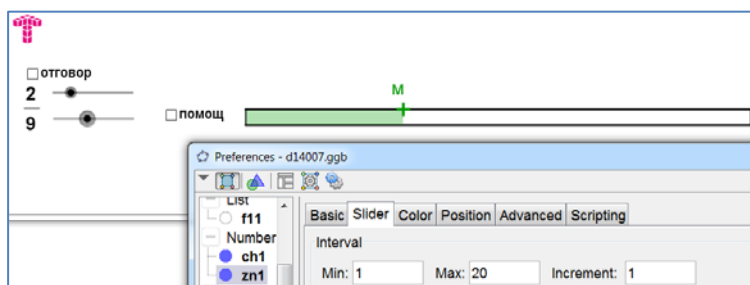
Figure 8: Modification of a dynamic file - changing the range of the parameters

Another option is to insert mathematical text in the file (several fractions in this case, such that their depiction by means of the sliders could lead to formulating a hypothesis, *Figure 9*).
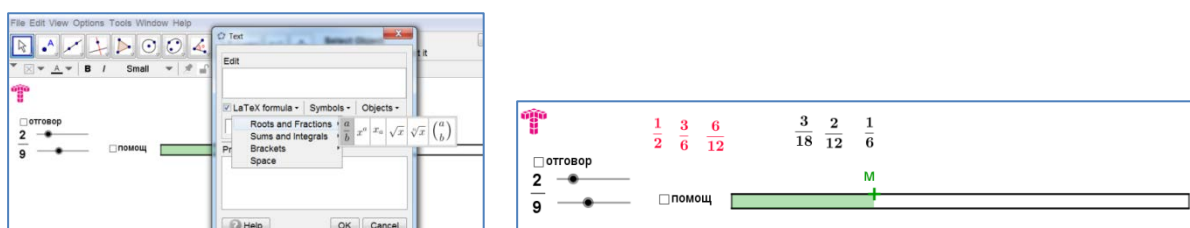
Figure 9. Modification of a dynamic file – introduction of mathematical text

The file could be modified so as to be used for solving the reverse problem – given the denominator and a colored part of a rectangle to figure out the numerator of the fraction corresponding to the colored part (*Figure 10*).

Figure 10: Modification of a dynamic file facilitating the formulation of reverse problems

The main use of the dynamic files is the possibility for explorations and formulation of hypotheses. When working files with dynamic constructions which could be investigated, it is common to perform additional calculations, to observe results, relations, measures. In such case it is convenient to show them on the screen. To achieve a better precision the appearance of the numbers might need to be tuned accordingly (e.g. more digits after the decimal point to be shown). In other cases additional constructions are helpful. Sometimes it is a good idea for the teachers to change only the design of the objects, e.g. if the constructions is to be displayed on a big screen, the lines would appear better if thicker, in a darker colour, etc.

According to our experience, to make use of the full potential of a dynamic resource developed in support of IBL the teachers should possess competencies at second level at least (modifying the files for a specific purpose).

The seminars under consideration have made use of *VirMathLab* (http://www.math.bas.bg/omi/cabinet/) and resources developed in the frames of the projects Fibonacci (http://www.math.bas.bg/omi/Fibonacci/), DynaMat (http://www.dynamathmat.eu/), mascil (http://www.math.bas.bg/omi/mascil/).

3   Other form of teacher education

Other PD forms in our practice include:

- PD events (seminars and workshops) in the frames of conferences

The key feature of these events is that the teachers have an active role and act as partners in a research team – they share their good practices in oral or poster presentations (sometimes jointly with their students), work in groups on specific tasks and present their ideas to the rest of the participants. Typical examples include the *Scientix National Conference* within the National seminar *Inquiry Based Mathematics Education (http://www.math.bas.bg/omi/nso/)*, the *Dynamic Mathematics in Education* conference (http://www.math.bas.bg/omi/dmo/), the seminars within the Spring conferences of UBM, the regional conferences organized by UBM sections, the International UNESCO workshop QED Chehlarova, 2012, Sendova, 2015.

Joint research sessions on a specific problem – e.g. face-to-face work on the *Problem of the Month* within the *mascil* project (Figure 3), possibly followed by a virtual meeting with teachers and students from the partner countries.

- Building and developing competences necessary for the students to participate in new types of mathematics contests, e.g. *Mathematics with a*

computer, Theme of the month (*Figure 11*) (Kenderov and Chehlarova, 2014), (Chehlarova and Kenderov, 2015), Branzov, (2015), Gachev, (2015).

Figure 11: "Theme of the month": a long-term activity on a math problem modeling a real-life situation

- **Mathematics performances** – events raising the awareness of the general public about the role of mathematics for enhancing children's scientific curiosity and endeavour to learn (Chehlarova and Sendova, 2013). The examples include: Performance at the History Museum in Stara Zagora, organized by the UBM section in the town, performances during the Researchers' Nights (2011-2014), Science festivals (in Italy, Romania, Greece) (*Figure 12*). It is important to note that the teachers act as multipliers of the IBL ideas during these events as well – they participate with their students, and occasionally lead the performance.
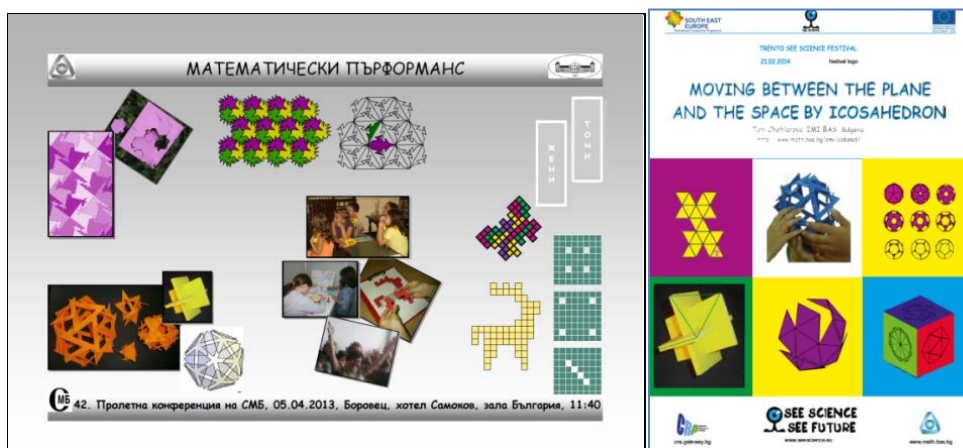
Figure 12. Posters for math performances within Science Fairs

- **Individual work with teachers** – it includes support for the development of lessons, educational materials, mathematical fests, course projects, peer reviews, and preparation of a pedagogical experiment.

4 Conclusions

Although it is early to claim that the inquiry based learning of mathematics is widely used in Bulgaria, at least we could claim that our team has contributed to creating a community of teachers who implement and spread further this style of learning.

These teachers participate in pedagogical experiments not only as a *reality-proof of researchers* but as members of a research team, implement, modify and develop from scratch educational resources in support of IBL, share their good practices at seminars and conferences, and in professional journals. Some of them organize public events at a school and regional level for popularizing the Inquiry based mathematics education, for demonstrating the connection between mathematics and the world of work.

The students' motivation, their changed attitude towards learning of mathematics, and the recognition of their achievements are just one aspect of the teachers' success. The progress students make, their raising self-confidence, the feeling that they belong to a community of learners are the crucial factor which supports and enriches the community of teachers introducing, implementing and disseminating the inquiry based mathematics education (IBME) by means of specialized dynamic software.

Here follow what two teachers (the so-called *mascil multipliers*) have expressed after getting a special recognition of their activities in implementing and disseminating IBL:

Elisaveta Stefanova: *The best is not the award itself but the fact that we, the teachers feel members of a community of soul mates...*

Neli Stoyanova: *When I decide to give problems appropriate for IBL, I don't think of the curriculum and the syllabus, I leave my students to inquire, to think, to combine, to create and to surpass me!... The award brings a great satisfaction since many colleagues expressed their wish for future collaboration, and their interest is not less important. The decision of the jury is recognition for my long-term activities, a confirmation that the IBL ideas are well-received in Bulgaria and abroad, and most importantly – that the resources developed by my students do matter.*

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Supporting the teacher role during amusement park visits: Materials, workshops and interaction

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Amusement parks are among the most popular school excursions. Through materials and workshops, universities and parks can help teachers discover the rich possibilities for physics learning in amusement parks, through observations and experiments that illustrate important physical principles and often involve the whole body. Through the organization of the amusement park science days, the threshold for educational use is lowered. In this work we have studied teacher roles and student learning in amusement park and possibilities for scaling-up. We find that event managers can encourage and support teacher roles that are known to be beneficial for student learning. In addition, by choosing a format with interactions between teachers from different schools, the sharing of ideas, knowledge and experiences can becomes an integrated part of the activities.

Keywords: amusement park physics, forces, PCK, informal learning, teacher CPD

1   Learning opportunities in an amusement park

Roller coasters and other amusement rides involve unusual motions in one, two and three dimensions. These motions often illustrate common textbook situations, such as free fall, circular motions, parabolas and pendulums, where the forces act on the human body of the rider (Bagge and Pendrill, 2002, Pendrill, 2008, Pendrill et al _2012, Bakken 2014, Pendrill, 2014)_. A teacher can make use of amusement rides for physics teaching in many different ways. Even without amusement park visits, the rides can often be used as a "previous shared experience", supported by authentic data, photos and movies to illustrate different phenomena. How the teacher chooses to integrate the visit with the curriculum, including preparation and follow-up of the visit, is known to play a large role for the learning outcome (Rennie and McClafferty, 1995). However, many factors influence if and how teachers choose to bring their classes outside the classroom (Sagar et al 2012) and it is known that other parts of the planning for the visit often overshadows the curriculum integration (Sørensen and Kofod, 2004).

Amusement park visits can be arranged during regular opening hours, but possibilities for experiments and measurements need to be negotiated, as well as access to power supplies and tables for equipment during the visit. The threshold for a visit can be lowered by making suitable data and possibly worksheets available on-line (e.g. _Bakken 2014, Pendrill, 2014._) For first-timers, a quiz and joint class focus on 2-3 familiar rides can be a reasonable level of ambition, possibly combined with a preparatory lesson on force and

motion in a playground (Pendrill and Williams 2005, Pendrill et al, 2012). With more experience, the teacher may choose to divide the class into groups of 3-6 students, focusing on 1-3 rides each and reporting back to the rest of the class after the visit. Electronic data collection is an option made easier with increased access to sensors in advanced mobile phones.

This paper focuses on teacher roles during organized science activities in an amusement park, . We have been involved in Science days at Liseberg and Gröna Lund since 2002 and 2009, respectively, as described in more detail in Pendrill et al (2013). We build on research from other informal science learning environments, including studies of teacher roles in science centers, as well as models of effective professional development for teachers (Clarke and Hollingsworth, 2002).

2 Multiple representations of forces in amusement rides

The ride experience of the body can be complemented with measurements and experiments using simple toys or mobile phones (after discussions with those responsible for rider safety). However, for minds trained to think of acceleration as a mathematical description by an observer outside the moving system, the interpretation of the resulting accelerometer data from commoving sensors can be quite confusing. In spite of their name, accelerometers do not measure acceleration but the "g-force", $(a-g)/g$, as a vector in a coordinate system that accelerates and rotates along with the rider. Trying the equipment in everyday motion and in ordinary playground swings (Pendrill and Williams, 2005) is a good preparation for measurements in amusement parks. The combination of many different representations of acceleration offers a number of qualitatively different ways of experiencing the phenomenon, and can be expected to lead to deeper understanding, that can be transferred to new situations (Marton and Booth, 1997, Airey and Linder, 2009)

3 Supporting the teachers, before, during and after visits

How do we best support teachers to make use of the learning opportunities in an amusement park? Sagar et al (2012) have investigated what barriers and requriements teachers perceive for integrating collaborations outside school into the school curriculum, and identified a number of factors, including requirements on time, school leadership, scheduling and opportunities for professional development. During the early development of science days at Liseberg, we focused on the learning and involvement of students, and found that students who were uncertain about the physics involved were often reluctant to discuss pupils' observations at the rides.

During the last few years, we have further developed the format for Edutainment days and Physics days at the Gröna Lund and Liseberg amusement parks in Stockholm and Göteborg, Sweden, building on experiences and materials from science days arranged at these and other parks. (Pendrill et al 2013). We have emphasized the recommendations to use

worksheets and encouraged teachers to divide the class in groups of about 4 pupils who focus on 2-4 different rides. The groups then report back to the rest of the class, providing a richer experience. We have found that the use of worksheets with different rides helps circumventing long queues, where students cluster on a few popular rides. An important aspect of our development of the design of Edutainment days is the emphasis on the role of the teacher, supported not only through worksheets, but also by a workshop, where teachers have a chance to get familiar with the rides, as well as sharing and discussing previous experiences from working with the material, before during and after the visit. Schools participating for the first time in the Edutainment days are required to send at least one teacher to the workshop. For the smaller Physics Days at Liseberg, e-mail addresses were collected for all physics teachers taking part, and they were assigned one hour at a ride station, together with a couple of colleagues from other schools, to discuss with all students going on that ride. Teacher instructions and dialogue suggestions (1-2 pages) for individual rides were made available before the visit and teachers did come prepared. Pre-visit e-mail contacts with all participating teachers seems to lead to increased involvement and sense of shared responsibility for the success of the day. The work continues, in international collaboration (Pendrill and Pezzi, 2013), to adjust the format to ensure that the days become optimal and enjoyable learning experiences, both for the classes, and their teachers.

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Using Blended Learning in a Math Pedagogy Course for Experienced Teachers -

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1 Introduction

This article is about a particular approach in the continuous professional development of experienced math teachers working in secondary education. This is exemplified in a course, called *School Mathematics*, which aims at further developing a rich and well-founded personal vision on math pedagogy and creating open mindedness towards innovative teaching approaches. Its development started about two years ago at the HU University of Applied Science in the Netherlands. Two student groups have participated in the course since, resulting in readjustments of the course design due to evaluations and progressive insight.

Our approach is based on a general model of blended learning that the HU is gradually implementing. However, the basic ideas are useable in any pedagogy course for math teachers as long as a rudimentary electronic learning environment is present and as long as students have the possibility to try things out in their own classrooms. Also, our approach is in no way specific to the Dutch situation.

This article addresses two of the *questions* in the conference's second track: (i) What are the features of successful, blended learning concepts? (ii) How can e-learning impart complex content that affects teachers' focal points and attitudes?

The goal of this exposé is threefold. First of all, it is about sharing ideas and, hopefully, inspiring others – we spend a lot of effort developing the course and we are quite proud of the result ourselves. Despite this, there are aspects of the design that are in need of improvement – so as our second goal, we've used the presentation to discuss some of these aspects and this led to some valuable new insights. The third goal is of a more personal nature. In the process of development, one frequently finds oneself in lack of time to thoroughly think the design through and properly reflect on things. A presentation like this is a good insensitive to do just that.

The structure of this article is as follows. In section 2 below, we will sketch the context in which the course is situated and what the course is about. Section 3 presents the first course design and our first experiences with it, which we relate to theoretical models of blended learning. Based on the evaluation and changes in the context, we are in the process of making adjustments to the course, which are described in section 4. Again we do our best to link the course description to general ideas about blended learning.

2 Context

In this section, we will describe our student population, the objectives of the course and the general approach adopted by our institute towards blended learning.

2.1 Student population and course's aims

Dutch secondary math teacher education has two stages. After the bachelor phase, students are legally allowed to teach math to students between 12 and 15 years of age and in intermediate vocational education. With a master's degree, they are allowed to teach at pre-university level. Most students, having obtained their bachelor degree, postpone their master phase and in the meantime build up experience as a math teacher. Therefore, the age of students in the master varies between 23 and 65 and most students have already a lot of teaching experience. The master curriculum involves mostly higher mathematics and educational research skills. But there is also room, albeit little, for revisiting math pedagogy and that is the topic of the course *School mathematics* we would like to present.

In our experience, participants in continuous professional development programmes have existing beliefs and practices that are often implicit and which they find hard to overcome or to think critically about. It is therefore difficult to get experienced teachers adopting new pedagogical approaches – like inquiry based learning. In particular, we notice that a lot of our students tend to focus strongly on the sole aspect of procedural fluency in the broad spectrum of mathematical proficiency (Kilpatrick 2001). Familiarizing them with other pedagogical insights or trying to convince them to adopt new approaches does not suffice. It is very important to let these teachers discuss existing and new practices, let them try it out in their own classrooms, and afterwards share experiences with each other (Swan 2011).

Although existing beliefs and practices are hard to overcome, experience shows us that many students really want to study math pedagogy – they are highly motivated. One reason is that they have just begun to teach in higher grades, so they find themselves in unfamiliar territory. Another reason is that the subject of math pedagogy feels more concrete and relevant next to courses about high-brow math or educational research methodology which are also (justly) part of the university's curriculum.

Motivation is counterbalanced by another observation about the student population: they almost all have a demanding job as math teachers and busy family lives. A query carried out this fall showed that our student's average job size is 85% of a full job – and in the 15% that remains, they are demanded to both follow lectures one day a week and to work on assignments for another day or so. Furthermore, students can live a long way from the university. Some even need to travel more than two hours to get from home to the lecture hall – and then they also need to travel back at the end of the day.

2.2 Blended learning and the HU university

At the moment, the HU is in the process of redesigning all their curricula, based on principles of blended learning. Besides providing modern education with higher quality than before, the blended learning approach is particularly suitable for the lifelong learning programme, as it makes more personalized and more flexible education possible. This is in line with recent insights and policies of the Dutch government (e.g., Commissie Rinnooy Kan 2014).

When the university adopted blended learning as strategy, there where only vague ideas of what this meant – apart from the phrase 'a mix between learning online, in the classroom, at work (or internship) and in peer groups'. This last item, the peer group, is noteworthy as it is not common in definitions of blended learning (e.g., Staker and Horn 2012). A peer group consists of 3-7 students with the goal of supporting each other's learning process (cf. Garrison and Vaughan 2008, pp. 13-69).

Our course was one of the first ones in the university designed to fit in with the blended learning strategy. Our approach towards blended learning has co-evolved with that of our institute over the past years – and this process is still going on. We will explain some ideas in the next sections. But before we do this, we would like to report a general insight that plays a central role in our thinking.
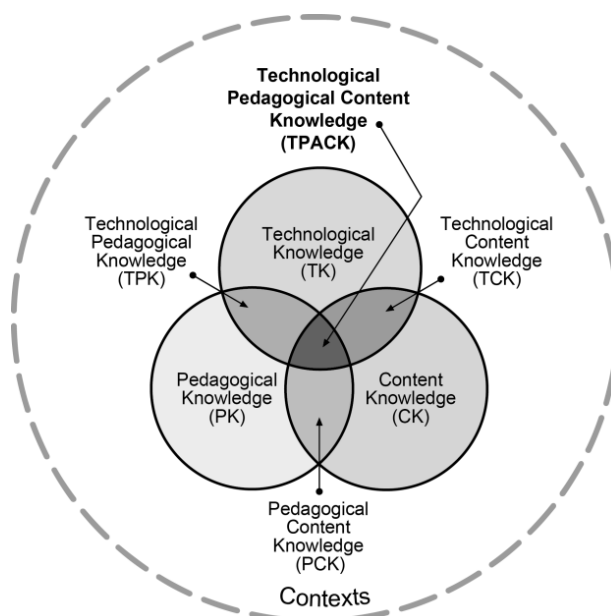
Figure 1: The TPACK framework of Mishra en Koehler. (Reproduced by permission of the publisher, © 2012 by tpack.org)

When we started thinking about blended learning, we first approached the topic from a general perspective: we tried to find a format that could be applied to all courses in the curriculum. This, however, is a dead end. The reason for this is explained by the famous TPACK framework of Koehler and Mishra (2009), pictured in Figure 1. First of all, this framework describes knowledge teachers need to have: about pedagogics, content and technology. It also

describes how these three categories are related. For a given content, the teacher chooses the appropriate pedagogical methods and technical resources. This implies that these choices are strongly depended on the content, so that any approach to blended learning that is not content-specific must either be very generally phrased or cannot be applied in all parts of the curriculum. To give a concrete example: below we will describe that the use of a forum was very effective in our course *School mathematics;* but when we used the same format in a course on number theory, the forum failed miserably.

3 First design: stretching up the learning process

In this section, we will present the primary course design, which dates from the spring of 2013 and has been strengthened and slightly adjusted in 2014. We will end this section by describing our experiences with the two groups that have taken the course and the evaluations that where carried out.

3.1 Course design

The course *School mathematics* lasts fourteen weeks. It is structured on the basis of a weekly cycle presented in the e-learning environment. Besides studying at home and at their workplace, students visit the university building once a week where a lecture room session takes places. The study trajectory is organised in a digital learning platform. We use a platform that that was developed, and still is in a process of development, in close cooperation with the teachers. (For those interested in the technical aspect: it is a platform designed by the Danish firm *Mentorix* using the open source Drupal technology.) Figure 2 gives an impression of what the course site looks like. In this text, we will describe the course only from a functional level, as the technical aspects are peculiar to the HU and therefore not of general interest.

Figure 2: Two screen shots of the digital learning platform 'HUbl' from the course School mathematics

At the beginning of the weekly cycle, students study individually. They have to study literature, such as the standard Dutch handbook of math pedagogy (Drijvers, Van Streun and Zwaneveld 2012), texts on the purpose of math education (e.g., Bramall and White 2000) and texts about innovative teaching approaches (e.g., Windels 2012 or material from the European Primas project). Via the digital platform, students are not only instructed to study these texts, but also to work through supporting materials like online videos, quizzes, etc. As a 'trigger' there is a weekly poll and students have to prepare some input they will have to present or discuss in the group session. We particularly invested in the online video material, as we wanted these to be as motivating as possible. We tried to have a video every week that was not longer than twelve minutes or so, filmed by a professional film team on locations that were both interesting to see and had a relation to the film's content.

Having finished the individual part, students came to the classroom to perform varying assignments such as discussions or making lesson plans – in this part we took strong inspiration from Swan (2011) among others. We tried to avoid 'lecturing' in the classroom, as most of the relevant information had already been presented in the individual phase. Instead, a lot of classroom activity happened in small groups – the peer groups typical in the approach of the HU towards blended learning – or in classroom-wide discussions.

Up to this point, the situation may not be different from what can happen in a traditional educational setting – except, of course, for the multimedia content which, in our experience, is an enormous stimulus for students to really put serious effort in preparing for the lecture room meeting. But in the phase after the classroom meeting, blended learning really brings in a new element. Back at home, students are asked to reflect on the discussion that took place in the classroom and to report on this in the online forum. In this forum, they are also asked to respond to at least one other student. In this way, the learning process does not end with the meeting in the classroom, but continuous in the forum where lively discussions emerge and students feel themselves obliged to really think through and motivate their observations and ideas.

Parallel to this, students are asked to try things out at their own workplace. Some students report on this in the forum, but all students share their experiences in the lecture room session in the form of presentations followed by classroom discussions. The lecture room is also the place where the teacher explicates salient points from the forum discussions, relating it to theoretical insights or new innovations. Students are graded on a few final assignments, a three-page vision document and a lesson plan being the most important ones. In these assignments, they can incorporate all insights gained during the weekly cycles.

3.2 A theoretical model

The course design seems to fit in nicely with a model described by Collis and Moonen (2001). They organise education around, in their words, a *key event*.

The key event in our course design is of course the classroom session. They divide the learning cycle into three phases: *before, during* and *after* the key event. The phase *before* the key event is about acquisition of knowledge. Furthermore, this phase has a high amount of flexibility for the student, since he can perform the learning tasks at wish somewhere in a relatively broad time interval at any location. This flexibility is also a property of the *after* phase, but this phase is no longer about acquisition, but about contribution. The transition from acquisition to contribution happens in the classroom phase, which of course has little flexibility to offer to the student. Collis and Moonen say that in the classroom you 'make the U-turn' – a metaphor that is explained by a particular visualisation of the process they present.

We would like to point out one more feature of our course design (not in Collis and Moonen) that distinguishes the *before* from the *after* phase. In the former phase, students have nothing to do whatsoever with other students. They study the material alone and all tasks are carried out without taking note of ideas of their peers. In the latter phase however, students not only have exchanged and discussed their ideas with their peers in the classroom, but they also have to delve into the ideas of their peers in the forum. So in the *after* phase, communication is taking place. But, contrary tot the classroom, the communication is only asynchronous.
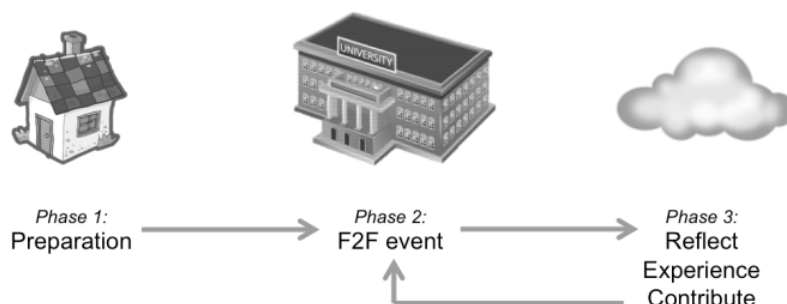
Figure 3: The basic model of the course design

Now, Collis and Moonen add something to their model that, in our opinion, is essential to the success of the model. They prescribe that in the *after* phase students contribute something to the course. Collis and Moonen give several examples of such contributions – in our course the weekly forum and the sharing of classroom experiences are the most noteworthy ones. While in Collis and Moonen's model, the contribution of a student from the *after* phase is embedded in the next *before* phase of the cycle, this is not feasible in our situation: a week between key events simply is to short an interval in our context. Therefore, we incorporate the various contributions in the cycle's next classroom session: by pointing out saillant points in the forum, by continuing forum discussions as classroom discussions, and by sharing various cases. The whole cycle is schematically represented in Figure 3.

3.3 Evaluation and reflection

The new course design has been carried out twice: in the spring of 2013 and in the spring of 2014. Both rounds, there were approximately 17 students participating (e.g., in 2014, nineteen started, but two dropped out). All students visited the classroom weekly, missing only one or two of the fourteen sessions. Almost all students participated in the forum and kept on doing this for the duration of the course. To give an impression: an average forum contribution consisted of 300 words or so and there where fourteen contributions per student (one each week), although some student contributed twice, revisiting the forum to respond to new contributions. Note that contributing was not obligatory and was not part of an assessment – although students were told that in the final assessment they had to formulate a vision on math education for which forum discussions could be a very useful training.

Our experience is that, due to the consistent weekly structure, students quickly become familiar with this way of working. Students are strongly triggered to continue, and reflect on, classroom discussions in the forum and to try things out at their own workplace. In this way, the learning process is stretched up compared to the traditional situation.

The course was evaluated the first round using standard questionnaires. The over-all course score was 8.6 (on a scale from 1 to 10, with 10 being excellent). An impartial colleague who was responsible for processing the questionnaires wrote in the report: "Extremely high scores for this course on all points of the questionnaire. The new set-up can without doubt be called a success." Besides the questionnaire, student interviews were carried out: both times in a group session and the second time also individually. This strengthened the picture: the setup was highly appreciated, with suggestions for improvements lying not in the functional design, but in particular aspects of the course content or on technical features of the online learning platform. One outcome of the evaluation was remarkable: in the first round, the appreciation of the forum dropped half way the course. In consequence, the next round of the course we explicitly discussed this with the new student group when they were half way through the course – but here the students unanimously told us to continue with the forum. We have no explanations for this.

From the teacher's point of view, the first point to notice is that student's learning was deeper and more transparent than it was before blended learning was adopted in the course design. This was mainly due to the forum and the fact that classroom time could be used more efficiently for discussion. However, it is difficult to make this 'gut feeling' objective – course grades are not a good measure since assessment requirements also changed in the redesign. What is apparent is that in reflection and research reports student's have to make as part of their training's curriculum *after* the course has finished, a richer math pedagogy appears.

On two important points, the teacher's impression was not satisfactory. First of all, too little 'learning in practice' happened during the course. An important reason for this is the short span of the course: both in between topics (usually

only a week) and for the whole course. Maybe due to this, the learning outcomes of the course fell still too much in the category 'knowing', not in the category 'applying'.

4 Adapted design: making the learning process more flexible

At the moment, we are adding new aspects to the course. The incentive for this lies partly in a changing policy towards blended learning of our institute and partly in the appearance of a new group of students who are taking the course. We will explain this in the first subsection. In the second we will describe theoretical models for this new approach, which are partially developed by us. Although this new design has not been tested with the course *School Mathematics* yet (this will happen in the spring of 2015), we did try it out in a course with learning goals quite similar in nature to the ones of *School Mathematics*. We will report on our findings in the last subsection.

4.1 Further desiderata

For the university, an important goal for adopting blended learning is flexibility for students. In subsection 2.1 we mentioned that students struggle to balance work, study and private life and flexibility on the part of their study could help them with this. But there are other important incentives, namely opening up education for potential student groups that cannot participate in the old situation. As an example, we will consider the distant Dutch province of Limburg – distant from the point of view of Utrecht, where the HU university of applied sciences is located. Although there is a shortage of teachers for pre-university level in this region, there is no institute nearby offering teacher education at this level. The HU University made an agreement with the school associations in the Limburg region to provide education in a form where students do not have to visit Utrecht on a weekly basis – but, in fact, only eight times a year. There are other parts of the country where the university is involved in similar developments.

The pitfall of economizing on the frequency of classroom activity is that the learning process becomes more individual, less social. For us, the social aspect was very important – especially for pedagogy courses. Not only is there strong evidence in the literature that deep learning is a social process (in the context of blended learning we refer to e.g., Laurillard 2002 or Reinmann-Rothmeier 2003), but we believe activity in a peer group is also an important factor in avoiding students dropping out during courses. Therefore, we wanted students to collaborate and work together weekly, despite the fact that this may not happen in the university buildings. This is the reason that the peer group is important in the blended learning philosophy of the HU.

4.2 A perspective on flexibility

Now our first design brought in no way more flexibility to students: the key event still happened at a designated moment and at a designated location. Nevertheless, adding flexibility to the first design is a relatively small step. The course is designed in such a way that lecture room sessions can happen less frequently and peer group sessions can be organised differently – e.g., in the vicinity of the student's homes, at their workplace or in an online conference. In this way, education becomes more flexible. In fact, the perspective of Limburg has been on our minds from the very start. We will now describe a new model that we adopted.

In section 2, we paraphrased a definition for blended learning as a mix between online learning, classroom learning, etc. An insight we had when thinking through the new desiderata is that we needed to drop the phrase 'online learning'. Learning takes place in four settings: individually, in the lecture room, in small peer groups and at the student's workplace – the online platform can in all four setting facilitate this. What is important for flexibility is the location and time at which learning takes places – not whether this happens online or not.
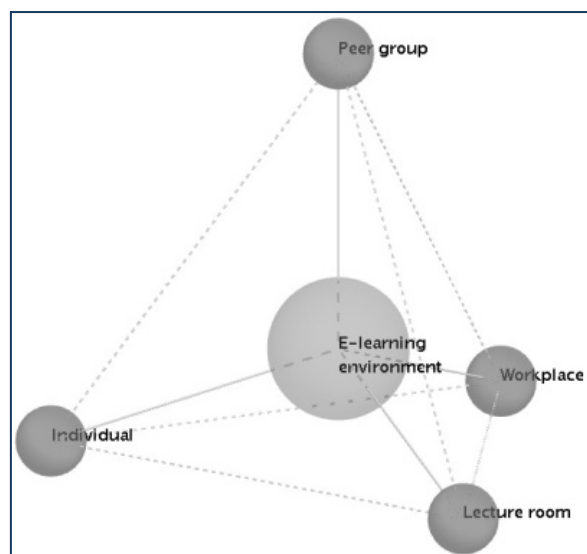
Figure 4: The tetrahedron model for blended learning

The online learning platform became for us the organiser and starting point of the course design – a role traditionally held by the classroom sessions. Traditionally, the classroom session was the key event. An educational designer distributed the learning content over the classroom sessions and placed 'homework' in between these. In our new paradigm, we started with the learning aims and distributed these over the different settings where learning takes places. No longer was there a key role for the classroom session. (This point of view underlies the design of the e-learning environment that was tailor made for the HU.) Our new model is pictured in Figure 4.

In this way of thinking about educational design, we find the curricular spider's web of Van den Akker (see e.g., Thijs and Van den Akker 2009) very useful. It is depicted in Figure 5. In the spider's web there are the aspects that need to be addressed when designing education. This leeds to questions as 'Where does learning take place?', 'With whom?', 'How does the teacher support the learning process?', etc. The metaphor of a spider's web is used to emphasize that a choice in one of these aspects (e.g., the location) influences choices in others (e.g., learning activities).
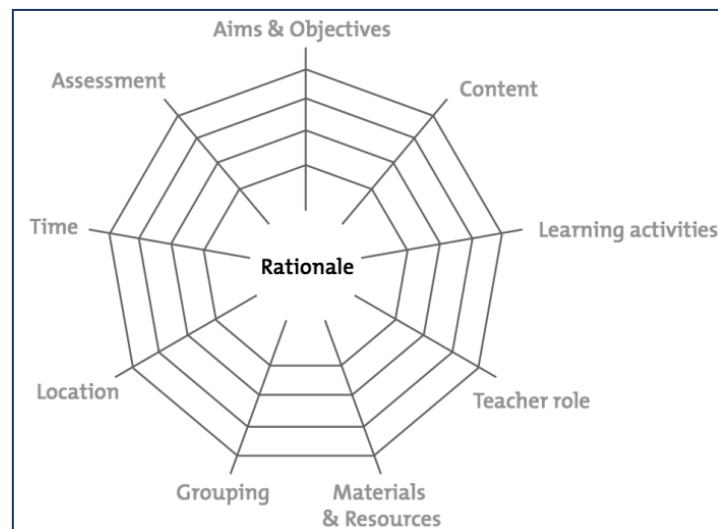
Figure 5: Curricular spider's web. (Reproduced with permission from Thijs and Van den Akker 2009)

The fact that there is not one canonical answer to the questions addressed in the curricular spider's web, is again explained by the TPACK framework mentioned in section 2. An important aspect of this framework is the context – the big circle surrounding Figure1. The answer to questions like 'where' or 'how' depends not only on the course's content and aims, but also on the context: what needs do students have? where do they live? in what way can they combine their study with work and social life? Etc.

This way of thinking leads to a new course design. In this design, we have kept the weekly cycle and the key event of our first model. This cycle is a strong and helpful guideline both for the designers and for the students. But no longer is the key event necessarily something that happens in the classroom – we differentiate, prescribing different activities for different learning settings. Students can still choose to come to the classroom, but they can also decide to meet each other in the neighbourhood of their homes for a peer group meeting, or they can have a peer group meeting 'at a distance', using modern communication technology. In the latter cases, the teacher supports the process more from a distance.

4.3 Experience

We are going to incorporate this new model when the course is carried out again in the spring of 2015. However, we have already tried out our new model in some other courses and we will report on our first findings. We will concentrate on a course about the philosophy of mathematics, since the type of content of this course is comparable to *School mathematics* in the sense that discussion and opinion forming are important.

In the course under concern, the key event involved reflecting on some difficult philosophical texts. Students were asked to discuss implications for the way they teach mathematics or to illustrate the theory with examples from the secondary school curriculum. Students were given a choice where to perform these activities: they could do it in the university building in the vicinity of a teacher, but they could also decide to do it in another form. In both cases, they had, as a group, to make a short report on the outcomes of the discussion on which the teacher provided feedback. Besides the peer group, there were also short plenary classroom meetings. They were offered in two forms: weekly, one-hour sessions – or a longer session every four weeks. In this way, it was possible to fulfil the promise that students only have to travel to Utrecht a few times each year.

This new setup has been evaluated thoroughly in two extensive questionnaires and a focus group. Working in peer groups was highly appreciated by the students and much more collaborative learning took place than in the classical situation. There were different forms of organising the group discussions. Of the ten peer groups, six decided to collaborate in the university building, immediately after the short weekly plenary classroom meetings – these, of course, where not students located in the region of Limburg. One team decided to meet at one of the member's homes. Two teams collaborated using Skype. And there was one team who had a very quick meeting after the plenary session and finished the discussion in extensive WhatsApp conversations.

From the teacher's perspective, as in our first design, the learning process seemed deeper and more transparent. Also, there where richer feedback possibilities since the teacher could give written feedback on the discussion reports, where before he only did this orally in the classroom from conversations that happened to catch his ears. On the other hand, the teacher found this way of working a little less enjoyable, as he was less involved in social interactions with the students. The teacher offered to the teams who were not in Utrecht on a weekly basis to have a weekly Skype session – in practice, students requested this only once every three or four weeks or so. Arranging 'synchronous distance contact' turned out to be difficult – not because of technology or schedules, but to make this something of added value to the student. This will be a topic of concern in the next round.

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6.3 Track 3: Disseminating and scaling-up through materials

Learning through inquiry in the world of work at Primary School -
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Introduction and objectives

There has been a big concern for many years on how to best match science education to the motivations, minds and ways of knowing of young kids. Within the international community of science educators there is also a preoccupation for the decreasing interest in science (Commission, EACEA, Eurydice 2012), which can certainly influence not only students' performance and achievement in this area, but also the potential for educating future scientists, who can lead research and innovation in our knowledge-based societies. Along with these concerns there is also an emphasis not only on knowledge acquisition but also on the development of process skills, competences and scientific practices (NRC 2012). Such practices can potentially enable individuals to use and transfer knowledge to adapt to new situations, solve problems, understand and evaluate information that is presented to them through the media, and develop lifelong learning skills.

One of the approaches that can potentially help students develop scientific practices, competences and knowledge is Inquiry Based Learning (IBL). IBL has been proven to have a positive effect on students' interest in science, the development of process skills and the understanding of key topics in science, revealing it as an adequate approach to meet current concerns and demands in science education (Minner et al. 2010). According to the National Science Education Standards "Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results. Inquiry requires identifications of assumptions, use of critical and logical thinking, and consideration of alternative explanations" (NSES, p. 23).

Based on the aforementioned, the main purpose of this paper is to discuss the issues and concerns of using IBL in primary school science. Specifically, the discussion will focus on the following question: Do primary school students have the matureness and capacities required to engage in IBL processes?

The former question gets even more challenging when IBL is introduced in real world contexts, where there is a need to simplify and model situations in order to be able to solve problems.

mascil stands for Mathematics and Science for Life and is the acronym of a Seventh Framework European Project which intends to improve science and mathematics learning through making connections with professional settings. The main goal is bringing a sense of purpose and meaning in the mathematics and science to be learned through the use of IBL tasks, which offer opportunities to apply science and mathematics to solve problems in the world of work (WoW).

This paper intends to raise debate on whether IBL and WoW can be successfully integrated into primary school and identify specificities, obstacles, opportunities and challenges for using these approaches with young students. In order to do so we will analyse evidence from the specialised literature and discuss the potential of some mascil tasks for Primary School Education.

Is scientific inquiry within reach of young children?

Cognitive developmental theory, particularly Piaget's stages of logical-mathematical structures have had a huge impact of the science education community. According to this theory children within the first six or seven years of school would experience serious limitations for formal thinking.

However some authors argue that Piaget offers a theory on development not on learning and therefore, it does not consider how children's development can be influenced by effective instruction. Conversely, educators need a theory that describes how children can think and what children can understand, provided meaningful contexts, cognitive collaboration, communication and scaffolding (Metz, 1998).

A review of the specialised literature on the use of inquiry processes with young children shows that by seven years of age, kids understand the goal of hypothesis testing (Sodian et al. 1991) and grasp a number of scientists' metaconceptual criteria for theory selection, including range, empirical consistency and logical consistency (Samarapungavan 1992). Other works show that children's theories resemble scientific ones in the sense that they: transcend what is concrete and directly perceptible; are internally consistent from the child's perspective; frequently involved an attempt to integrate different sources of information e.g., what they have heard from adults and their own observations; and have exploratory power (Brewer and Samarapungavan 1991).

Metz (1998) also reviews some works that show how children can make sense of key science concepts through guided inquiry and highlight the key role of cognitive collaboration and scaffolding in students' achievement though IBL pedagogies.

Recent studies also reveal a positive impact of IBL at early ages. Samarapungavan et al. (2008) have carried out a comparative study on the use of IBL in kindergarden. Statistical analyses of data indicate that the intervention group showed significantly better understanding of scientific

processes and on important science concepts than the control group, which did not go through an IBL intervention (Samarapungavan et al. 2008).

Opportunities and challenges for bringing the world of work into Primary School

The reason why authentic setting are important and the reason why authenticity is receiving so much attention arises from the recognition that the knowledge and skills that learning activities produce are closely tied to the situation in which they are learned (Edelson, 2003).

Learning tasks set in the world of work offer powerful opportunities for developing meaningful and situated learning increasing students' motivation. Research findings show that students experience and understand the functionality, purpose and utility of disciplinary knowledge in the workplace (Ainley et al. 2006, Dierdorp 2010, Mazereeuw 2013).

However, although engaging students in IBL tasks situated in the world of work is a promising approach to improve science education, there is a strong concern about the low level of domain-specific knowledge that students possess at primary school.

In this paper we will describe an experience, which has addressed these challenges and successfully combine IBL and the WoW to enhance science learning at Primary School.

A successful experience: Decision making on a local environmental problem

Teachers taking part in a mascil professional development course in Cyprus were invited to design tasks, which offered opportunities for inquiry on real context. This paper focuses on one of the tasks designed and implemented by a participant teacher. The main purpose is to use a concrete experience to illustrate how these approaches can be satisfactorily introduced at early ages.

The task chosen encouraged students (10-12 year old) to inquiry and search for an optimal solution to a local problem: an excessive amount of mosquitoes in the area close to a salty lake.

First of all the teacher was asked to design, reflect on and discuss a lesson plan in order to become aware of the desired learning goals and the most appropriate way to subtly guide students to these aims. This activity also allowed the teacher to think of time and classroom management issues and to anticipate to their potential students needs. Table 1 presents the lesson plan proposed. Figure 1 shows a photo of one of the models built by primary school students to study the local problem.

Students' answers were recorded in order to analyse the impact of the experience. Several quotations are offered below to provide some evidence about students' motivation and the development of a sense of ownership and empowerment:

"I really liked the fact that <u>we tried all together</u> to find the best solution and we worked in groups" (Student aged 16, boy)

"I liked that <u>we went to the lake and experienced the real phenomenon</u>" (Student aged 18, girl).

"I liked that <u>the local councillor listened</u> to our solutions and what we had to say. She might not be able to do something about the problem herself but at least she listened to what we did. I understood how these people work" (Student aged 18, girl).

"It was not a lesson from a book, it was great that <u>we studied the theme in depth</u>; we discussed many details for each organism" (Student aged 14, girl,).

"I liked the fact that <u>we were free to find our own solution</u>"(Student aged 14, girl).

Lesson	Activities	Key issues
Lesson 1	Introducing the problem: What is the best solution to decrease the amount of mosquitoes in our local area? Students work in groups and proposed a working plan	To promote motivation and engagement
Lesson 2	Each group presents and explain their proposal Discussion, argumentation and decision making on possible solution: Chemical spraying Biological spraying to kill mosquito larvae Introduction of new species Genetic modification of mosquitoes	Facilitate students' empowerment Promote discussion and argumentation on benefits and cons associated to each solution
Lessons 3-5	Visit to the salt lake to study the ecosystem of the area and facilitate the understanding of the underlying problem	Guide students towards profitable ways of working and investigable issues
Lessons 6-8	Students worked in their groups, and built a three dimensional physical model of the salt lake to represent the data gathered. They present and explain their model to the rest of the group, justifying their decision making	Draw attention on the role of models to represent and study phenomena
Lessons 9-10	Students worked in their groups, using their model as a visual aid to help them understand the effects of the proposed solutions, and for each proposed solution, to argue either for, or against.	Value evidence-based and justified decision making
Lessons 11-12	Each group presented their model, justifying the solution chosen, and had the opportunity to challenge other groups' solutions.	Promote the communication and discussion of results and the evaluation of alternative solutions
Lessons 13-14	A municipal chancellor visited the class. Firstly, each group presented the proposed solution through their models showing possible effects and justifying their choice. After the presentations the municipal chancellor asked questions about the effects of each solution	Students developed a sense of ownership and empowerment and contribute to the search for solutions with a final product

Table 1: Lesson plan for the task 'Searching for solutions to an excessive amount of mosquitoes in a salty lake'

Figure 1: Model for studying different solutions to an excessive amount of mosquitoes in a salty lake

Final considerations

Further analyses and reflection on the experience above described, highlight the potential benefits associated with the implementation of inquiry in real world contexts at elementary school. These approaches promote a positive attitude to science learning, engage students in scientific practices and promote an adequate view of the nature of science. They also support the development of process skills and the critical use of information. Inquiry and searching for solutions provides also opportunities for understanding and meaningful application of knowledge. Other benefits are related to introducing students to uncertainty and decision-making and prepare them for real life.

In spite of the constrains and challenges associated with the introduction of inquiry and the world of work into primary education, the present experience shows that appropriate teacher training can result in successful use of these approaches.

Acknowledgements

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An IBL application from the inside -

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Abstract

In this contribution we present our experiential application of an Inquiry-Based Learning (IBL) activity from the perspective of prospective teachers. In this innovative way of teaching, students are required to engage, explore, evaluate and collaborate. Moreover, a teacher has to value and build up on students reasoning and also connect to students experiences (Artigue and Blomhøj, 2013). Based on the above, we designed a teaching intervention in the mathematical field of geometry. The project was inspired from the initial task "circular pave-stones backyard" in mascil website. More specifically, students had to deal with a packing problem in which they had to discover and prove the best way to cover a yard using circular paving stones. After the implementation took place, questionnaires were given to students in order for us to see their point of view about this IBL experience. In this paper we display our involvement in the process of selecting, modifying, applying and analysing such an intervention in a classroom, as well as to examine the involvement of students during this activity. In addition, we aim to present the evaluation of this IBL activity through students' eyes.

1 Introduction

This project is an experiential application of an Inquiry-Based Learning (IBL) activity, and it was designed and conducted from the perspective of prospective teachers. Specifically, during our master's course in 'Research in Mathematics Education' we worked in a team of four postgraduate students in order to design a teaching intervention that was research-based and promoted an innovative way of teaching. In this paper, our aim is to display our involvement in the process of selecting, modifying, applying and analysing such an intervention in a classroom, as well as to examine the involvement of students during this activity. In addition, we aim to present the evaluation of this IBL activity from the students' point of view.

2 Theoretical considerations

In the beginning, we present our view of IBL, emerging from our readings. According to Confrey and Sibel (2006) "Mathematical ideas are fundamentally rooted in action and situated in activity". Maaß's and Artigue's view of IBL is that it describes "a more student-centered perspective for learning mathematics and science that promotes a learning culture in which students are invited to work in ways similar to how mathematicians and scientists work" (Maaß and Artigue, 2013). In this frame, the culture of the classroom differs from the traditional one, as students are required to engage, explore, evaluate and collaborate (Artigue and Blomhøj, 2013). Concerning the role of the

teacher, he has to value and build up on students reasoning and also connect to students' experiences. For this purpose, carefully designed classroom tasks could be a lever for a meaningful accomplishment of an IBL activity. A very important recommendation for the design of such activities is the use of open questions that provide multiple solution strategies (Artigue and Blomhøj, 2013). In these terms, as Perso (2003) suggests, students learn better by observing, imitating, and through trial and error.

3 Transforming and conducting a Mascil task

3.1 Phase 1: Designing the intervention

In the design phase of our implementation, we selected a task from the Mascil classroom material. Taking into consideration factors such as available time and classroom constraints, we modified the initial task and designed our own intervention. Our changes were influenced by our readings on the characteristics of an IBL activity, as they were pointed out in our theoretical framework.

3.1.1 The activity

The initial activity was the "Circular pave-stone backyard" from the Mascil classroom material, which concerned the covering of a backyard with circular pave-stones so as to leave the minimum uncovered area. The modifications we applied were that we used hand-on materials, we recasted some of the questions and we added an extra sub-question. Here, we present some examples of the adjustments we made. The first question of the initial task was: "We will use coins to model the pave-stones. Study the two different orderings of coins in the last two pages. In which of the two orderings do you think that the coins leave less empty space? Discuss.". In our intervention, the students were given different kinds of circular discs and a piece of paper, and were asked to experiment in pairs in order to discuss in which way they could order the discs. Deliberately, we gave the students circular discs of different sizes and asked them if the radius of the circles affects the choice of the preferable ordering. Also, at the initial task, the second question was: "Focus on the centers of the coins. For each of the two given orderings, design repeating polygons to cover the whole space". Right after, in the third question they were being asked to "calculate the percentage of the surface that is covered by the coins for the various patters for the two orderings that they created" and to "interpret their findings". At this point, students should find the smallest repeated polygon so they could come to an answer. In this direction, we added an extra subquestion between the two questions, where we asked them to find the smallest repeating polygon that is created for each of the ordering. Our intention was scaling up and to help the students to answer the third question. The final activity is attached at appendix.

3.1.2 The classroom management

In the same context, including our theoretical considerations and the available time and classroom constraints, we organized the classroom management. Furthermore, we decided that the activity would be conducted by all four of us, circulating around the classroom and helping students to overcome their existing obstacles. Moreover, our intention was to keep our guidance as restricted as possible. Concerning the way we would like students to work, our plans were to divide theme in groups of two at the first task and at the rest of the activity in groups of five. Furthermore, in order to encourage the communication and collaboration among the students, we planned to engage twice the whole class in lively discussion. In these two discussions, along with our guidance, the students could comment on and compare their findings among each other's. The aim of the discussions was, also, to help the students connect the findings of each different task of the activity.

3.2 Phase 2: The intervention

3.2.1 The context

In the context of the intervention, 32 students participated, 10 of which were boys and 22 were girls. All students were 16 years old and studied in a Greek high school with a good reputation. The intervention lasting 2 hours and was conducted during the course of Geometry in March, 2014. In addition, all basic concepts needed on part of the students for the facing the task had already been taught.

3.2.2 Description of the activity

In this particular activity used, students must work as architects/ or designers of exterior places and cover a backyard with circular pave stones aiming to find the configuration with the maximum density. The required knowledge here is the calculation of the area of various shapes (polygons, circular discs). The activity starts with the following introduction:

"You work as an architect/designer of exterior places. Your client has a rather difficult taste: he doesn't like vertices; therefore he would like his backyard to be covered with pave-stones in the shape of circular discs. He also wants the pave-stones to cover the maximum possible area, so as the grass that grows between the stones is as few as possible. Your job is to find an ordering for the circular pave-stones, that leaves the minimum possible empty space between them."

3.2.3 The activity

3.2.3.1 Task 1

"In which way could the architect order the circular pave stones? Experiment with the given objects."

At this first task of the activity students worked in pairs. The objects were one sheet and some circular objects such as coins and other kinds of discs, per pair. Here, it was important that the given discs were not enough to cover the full area of the sheet. Also, different pairs of students were given differently sized discs.

The purposes of this first task were for the students to use their intuition in order to discover the two desired orderings which were going to deal with in the rest of the activity (Figure 1). We wanted them to generalise these two orderings and make the conjecture of the best one between them.

Figure 1

Figure 2

The findings here show that students experienced difficulty in making the generalisation (Figure 2). For example, one student characteristically said: *"I suppose we don't have to cover the whole thing. We can't. They are not enough!"* They also deviated from the required, due to the fact that they believed they could decorate the yard as we do in real life. So they made houses, lakes, rocks, doors, flowers etc., as a student said here: *"I did it that way so that the yard looks nicer!"* (Figure 3).

Figure 3

At this point, the first classroom discussion was conducted, where two conjectures were expressed. The first conjecture was about size of the disc

and what part it plays in the covering. For example, one student here wrongly thought that *"With the small discs you get better covering, on the other hand with the big ones you get bigger gaps between them."* The second conjecture was about which of the two orderings they found was the best. Here, we did not ask for any justification on part of the students, as we only wanted to use their intuition.

In order for the students to encounter the remaining task of the activity, they were instructed to work in groups of five.

3.2.3.2 Task 2

" i) Focus on the centre of the coins for each one of the two orderings, draw repeated polygons in order to cover the entire surface.

ii) For each ordering find the smallest repeated polygon you can draw based on the sub-question (i)."

Through this task we anticipated from the students to design various patterns which would be generated by the repletion of a polygon. Furthermore, sub-question ii) was added in order to motivate students to investigate and discover the smallest geometrical unit. In the first ordering the smallest is a right-angle isosceles and in the second an equilateral triangle. This sub-question was added in order to facilitate the transition to the remaining tasks.

As far as the findings concerned, many students encountered difficulties to generalize to infinity. Here is a quote from a student that demonstrates this difficulty: *"So now we need to make triangles across the whole area? Are they crazy? I feel tired already."* Finally, some students managed to generalize to the infinity and characteristically commented: *"Okay, let's do the first 2 lines anyway because the same pattern is repeated then!"* and referring to the first ordering: *"Triangles. Every three is a triangle. And so the entire surface is covered."*

The following pictures are examples of the successful answers of some students. In other words, a group drew hexagons, focusing on the center of the coins, and found the smallest geometrical unit, which in this case is an equilateral triangle (Figure 4). Moreover, another group of students drew squares and concluded that the smallest geometrical unit is a right-angle isosceles (Figure 5).
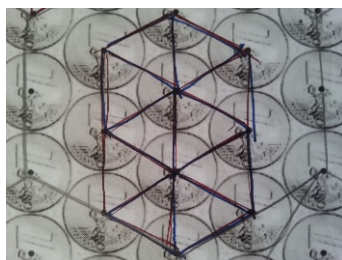
Figure 4
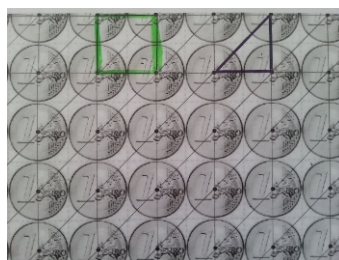
Figure 5

Last but not least, some students got carried away and drew all the possible polygons they could imagine and observed that all of them could be repeated, so they could become a pattern (Figure 6).
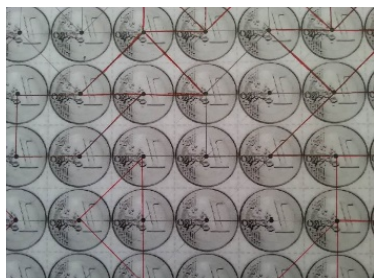
Figure 6

When all of the groups managed to complete, successfully or not, the second task, we continued with the rest of the activity, where each group coped with only one pattern, in only one ordering.

3.2.3.3 Task 3

"Calculate the percentage of the area that is covered with coins for the previous various patterns in each ordering. How do you interpret your findings?"

This task was aimed to study the transition from the percentage of the covering of a surface to the areas ratio. At this point, because the students experienced difficulties to make the transition from the percentage of the covering to the area ratio, too much time was consumed. Furthermore, some students failed to recognize that within the polygon lies an entire coin. In order to overcome these difficulties our guidance was inevitable, especially in order for them to find the percentage. Here we quote an exemplary dialogue, where one of us tried to help a student and said: *"If I ask for the ¼ of the area of the table, what would you do?"* and the student spontaneously responded: *"I would do subtraction. It is 75%."* When, after too much effort the groups completed the task, they confirmed the second conjecture by comparing the two ratios. Here, they could, as well, recognize which is the best ordering.

At this point we gathered the findings of each group (Figure 7) and encouraged a second conversation with the whole classroom. Here, the students came to the conclusion that the coverage percentage does not depend on the different patterns but on the kind of ordering. Moreover, they commented on whether the radius' size influences the covering. So, a student, who is characterized from his teacher as weak and uninterested in mathematics, called enthusiastically: *"The radius is simplified, so we don't care if the discs are smaller or larger!"*
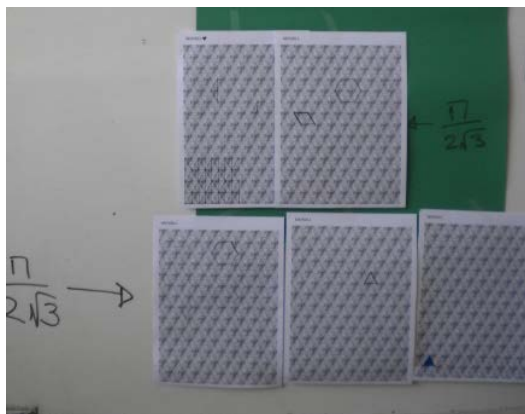
Figure 7

3.2.3.4 Task 4

At the final task of the activity, students should use the outcomes of task 3 in order to prove which ordering is the best. Specifically, the question was: "*Given the following pictures, compare the areas of the square and the rhombus, which have equal sides. According to the previous results, answer the question: Which of the two given orderings is the best?*"

Figure 8

At this point, the students have to find and compare the areas of the two polygons. Moreover, they have to recognise that inside of each polygon there is a whole coin. So, they can conclude that the less empty space between the coins exists at the case of the rhombus.

As we said the purpose of this question is to examine if the students are capable to reorder the coin and to compare the two geometrical figures in order to prove the conjecture of the best ordering. Moreover, we would like to see if they are going to use the outcomes of the previous questions.

Surprisingly, the majority of the students did not find any difficulty solving this part of problem. All the groups came to the result very quickly. Moreover, we had prepared some hand on materials whose purpose was to help the students if they would face difficulties, but finally there was no reason to use them.

So, the initial conjecture was verified and the best ordering was discovered!

3.2.3.5 Task 5:

"Could you transform or adjust this problem? Think of similar problems, cases or situations."

At our initial design of our task we had included this extra question. At our initial design of our task we had included one more question. The purpose of this question was to examine whether the students are capable to generalise their findings and to transfer them in a different frame. Unfortunately, there was no time to examine this question properly. Although, a group answered "Oh! Now, I know how to put the cookies at the oven in order to fit more."

4 After the Intervention

At the last phase of our project we would like to examine the student's view of our intervention. We wanted to see which factors of IBL the students will point out and criticize.   For this reason, we designed an open ended questionnaire of four questions which was distributed two days after the intervention, without our presence. The questions were the following:

1. What did you like and what did you not like about the activity?

2. What did you think of the four prospective teachers?

3. What you would change in the way the lesson was conducted?

4. Did you learn anything from this whole experience?

After we collected the answers, we firstly categorized them in benefits of IBL and negatives. Secondly, we grouped the answers according to the specific factor was highlighted in each one. Surprisingly, some noteworthy answers were recorded.

The analysis of students' answers showed that the majority of students found the activity really enjoyable and meaningful. Some of the characteristics they considered as benefits of the IBL activity were the use of hands-on materials, the group-collaboration, the strategies they developed in order to solve the problem, their self-evaluation and the connection with the real world. Specifically, in the question: "What would you change in the way the lesson was conducted?" a student's answer was: "I wouldn't change anything, because it was an original and creative lesson that combined playing with learning and thinking […] in a casual manner and allowing us to feel free to solve the problem through collaboration." Another typical answer to the question: "What did you like and what not?" was: "The technical support (i.e. hand-on materials, rulers, piece of papers, markers) made the lesson more vivid and fun. It was very interesting that they guided us in a way that we drew our own conclusions and found the answers." At this answer, it is mentioned, also, the effect that our limited guidance had. Furthermore, in the question: "Did you learn anything from this whole experience?" one answer was "Personally, I learned that geometry is part of our live and so we should know the basics. I, also, learned all the steps needed to solve a problem."

Moreover, they pointed out that this activity allows the combination of their pre –existing knowledge with the new one. "I learned in which way I had to find previous knowledge and how to combine all these in my mind in order to accomplish my purpose. Moreover, I learned the meaning of the cooperation and the exchange of ideas with my classmates." According to this frame, they mentioned that it was very interesting that the procedure of learning was experiential and that they had the opportunity to experiment and explore. At last but not least they pointed out the engagement of the weak students during the lesson. Specifically, at the question: "Did you learn anything from this whole experience?", a student's answer was: "We learned that while some of us neither have great interest of the subject, nor are good at it, they still can use their general knowledge and help a lot the others."

On the other hand, the break of the didactic contract is a challenge that someone has to deal with. Students' answers pointed out that our limited guidance was crucial and time management was a challenge. For example, in the question, "What would you change in the way the lesson was conducted?" an answer was: "I would prefer that the teachers had expressed their opinion for the tasks." Another significant answer to the question, "What did you think of the task?" was: "Brilliant, it helped a lot, but it is not practical. A 45 minutes lesson cannot be done this way."

5 Conclusion

5.1 Reflection

In conclusion we are going to present our thoughts after the end of the intervention that mostly refer to our initial design of the task. First of all, we had some second thoughts about the realistic character of the problem and the circumstances under which can a similar problem be solved in the real world. Also, a very interesting point is that students found it hard to understand what tasks required although we thought it was clear. Finally, we had a great difficulty to keep to the initial time schedule.

5.2 What we saw as prospective educators

Finally, we are going to present what we saw from the perspective of prospective teachers. First, we saw in practice what we read in theory. This implementation was a persuasive experience for all of us considering that working as professionals can be very engaging for pupils who are interested and those who are not so interested in mathematics. Last but not least, we all feel that is urgent to answer the following questions are urgent. How can we integrate an IBL activity in a traditional classroom? How can we overcome the curriculum constraints? We think that the task management required more than one teacher. Was the problem our lack of experience? Or was it the nature of an IBL activity?

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"You work as an architect/designer of exterior places. Your client has a rather difficult taste: he doesn't like vertices; therefore he would like his backyard to be covered with pave-stones in the shape of circular discs. He also wants the pave-stones to cover the maximum possible area, so as the grass that grows between the stones is as few as possible. Your job is to find an ordering for the circular pave-stones, that leaves the minimum possible empty space between them. "

Task 1

In which way could the architect order the circular pave-stones? Experiment with the given materials.

Task 2

Focus on the centres of the coins. For each of the two given orderings, design repeating polygons to cover the whole space.

For each of the ordering find the smallest repeating polygon that is created, based on the subquestion

Task 3

Calculate the percentage of its surface that it is covered by the coins for the various patters for the two orderings that you created above. How do you interpret your findings?

Task 4

For the following figures, compare the areas of square and a rhombus that have equal sides.
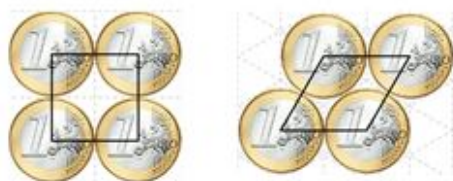
Based on the above outcomes, answer to the question: ''Which of the two orderings is better?''

Task 5

Could you transform or adjust this problem? Think of similar problems, cases or situations.

Science and Maths by inquiring about the image size in a camera obscura -

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1 Introduction and objectives

Our line of research[1] is based on IBL strategies applied to practical work as part of science teacher education. The present communication describes an activity carried out by prospective primary teachers as part of the unit "How can one learn through inquiry? In the context of a school inquiry into the camera obscura, it is shown how the students are encouraged to review their hypotheses using qualitative arguments, and a proposal is made for them to go deeper into that review using more quantitative approaches. The initial goal was for them to reach a result that possibly contradicts the first hypotheses. This expressly fosters the process of reformulation and the search for new explanations that can reconcile theoretical predictions with experiment. All this takes place within an activity of school IBL about the characteristics of the projected image in a camera obscura in which the students will find that, in some cases, one does not appreciate the expected change in size of the image when the depth of the camera is increased.

2 Methodological aspects (implementation and instruments)

As an example of IBL being initiated due to the existence of a question without an immediate answer, the students are grouped into teams of 4 to inquire into the following problem:

"What will be the characteristics of the image seen in the camera obscura?"

To delimit the problem, and focus the students' attention on the variables of interest, they were asked about the lighting, sharpness, and image size. We shall here focus on how this last variable (image size) depends on several characteristics.
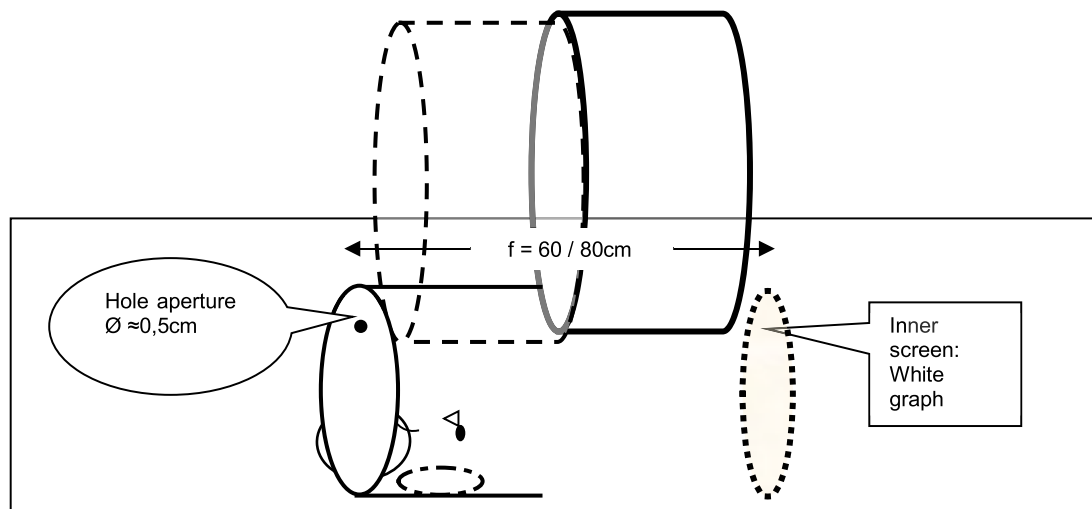
Figure 1: An observer, holding the camera made of black cardboard in their hands, has put their head inside.

The class IBL activity consists of the following phases:

I.   The proposal put to the students is for them to construct a camera obscura (Figure 1) for which they are given precise instructions, (Criado et al., 2007), reinforced with the help of an educational video[2].

II.   They are next asked to formulate their hypotheses in writing. This orients them towards considering factors that may affect the image's characteristics. They then consult a document on how the camera obscura works (Criado at al., 2007), revise their hypotheses, and prepare a table for data collection.

III. They then make empirical observations with the camera, and log the data in a table. They are asked to include observations made outdoors, viewing nearby buildings and a classmate.

IV.   With the data they collected, each group writes up a report, completing the tables by relating the hypotheses to the results (both definitive and inconclusive), and ending with a summary of the conclusions.

V.   The groups' results and conclusions are pooled, the differences found are discussed and analysed, and a revision is proposed for those which are most divergent.

VI.   For the case of how the depth of the camera affects the image size, the students are provided with another document (Figure 2) as support in their revision of their hypotheses, and a new brief experimental session is proposed to make the necessary checks.

3 Results

The students' hypotheses

In their first response to the problem, the students' commonest beliefs about what factors will influence the size of the image were, in this order: (i) the distance of the object, (ii) the depth of the camera, and (iii) the aperture. Once

they had written down their hypotheses, they consulted the documentation (which included Figure 2a connecting image size with depth of the camera). They then revised the hypotheses before going on to test them empirically. Their comprehension of the figure either supported their predictions or helped with their modification. The presumption that the diameter of the aperture might affect the image size had to be discussed in terms of an imperceptible influence.

The empirical verification and pooling of the groups' results

The students observed in practice that they did not always get the results they anticipated from the document they were given to consult. In pooling their results, there was no unanimity: some groups state they clearly saw the change in size of the image, and others not.

Looking deeper into their conditions of observation, different situations emerged. Some had made a camera that could only be extended 5 or 6 cm, while others to 20cm following the instructions. In other cases, one had to distinguish between observing a classmate 2m away and a far more distant building.

Revision of the hypotheses

The instructor encouraged the students to put forward an explanation of these results. Someone always realized that certain conditions must be met for extending the camera to produce a perceptible increase in image size. With blackboard drawings made by volunteers, the importance of the proportions between the dimensions of the variables involved was discussed. It was then understood, for example, that the change in image size will be small if the object is the building that is fairly far away. Following this pooling of results, to extend the information provided for their consideration, the students were provided with the qualitative description in the second consultation document (Figure 2b).

New empirical evidence, following review of the hypotheses

With this information, the groups were able to do their last empirical tests and thus verify the evident change in image size when they watch a classmate who changes their position from 2 to 4 m distant from the camera. But with the latter distance, if the depth of the camera is altered by only 5 or 6 cm, no changes are appreciated in the image size.

a) The image size in a camera obscura increases with increasing camera depth. (1st Revision of the hypotheses)

b) Sometimes, no increasing of the image size is observed. ¿Why? Check the change in image size, and the relative proportions between the depth of the camera, the size of the object, and its distance: when the "distance"/"object size" ratio is very large, elongating the depth of the camera has little effect on the image size. (2nd Revision of the hypotheses)

Figure 2: Consultation documents (a) and (b) on changes in image size on changing the depth.

4 Quantitative inquiry

The next problem proposed to the students was for them to record specific numerical data, and to predict under what conditions a change in the size of the image would be observed on modifying the depth of the camera. Depending on the difficulties that the students showed in this respect, the problem was further delimited with a progressive contribution of further information until they were able to reach a conclusion independently.

In a *first phase*, they were given Figure 3 with the relevant variables of the problem[3], leaving the angles unmarked until the next phase. In this *second phase*, they were required to use their knowledge of symmetry, trigonometry, similarity relations, etc., so as to be able to conclude that the parameters they had discussed before satisfied the following relationships:

$$H / D \ = \ h / f = \Delta h / \Delta f \qquad\qquad (I)$$

In a *third phase*, it was indicated to them that if the concentric rectangles on the camera screen have a 1-cm spacing then one can set the minimum appreciable size difference to that value. I.e., for the dimensions of our camera (depth, $f = 0.50$ m, and its increment, $\Delta f = 0.30$ cm), to be able to appreciate a 1-cm increase in the size of the observed object, one must have that:

$$\Delta h \geq 0.01m$$

The problem to solve now is therefore:

"What relationship must there be between the distance and the size of the object?"

To address this, the students can construct a table on a spreadsheet program such as Excel, with the actual values of the distances (D), of the characteristic parameters of the camera (f and Δf), and of the half height (h) and its increment (Δh) in the image. They can then make the checks needed to test

their hypotheses. Tables 1 and 2 are two examples of how this can be done. With the problem now reduced to the equality of the first and last fractions of Equation (I), one reaches the conclusions drawn from the values in Tables 1 and 2. I.e., for the change in the image to be perceptible when the camera is lengthened by 0.30 m, the ratio between the size (H) and the object's distance (D) must be:

$$D \leq 30 \cdot H$$
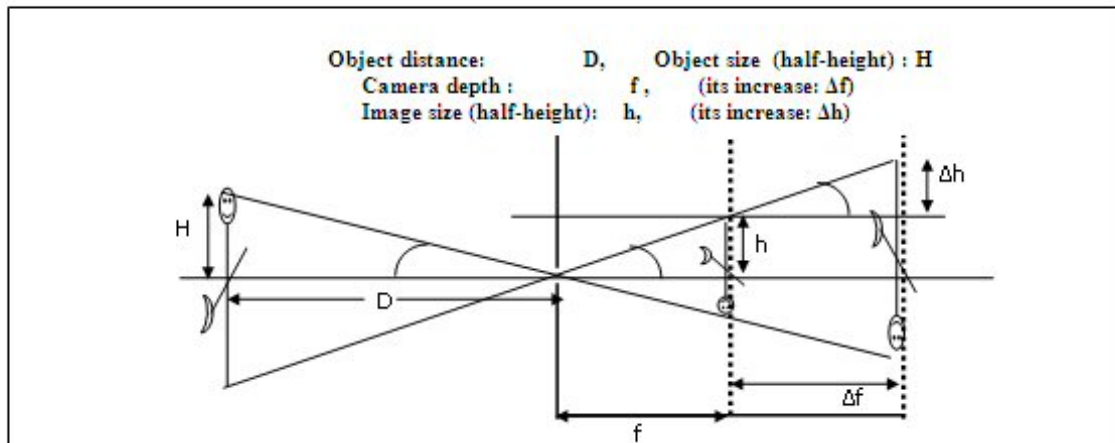
Figure 3: Parameters involved in the camera obscura image size.

Table 1: Calculation of the distance (D)/height (H) ratio of an object, so that an elongation ($\Delta f = 0.30$ m) of the camera produces a noticeable change ($\Delta h \geq 0.01$ m) in the image. The object is a person whose torso is H = 0.5 m.

D(m)	h(m) Image height when f = 0.50 h= H · f/D	h(m) Image height when f = 0.80 h= H · f/D	Δh(m) calculated as h(0.8)-h(0.5)	Δh(m) calculated as Δh=Δf · H / D	D / H
2	0.125	0.200	0.075	0.075	4.000
4	0.063	0.100	0.038	0.038	8.000
10	0.025	0.040	0.015	0.015	20.000
15	**0.017**	**0.027**	**0.010**	**0.010**	**30.000**
20	0.013	0.020	0.008	0.008	40.000

Table 2: Calculation of the distance (D)/height (H) ratio of an object, so that an elongation ($\Delta f = 0.30$ m) of the camera produces a noticeable change ($\Delta h \geq 0.01$ m) in the image. The object is a one-storey building (H = 4m).

D(m)	h(m) Image height when f = 0.50 h= H · f/D	h(m) Image Height when f = 0.80 h= H · f/D	Δh(m) calculated as h(0.8)-h(0.5)	Δh(m) calculated as Δh=Δf · H / D	D / H
10	0.200	0.320	0.120	0.120	2.500
50	0.040	0.064	0.024	0.024	12.500
100	0.020	0.032	0.012	0.012	25.000
119	0.0168	0.0269	0.0101	0.0101	29.7500
120	**0.0167**	**0.0267**	**0.0100**	**0.0100**	**30.0000**
121	0.0165	0.0264	0.0099	0.0099	30.2500
140	0.0143	0.0229	0.0086	0.0086	35.0000

5 Final assessment and expectations of the proposal

Although we have only presented the characteristics of the study with prospective primary teachers, the proposal can also be implemented for secondary education. In this activity, students learn in a natural integrated form: conceptual and procedural content of Optics and Mathematics; the use of a spreadsheet; the development of attitudinal IBL objectives; and the design of technological artefacts. In sum, they learn the practice school IBL processes, and, most importantly, they acquire a good attitude to inquiry in the classroom.

Endnotes

[1] This work is associated with the Curricular Project Investigating Our World [Investigando Nuestro Mundo, INM6 -12], designed by the GAIA research group (HUM133).

[2] Domestic recording (5 minutes) of the series Beakman's World, TV Series Directed by Jay Dubin.

[3] In the figures, there are various simplifications that do not conform to reality (such as the object and aperture located on the optical axis). Therefore, the conclusions will only be a rough approximation to what one sees in practice.

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The potential of a task for professional development across national contexts -

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1 Introduction

One of the challenges for professional development is to connect the learning of new teaching strategies or pedagogies with teachers' practices within the classroom. Teachers should feel the need and have the resources to adopt new ideas and to implement them in their daily practice. Classroom materials, like tasks for students, can play a crucial role in this implementation process. Tasks have the potential to reflect innovative aims, like inquiry-based learning (IBL) or using workplace contexts, and to inspire and support teachers in implementing these aims. However, whether a teacher recognizes and exploits this potential of a task and how she/he transforms it into her/his teaching is a complex process and highly depends on the adaptability of the task to his or her practice (Remillard, 2005). This seems especially the case when a task is developed for use across various European countries. We will present one task that is used for investigating the possibilities for implementing IBL in workplace contexts (the aim of the Mascil project) in four countries, Greece, Spain, the Netherlands and Romania. In Greece the adaptation and use of this task in the classroom took place in a master's course in Mathematics Education with prospective teachers. In Spain a group of researchers and one teacher worked together for optimizing and implementing the task. In the Netherlands an experienced teacher implemented the task to experiment with inquiry based-learning in connection with the world of work. In Romania the task was first introduced at a professional development course, where teachers had to solve the problem and then discuss the solutions and possible teaching strategies. Next, these teachers took the task and implemented it on levels varying from primary school to a master's course in Mathematics Education. We sketch these national contexts and provide rich descriptions of the cycle of designing, implementing and reflecting on the task and its use in actual lessons. With these experiences we reflect on possibilities and limitations of using one task across countries for in-service and pre-service professional development on a European level.

2 Mascil-tasks for IBL in workplace contexts

The aim of the Mascil project is to support science and mathematics teachers in extending their teaching repertoire towards inquiry-based learning (IBL) in workplace contexts. Both IBL and the connection to the world of work will make mathematics and science more meaningful and relevant to students. In a classroom where inquiry-based learning occurs, students take an active role,

pose questions, explore situations, find their path to solutions and communicate their reflection. IBL approaches aim to promote students' curiosity, engagement and learning in-depth (Maas & Artigue, 2013). In order to implement inquiry-based teaching and to connect mathematics and science education to the world of work, classroom materials and resources for professional development are designed. To achieve these aims Mascil collected and published examples of classroom materials, i.e. tasks for students and example lesson plans, for inquiry in rich vocational contexts in close collaboration with all Mascil partners (see: www.mascil-project.eu). In order to support IBL and connect to workplace contexts, these tasks have specific characteristics. Traditional textbook tasks that are cast in a context, often explicitly state the problem that needs to be solved and give exactly the information needed to solve it (e.g. Figure 1). The goal of such a task is to give students the opportunity to apply a specific formula or calculation.
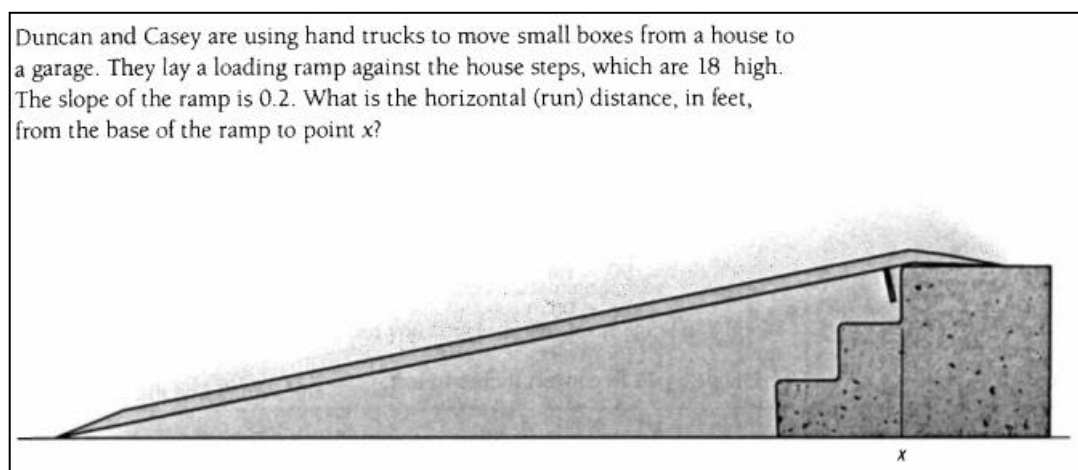
Figure 1: An example of a traditional textbook task

On the contrary, tasks that can be used for an IBL-lesson are open, do not provide a solution plan for the students, and have the potential to evoke a variety of solution strategies. However, the level of IBL supported by the task can vary. A task can include the main question to be solved and provide all information needed, but a task can also only sketch a situation that naturally incorporates one or more problems, without providing all information needed to solve one of these problems. The level of inquiry depends on the lesson created by the teacher with the task and the provided lesson plan that includes a possible pathway for scaffolding the inquiry process of the students. Consequently, learning to inquire in mathematics implies being able to deal with missing or superfluous data, being mathematical creative, and being able to use mathematics in non-routine situations.

Moreover, tasks that connect to world of work (WoW) use workplace contexts that provide a clear purpose and a need to know. The activities students do in the task are related to authentic practices from the WoW. If students' activities

are very similar to typical problems in textbooks for mathematics and science, the connection between activities and WoW is weak. Ideally, within the task students are placed in a professional role fitting the context of the task. The outcome of the task is a product made by the students in their role as professionals, meant for an appropriate audience. The product is similar to real products from the WoW. These task-characteristics are supposed to give students a sense of purpose and utility, and involve them in a 'real' research and design process.

Tasks can be an important resource for professional development. Mascil-tasks are framed by the above mentioned characteristics related to IBL and WoW. The use of the tasks in daily practice asks for specific teaching pedagogies. For instance, when a task provides less structure for students to solve it, the teacher needs to be able to scaffold their solution process in cases they get lost. Moreover, when a task is closely related to a workplace context, the teacher must be able to introduce the context for the students in such a way that role and product are taken seriously. By experimenting with a Mascil-task (prospective) teachers can experiment with new pedagogies related to IBL in workplace contexts.

We argue that these example tasks are crucial in supporting teachers involved in innovative processes, like the one supported by Mascil. However, we assume that the potential of a task depends, on the one hand, on its adaptability and, on the other hand, also on teacher's ability to make it fit to his/her needs and context. In this paper we want to explore both aspects in the case of a specific task used in four different countries and in four different professional development contexts. Further on, also to reflect on a wider question: *Is a Mascil approach, based upon the use of innovative classroom resources for supporting teacher professional development, possible across various European countries?*

3 An example task: Designing a parking lot

The design of a building is a complex task involving many variables. Architects have to think about the structure, the distribution of the space (staircase, corridors, rooms, entrance hall), orientation of the building, etcetera. Often, decisions taken in prior steps affect what it is possible to do in the next ones. This task is supposed to give students the role of an architect in the design of a parking lot in the basement of a building. The structure of the building and the distribution of the pillars have already been decided and cannot be changed (see Figure 1). In order to build a parking-lot in the basement, students will work on a good distribution of the parking spaces and the entrance ramp.

Working as an architect: parking in the basement

In designing a block of apartments the architect has to work out how to distribute parking places in the design of the basement car-park.

The diagram shows a plan drawn to scale of the area available. All measurements are in metres.
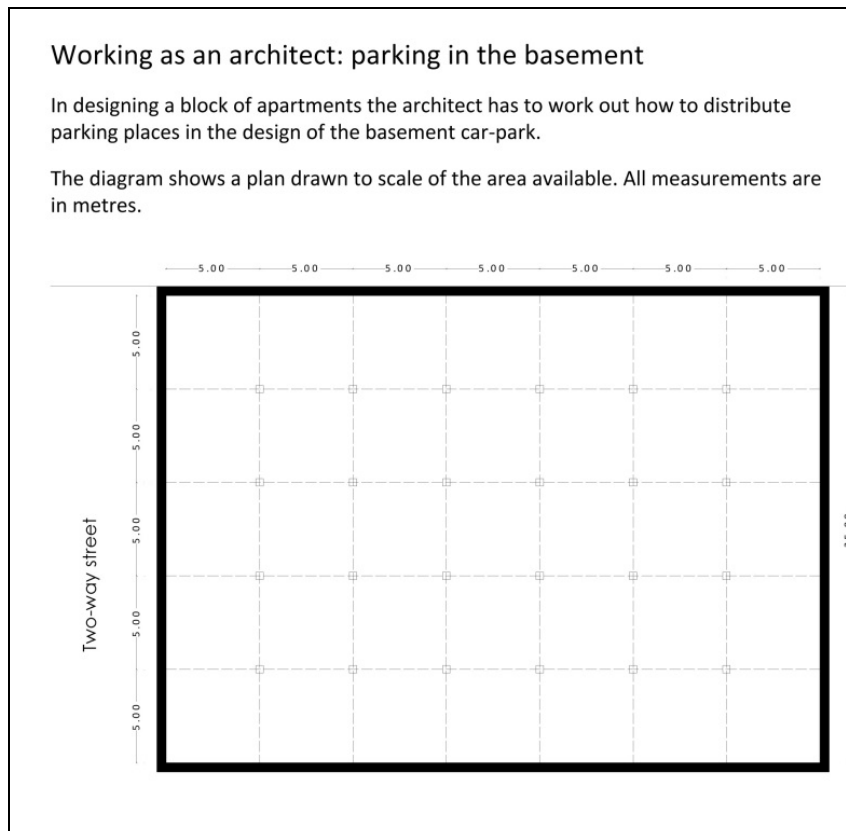
Figure 1: Worksheet for the Parking lot task

The worksheet for the task shows a plan of the area available. All measurements are in metres. The task has been designed by an architect, mirroring her work in the professional context. Constraints for the design have also been taken from existing regulations. Some constraints are that there need to be parking places for disabled people, parking places for motorbikes, a stairwell and a ramp by which cars enter and exit with a maximum gradient of 25%. The task leaves a lot of decisions that need to be made by the students (e.g. the size of a parking place for a car), is clearly situated in the context of the world of an architect and positions students in the role of an architect. The kind of activity they will be involved in mirrors the activity of an architect (e.g. creative design under constraints and working with scale models). And finally, the task does not ask for the one and only solution, but for a product that needs to be delivered by the students. Deciding about what makes a solution better than others is an intrinsic dimension of the task.

4 The task in Spain, Greece, the Netherlands and Romania

In Spain, a group formed by researchers and one teacher worked together in the implementation of the task. The initial aim was the piloting and optimization of the task. Previous to the implementation, a meeting took place. This helped the team to understand students' background and to organise the use of the task accordingly.

The task was used with twenty-five grade 9 students. Initially, three 50 minutes sessions were planed: session 1, guided by a researcher with the aim of introducing the task and initiate students' exploration of the situation; session 2, guided by the teacher, in which students should work in groups, designing their parking lot; session 3, altogether, where students will present their work, and argue about their designs. Finally, an extra session was needed in between. Students were used to work collaboratively, but not with an open-ended task like this. Groups were organised in advance and students were very engaged in the task from the very beginning. According to the description of the task, students' work was mainly focused in two issues: (1) spatial reasoning, optimising the distribution of the parking places and other parts of the parking; (2) geometry, calculating the dimension of the ramp so that the gradient is less than 25%.

We noticed that students had difficulties to interpret ramp's gradient in terms of percentages. They had some previous knowledge about gradients, but interpreted as the tangent of the angle. This made that most of the groups were stuck. Instead of a problem, this was perceived by the teacher as an opportunity to (re)visit the mathematics of trigonometry and triangles (see Figure 2).
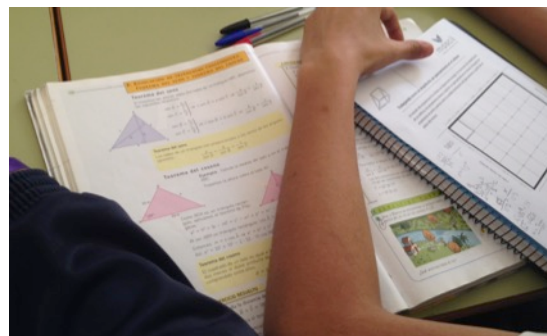
Figure 2: Students connecting the task with their trigonometry chapter

After the intervention of the teacher, most of the groups could translate the ramp's problem into a math problem, solve it, and interpret the solution in terms of the real situation, although the diagram of the parking conditioned their solutions. However, it was not clear if students made a deep understanding of the concept. Indeed, we observed that most of the groups draw the ramp they wanted first, calculating the gradient afterwards. Consequently, in most of the cases the percentage was higher than the 25% limit. Later reflections within the team lead us to identify the existence of a curricular gap. Indeed, in the Secondary Education, gradients are normally studied within the topic of linear functions, and associated with their algebraic expression. In geometry, when trigonometry is studied, the notion of the tangent of an angle is weekly connected with the notion of gradient. Therefore, students find it difficult to interrelate notions that are embedded in different

mathematical domains and related to different kinds of mathematical activity. We interpret this as the manifestation of a didactical phenomenon, that we called elsewhere *the phenomenon of the disconnection and atomization of school mathematics* (García, Bosch, Gascón & Ruiz-Higueras, 2006).

Finally, all the groups could translate the ramp's problem into a math problem, solve it, and interpret the solution in terms of the real situation, although the diagram of the parking conditioned their solutions. At the end, students were asked about their experience with the task. According to their feedback, they really enjoyed the task. They liked both the open-ended nature of the task, and doing mathematics like professionals do outside school.

Figure 3: A result from Spanish students

In Greece, the task was adapted and used in the context of a master's course aiming to link research and theory in mathematics education to the practice of mathematics teaching. A group of three prospective teachers chose the parking problem task to investigate how this would work in an 8th grade mathematics classroom. Initially, they read about IBL in learning and teaching mathematics and they linked the characteristics of IBL with the task. Then, they posed their own goals and questions to explore, provided a plan of a building to familiarize the pupils with the work of an architect and materials to use. The students worked in small groups and by adopting the role of an architect they constructed their own plans and argued about their appropriateness. The prospective teachers identified students' solution strategies, their arguments and realized pupils' difficulties with the mathematisation process and the understanding of the underlying concepts. They also reflected on their own teaching and realized on one hand the potential of the tasks in promoting students' motivation and mathematical meaning but on the other hand the difficulties to manage these tasks in the classroom. The following extracts from the journals of three prospective teachers illustrate their realisation of the role of these tasks in learning and

teaching mathematics: "The students were really involved in the tasks and they were keen to express their opinions and to argue for them … We could have managed better the time allowing students to provide more arguments for supporting their claims"; "I was surprised that students who were not considered as good students by the classroom teacher were really engaged in the task."; "The students seemed to link the problem with the reality. They were checking whether their calculations provided realistic results. In one case they discovered an error in calculating the covering area, as their result was larger from the parking area. Visualization seemed also very important in the tackling the task."

In the Netherlands, the task was used by an experienced mathematics teacher in two 8th grade classes. Her experiment with the task was part of a pilot for the Mascil project. This pilot was intended to create opportunities to explore whether and how a Dutch teacher can adapt such a task to her teaching practice. Moreover, we used the pilot to investigate what task characteristics and what pedagogies support the inquiry process of the students and how the teacher and her students experience the task characteristics related to the world of work. Initially, the teacher was a bit sceptical about the possibility of using the task as it is rather open and students need to deal with quite some missing information. After discussing the lesson plan that scaffolds the students' activities (see Figure 4), she was willing to try out the task. She adapted the lesson plan to her time frame (one lesson of 70 minutes) and added a Dutch video of architects presenting their design for a parking lot.

She started the lesson with introducing the task, watching the video and a short discussion about the task situation. She asked what further information the students would need to start designing. Some students, for instance, asked for the size of an average car. She rephrased the question and asked how you could solve such a question. Students suggested to go outside and measure cars or to browse the internet. Both possibilities were rewarded and after dealing with all the questions the students started working on the task. Also in her case, they worked in small groups, adopted the role of an architect seriously and designed their own plans for a parking lot. Afterwards, the teacher was amazed by the enthusiasm of her students and of their work. In a quite natural way they worked with scale and ratio and created beautiful models with accompanying information to 'sell' their design (this was organized at the beginning of the following lesson). In retrospection, we reflected on the importance of discussing the lesson plan in advance, the openness of the task that stimulated the students' inquiry and creativity, and the motivational role of the explicit workplace characteristics offered by the task.

5 minutes	Create groups of 4 and introduce the problem
10 minutes	Students work in groups and identify what further information is needed
5 minutes	whole class discussion to share questions and sources or strategies for answers, to distribute responsibilities and to give feedback on the final product
25 minutes	Students continue and finalize their designs and underpinning
10 minutes	Presentations of (some of the) groups
5 minutes	Reflection

Figure 4: The lesson plan of the Dutch teacher

In Romania, the Mascil team was convinced that an IBL task – especially when connected to the world of work – has the most success in being implemented if it is solved first by the teachers themselves. This is why the task was introduced at a professional development course, where 23 teachers had to solve the problem and then discuss about the different solutions. Teachers worked in small groups and were left to work entirely by themselves within a time limit. Due to the openness of the problem and all missing data, teachers spent almost an hour documenting and calculating. When time was up and a tentative solution was presented by each group, every group got five minutes to optimize their solution. The presentation of different solutions was followed by a brief discussion and all teachers were convinced that this task should be implemented in classroom practice. The task was used by primary school students (grade 3), secondary school students (grade 8), mathematics education master's course students, and by a high school class (grade 10). On different levels the quality of solutions was almost the same while the main focus of the discussions, the main difficulties and the possible lessons learned were quite different. Since the task was initially proposed for secondary school and high school students, implementing it in primary school was a great challenge.

It was clear from the beginning that young children can learn a lot from this task by simply trying to understand the problems and going through a solution

process. However, it was a real challenge to guide them through this process and to emphasize links to mathematics without controlling too many aspects. Special preparations were needed: the parking lot plans were considerably enlarged, paper cars were printed out, already made stairwells (see Figure 5) were used and also some tools (like measuring-tapes) were brought in. More than half an hour was spent on having the students understand the task and all its details. For example, when the printed plan was shown, they thought they had to design a multilevel parking house. The cards (cars, stairwell) were only given to a group once the children in the group understood the task at hand. This was absolutely necessary in order to ensure the necessary contextual knowledge. Once they started though, the groups came up with a solution very quickly. After some optimizations and corrections done with the help of the attending teachers, these solutions were on par with the solutions given by teachers at the PD course.

Figure 5: Third grade student working with pre-printed paper cars and stairwell (the red square) and master students voting the best designs and identifying criteria for evaluation

Working with the same task on several levels offered a unique perspective about the undergoing processes, the typical reactions that came up in the activities. A striking difference was in the time management and in the use of tools. While teachers understood the task quite quickly, they spent a lot of time on gathering the missing information and in creating their first design, the younger students spent more time on understanding the task and only a small amount of time with the first design. The process of optimization needed teacher intervention (in most cases just a few well-chosen questions for each group) and a longer time period with the young students, while the group of teachers wanted to design an optimal plan from the very beginning. Young students got artefacts (printed cars, stairwell, ramp) from the teacher and they relied on these during the design process while older students and teachers had the opportunity to make their own artefacts (with paper, scissors, etc.) and they knew that they have to construct a model for their presentation, but first they made a paper-pencil design. It was also interesting to discuss with the master students and the teachers how to evaluate the activity, the work of the

groups, the work of individual students and the differences with evaluating usual textbook exercises.

A central question for the Romanian team was: on what level could this task be implemented? Especially in Romania, with a strongly content focused curricula and a tight time frame for teaching mathematics? During the activities it became clear that the task can be used on all levels. In primary school, to help understand the concept of areas, scaling, multiple solutions, optimizations; in secondary school as application of trigonometry to real-world problems like the length of the ramp, the maximum slope of the ramp or in high school as an optimization problem. However, the success of the implementation highly depends on the teacher.

5 The potential of tasks for professional development across countries

One task was used by teachers from four different countries. In each country the task was not used in an average classroom but under specific and different constraints. In Spain, researchers and a teacher worked together to try-out and optimize the parking task.

In Greece, the task was used in a rather exploratory way and the focus of prospective teachers was to investigate pupils' thinking and solution strategies while being engaged in the task. In the Netherlands, the task was used by an experienced teacher to investigate its potential for inquiry-based learning and connections with workplace practices in the Dutch context while in Romania the task was used with several age groups in order to fit the task within the existing curricula and to experiment typical reactions/difficulties in connection with the task and more generally in connection with IBL and WoW oriented tasks.

In all four countries the teachers acknowledged the enthusiasm of their students taking the role of an architect, the activities that reflected the work of an architect and the creativity in and ownership of their products. The task also created opportunities to apply and deepen mathematics, to deal with missing information, to solve an open problem, and they experienced ways to communicate about their results. The teachers in each country recognized the potential of the task, the value of task-characteristics like the openness, the 'taking a role', creating a product collaboratively, the use of workplace artefacts, and an introducing workplace video (see Figure 6). They highly appreciated this way of working.

Figure 6: Task characteristics in the Mascil-framework (Doorman & Jonker, 2014)

The task appeared to be a potential resource for these teachers to get experience with and reflect on IBL in workplace contexts. The teaching experiments created opportunities to reflect on scaffolding students' inquiry with an initial exploration of the situation and a whole class discussion of emerging issues before starting group work. However, switching between a creative process and the discussion of mathematical issues that arise during that process asks for a careful planning of the lesson.

The experiences with this task in these four countries are promising for using the task in professional development of (prospective) teachers. Further experiments might provide us with the role of the different educational realities in the development of mathematics teaching and teacher education in integrating such tasks confirming that they are powerful resources for teacher education in each of these countries, and consequently, for scaling up professional development in Europe.

Acknowledgements

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Professional development of teachers by developing, testing and teaching curriculum materials of an interdisciplinary STEM-course (NLT) for senior high school -

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Abstract

In 2007 a new interdisciplinary STEM course for upper secondary science students was introduced in the Netherlands. Teaching and learning in this course is based on a selection of modules, each taking 40 hours of study for the students. In the development and implementation of this course several opportunities for professional development of science teachers arose, such as material development, piloting materials, contacts with domain specific experts, and school, regional and national meetings. Since 2006 over 70 modules have been developed. Teachers from almost 100 schools participated in development teams, and experts from 10 universities, 12 colleges and 25 other institutes were involved. First drafts of modules were always tested in schools which were not involved in producing the modules. Teachers from more than 50 schools participated in these trials. They commented on the quality of the modules and gave suggestions for improvement. Finally some factors are outlined which are relevant for the success of teaching the NLT course.

1   Introduction

Most teachers at senior secondary level in The Netherlands have few opportunities to deal in their classes with topical issues in science, technology, engineering and mathematics (STEM). This is due to time constraints and overloaded discipline based curricula, assessed in high stake examinations, combined with limited knowledge of teachers on modern issues, especially on interdisciplinary topics, which go beyond the limits of their disciplinary knowledge. However, we are living in a society in which new developments in STEM play an important role in interdisciplinary issues at local, national and global level, such as communication, safety, environment and health. For all citizens basic knowledge in these fields is important, but moreover society needs STEM-workers at a variety of levels who are able and willing to contribute to challenges facing modern societies.

Therefore, in The Netherlands a new course for senior high school, named Nature, Life and Technology (NLT) was developed (Michels, Kruger and Eijkelhof, 2011). Aims of this course are (1) to make further studies in STEM more attractive to students and (2) to increase the coherence between school subjects. It is an elective course, chosen additionally to regular courses in mathematics, chemistry, physics and biology in senior high school. Schools are free to offer NLT. Students in pre-university streams who enrol in NLT are

required to spend 440 hours (within three years) on this course, which is assessed with a school based exam.

Teaching and learning is based on a selection of interdisciplinary modules, each taking 40 hours. Currently more than 75 modules are available, so teachers have a wide choice in selecting topics, within the boundaries of the examination programme, which ensures some variety in the fields covered. The NLT-modules deal with a wide range of topics in areas such as climate, sports, diseases, health technology, energy production, crime science, food production, astronomy, water management, nanomaterials, earth science, logistics, dynamic modelling, quantum chemistry and physics, and brain functioning. This variety of modules is meant to contribute to student awareness of the possibilities for further education in a scientific or technological area.

At present more than 200 schools are offering the NLT course, 40% of the schools in the country. In this paper we describe and evaluate the possibilities for professional development in the context of the NLT course. Central questions are:

a) *What are the contributions of teachers to the development of the subject NLT?*
b) *In which way does participation of teachers in NLT contribute to their professional development?*

2 Teacher participation in NLT

2.1 Developing and testing modules

In 2006 no lessons materials were available for the intended course. It was clear that the STEM area is wide and in order to show students possibilities of further studies in STEM many modules would be necessary to cover the field. Moreover, school teachers are usually not familiar with new developments in STEM and experts in these fields are in general not familiar with school curricula and culture of teaching. Therefore expertise from science experts and active teachers was expected to be required in order to produce innovative teaching materials which are both up to date and suitable for teaching in senior high school. All development teams consisted of teachers of at least two secondary schools and experts from universities, colleges, research institutes or industry. Teachers from almost 100 schools participated in development teams and experts from 10 universities, 12 colleges and 25 other institutes were involved.

First drafts of modules were always piloted in schools which were not involved in producing the modules. Teachers from more than 50 schools participated in these trials. These teachers and their students commented on the modules and gave suggestions for improvement. In addition, external experts reviewed the contents of the modules and science education experts added advice on the educational quality of the materials. After a revision, taking into account all

these experiences and ideas, the national NLT Steering Committee certified the modules for national use. So far, 77 modules have been certified. For examples, see Table 1.

(* available in English)
Forensic science
Driving and drinking
Care for your heart
Living in the ISS
Glue and attach
Medical imaging
Blue Energy
Lab on a chip
Dynamic modelling
Ice and climate
Digital technology
Brain and behaviour
Measuring galaxies
Bio-sensors
Medicine development
GIS and safety
Sport science
Air quality
Molecules of life *
Food or fuel *
Moleculargastronomy *
Dynamic earth *

Table 1: Examples of NLT modules

2.2 Teaching the course

As the course is interdisciplinary and deals with new developments in the STEM field, teachers will not be able to teach all modules on their own. For this reason it is highly recommended that the NLT-course is taught by a team of teachers, at least three with different disciplinary backgrounds. This strong cooperation between teachers of different disciplines might also contribute to the interdisciplinary learning experience of students.

Therefore the Steering Committee asked schools to register and agree to involve at least three teachers from different subjects, to offer time for teachers to prepare the lessons, to attend NLT team meetings and to have opportunities for professional development, and to use at least 75% of the time certified modules.

In practice, on average five teachers per school are involved in teaching NLT. The way they cooperate differs. For example, in some schools the modules are taught collectively by a group of teachers, each giving classes close to his or her area of expertise. In other schools all NLT classes are programmed on one afternoon, which allows teachers to move between classes and students, where their expertise is required. Another practice is that one teacher is responsible for teaching classes and supported by other teachers in preparing the lessons and by contributing as guest teachers where appropriate. In one region – Nijmegen - six school cooperate with the Radboud University and the modules are taught weekly on an afternoon by a team of university lecturers and school teachers. Many schools invite experts as guest lecturers or organize excursions, for example to universities, hospitals or companies.

One obvious success factor of NLT is that teachers are willing and able to cooperate with colleagues of different disciplines. In the Netherlands this is quite innovative as usually the sciences and mathematics are taught in single disciplines without much connection between the subjects. Another important success factor is the time provided by school management for cooperation between teachers and for external contacts.

2.3 Professional development

In order to support teachers in teaching the NLT course all modules are accompanied by teacher guides. Furthermore, 10 regional support centres have been established across the country at universities and colleges. These centres organize meetings for NLT-teachers, collect experiences with modules, are responsible for updating modules, and share experiences with other centres. Visser (2012) investigated at one centre a professional development approach supporting NLT-teachers implementing a new NLT-module at their school.

Annually in February a one-day national NLT conference is organized with lectures and workshops which are relevant for NLT-teachers.

Conclusions

We conclude this paper with answers on the two main questions from the introduction:

a) *What are the contributions of teachers to the development of the subject NLT?*

Teachers have been very important in developing the modules. Firstly, They know which topics are covered in the regular physics, mathematics, chemistry

and biology classes, they have experience with teaching 16-18 year olds and know more than experts about the abilities and interests of the target group of students. Secondly, the draft modules were quite innovative and - as may be expected – had quite a few shortcomings. So the trails appeared to be necessary and very useful for the process of module development. Thirdly, many teachers were willing to share their experiences of teaching the certified modules with colleagues at the regional and national meetings. Finally, NLT is a new subject and is at school level in competition with other optional subjects. So NLT teachers put a lot of effort in motivating students (and often their parents) to choose NLT as subject in their final years of secondary school.

b) *In which way does participation of teachers in NLT contribute to their professional development?*

Teachers not only contributed to the development of the subject, they also personally benefited by participating in various activities. Firstly, those teachers who participated in writing curriculum materials learned a great deal from the experts involved. Secondly, the teachers who piloted and evaluated the modules in their classes learned from the experiences. Thirdly, by being allowed to choose from the whole range of modules their autonomy and commitment was strengthened. Fourthly, preparing for teaching such innovative modules required time for professionalization as the teachers had to become familiar with new developments in STEM which so far were not part of the school curricula. Fifthly, by working together with colleagues teachers got more familiar with teaching practice in other subjects which contributed to a more coherent STEM teaching in the schools. Finally, exchanging experiences with teachers from other schools and contacts with experts at regional and national meetings formed part of professional development.

- Currently about 1100 teachers are involved in teaching NLT. Several factors are important for the success of teaching NLT :
- A personal interest of teachers in new developments in science, mathematics and technology.
- A school climate in which teachers are willing to cooperate with colleagues of other subjects.
- Support from school management in providing time for professional development and adequate timetabling.
- Regional networks of schools, institutes of higher education, research institutes and industry.
- A national body for quality assurance and contacts with professional organizations of scientists, industry, teacher associations, teacher educators and the Ministry of Education.

For further information about NLT see www.betavak-nlt.nl/english

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Raising the professional competence of mathematics teachers in Sweden: The challenges of practice viewed from a material developer's perspective -

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1 Introduction

The Swedish National Agency for Education is implementing a project (called *Matematiklyftet*) aiming to raise the didactical competence of mathematics teachers in all forms of schooling and at all school levels during 2012-2016. The project uses a praxis-based collegial learning approach supported by facilitators and framed by the project web portal https://matematiklyftet.skolverket.se/ (see fig. 1). By the end of 2014 twenty eight study modules have been made available there for different school levels. Over twelve thousand teachers from about three hundreds schools take part in these activities yearly.

Figure 1: Entrance to Matematiklyftet web portal

The teachers work with one module per term, for example with the high school module "Competence based mathematics teaching". The author of this paper was the leader of the material development team for this module. Each module consists of eight parts each with a focus on a specific topic. Thus, the above mentioned "competence" module has the following parts:

1. Working with mathematical competencies

2. Problem-solving competency

3. Conceptual and procedural competencies

4. Modelling competency

5. Reasoning competency

6. Communicating competency

7. Development of competencies

8. Experiences and challenges

In each part participants carry out activities in four steps with the following allocation of time: individual preparation (45 – 60 min), collegial discussions (90 – 120 min), practical activities/lessons (one lesson), and common follow up and reflections (45 – 60 min).

The Swedish National Agency for Education invites groups of mathematics educators and researchers from different universities to develop study modules. Usually, representatives from two universities build a team for module development. Each module should be developed within a six to eight months period and a team gets a budget for work-time. The material developers' work is structured and timed around four meetings at the headquarters of the Swedish National Agency for Education in Stockholm. Representatives of the central project team give guidelines for the module development (introductory meeting) and evaluate work progress in three other meetings scheduled at regular time intervals. Practicing teachers and the Swedish National Centre for Mathematics Education are also involved in the material quality evaluation.

The aim of this paper is to discuss the project from a material developer's perspective. The paper attempts to highlight a question: what lessons could be learned from the process of material production for the professional development of mathematics teachers in Sweden?

2 Findings: reflective insights on the work process

2.1 Starting point

During the introductory meeting for each module the developers learn that the sources of inspiration for the project have been:

- John Hattie's studies showing the importance of improving teacher competence for raising learners' performance (Hattie, 2009);
- Japanese "lesson study" model consisting of lesson preparation, auscultation and collegial reflections about the implemented lesson;
- the SINUS project (Germany), in particular a scaling up form of using study modules, facilitators, and Internet based platform (Ostermeier, Prenzel, Duit, 2010).

The project leadership made clear for the module developers that

- it is not possible to ask teachers to do auscultations of each other's lessons,
- to provide material that demands more than sixty minutes time to prepare for the first group discussion meeting,
- the module content should encourage discussion of teachers' own actions rather than the learners' performance, and
- all material should be produced in Swedish language only.

In introductory meetings a lot of time was dedicated to presenting the political framework of the project and copyright policy issues. Bureaucratic steering and "you do what we tell you, because we pay" relations that will dominate over academic reasoning became obvious there.

We also found to our surprise that budget frames allocated to different modules could vary significantly, concerning the time-pot for a module's development, number of people involved, overhead costs, etc.

At the start of the project it appeared to be a very loose plan for material development. The number of modules and their content/titles were not defined from the beginning. When you start work on a module you do not know if related contents have already been ordered for development or will be developed in other modules later on.

These uncertainties in the frame of the project could eventually be related to the fact that the Swedish mathematics education research community is rather small. Most of the researchers are busy with other tasks and have limited possibilities to impact on teacher professional development in general and on the modules development in particular. There are few Swedish mathematics education research papers directly suitable for teachers to read while working with modules. On the one hand, most mathematics education research in Sweden is published in English, and on the other hand, research papers use different discourse traditions than practitioners are familiar with in schools. Leading researchers also do not have much time to popularize their own research through material production for the teacher professional development project. Therefore, most of the reading material for the modules had to be originally developed. It was a challenging task for the national project leadership to find qualified writers' teams. The project was constructed and reshaped as it was going on.

2.2 Module development work

One of the important tasks for material developers was the selection of topics to be presented for the teachers in each module and creating an appealing style for their presentation. Content selection was made based on international mathematics education research and proven didactical experience from the field. Modules were intended to be self-instructive and serve as a steering and framing tool for the teachers' work. They all had a common, clear four-step structure and needed to be presented in clear language with the support of multimedia where appropriate.

The original project idea, that all module developers were encouraged to follow, included both the development of video films based on field experiences to inspire teachers to use different work methods and also the introduction of new didactical approaches. This became a very challenging task for the module developers. Only those modules that were grounded on long-going research projects in schools with a rich collection of video material could cope with this task. Otherwise films tended to present an idealized

classroom environment or not be very informative. Private film companies were not able to provide quality ad hoc solutions for this problem.

Reviews from practicing teachers were required on two occasions during the module work, when drafts of two blocks of module material parts 1-4 and 5-8 were produced. As a rule, the teachers' feedback concerned mainly forms of presentation and estimation of time required for readings and discussions. It provided a very rough indication of the didactical quality of the material as expected by the future participants of the professional development program. The teachers also asked for easy to use material, such as banks of problems with given solutions. They wanted to have resources that would facilitate their daily professional life. However, they provided few content related comments that could contribute to the improvement of the drafted material.

Two open peer review meeting were organized by the project leadership to discuss the material produced with four selected reviewers, experts in the corresponding field. Their feedback was valuable but was given on the same occasions and frequently appeared to be repetitive and sometimes contradictory. Possibly, feedback could be more productive if developers had the opportunity for discussion with experts on a 'just-in-time' basis, when the need for a third opinion arose.

2.3 Challenges and tensions

In each module the common didactical perspectives, such as competencies, classroom norms, formative assessment, interactions in the classroom, etc., that should penetrate the material content were decided centrally. Their role and weight varied in the different modules and sometimes even changed during work on the same module. The reasons for this remained often obscure as also grounded justification for the introduction of new perspectives (e.g. mathematical cultures, language and mathematics) was not provided for developers. Contradictory messages during the process of module development, from a representative of the central project leadership, concerning style of writing or form of reference presentation were not unusual during the work process.

The idea of "lesson study" was implemented without teachers attending colleagues' lessons and became a debilitated version of the Japanese model. Lesson without peer auscultation is a half-blind activity. To compensate for the absence of a colleague's feedback teachers had to rely on personal reflection and self-monitoring, which is a particularly demanding activity needing special development. An attempt to substitute "auscultation of a colleague's lessons" by the practice of "noticing" (Mason, 2002) was centrally promoted but not eagerly accepted by practicing teachers. Teachers had difficulty in impartially sketching notes of the events attracting their attention during the teaching for further reflection afterwards. Therefore, in the common follow up and reflections after a lesson teachers could immerse in a culture of discussion,

but did not have the chance to develop a culture of giving and taking feedback, which is very important for their didactical development.

3 Potential for improvement

The experience of material development suggests existing potential for the improvement of practice. The time frame for individual preparation (maximum one hour) seems to be too short for a teacher to become familiar with the suggested readings and make serious preparation for common discussions in the second step of module activities. This limitation significantly affects the material developers' ambitions and opportunities for depth and quality of content presentation. Reference to the unrealistic amount of required preparation work that should be done in one hour was a recurrent issue in all module review stages.

Modules do not include any guides for the facilitators who coordinate and monitor teachers' activities. Such guides could facilitate participants' group work. Facilitators do not receive any orientation about the modules, their key contents and expected work-forms. Provision of a manual for facilitators could make the 90 min allocated for collegial discussions more effective.

Teachers develop and test many ideas and tasks during the module activities, but there is no requirement for their collection, systematization or any form of distribution. It could be argued that building a bank of teachers' ideas and tasks in each module can create the necessary preconditions for perpetuating in-school professional development activities. However, it seems that potential difficulties for the project leadership in planning for this extra activity and solving the technical issue of storing material on the web has deprived modules of this valuable addition.

The opportunity for material developers to network was not organized by the project leadership. There was no given opportunity for sharing experiences when working with different modules. However, private contacts showed the importance of getting insight from other module developers. This accumulated experience of work with several modules was concentrated solely in the central project group and was only clearly exposed during the review meetings.

The evaluation of modules was not built into the module structure, for example, to be included in the final part of the module work. Thus, module evaluation becomes a separate part of the project with unnecessary extra costs and logistical difficulties in collecting evaluation material from the schools.

4 Conclusions

The project of raising the didactical competence of mathematics teachers implemented by the Swedish National Agency for Education is an important step in the improvement of mathematics education in the country. The major strength of the project has been that it relies to a great extent on teachers' professional wisdom shared in collaborative work. The teachers are conceived as internal experts who, in part, can professionally develop each other through regular collegial work within the project and hopefully also after. The teacher collaboration started in the work with modules has the potential to continue on a regular basis in the schools involved in the project.

From the developers' perspective a more transparent, open and less bureaucratic style of project management is to be desired that focuses less on orders and regulations rather than on dialog and a search for new opportunities.

Some points raised in this paper would be universal for all module developers but other insights are probably coloured by the specific module work contexts the author was involved in.

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Integrating inquiry-based tasks and the world of work in mathematics and science teacher education -

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1   The main focus of the paper

In this paper our goal is to explore how tasks aiming to promote inquiry-based learning (IBL) and the integration of the world of work (WoW) in mathematics and science teaching, developed in the context of Mascil project (see: www.mascil-project.eu), have been embedded into prospective teachers' (PTs') mathematics and science education. Our focus is on PTs' engagement in designing, implementing and reflecting on Mascil tasks or tasks developed by them in the same spirit. In particular, we present examples of such tasks, their transformation in actual teaching and PTs reflections on their experience. Finally, we discuss the emerging issues as regards the PTs' engagement in working with tasks that support IBL in workplace contexts and the nature of teacher education that promotes the integration of IBL and the WoW in the teaching and learning of mathematics and science.

2   Theoretical framework

Research informed teacher education programs have been considered as contexts for prospective teachers' professional development. For instance, some of the main approaches adopted in mathematics teacher education programs are: engagement in mathematics-related tasks to develop awareness of the mathematical structure and power of tasks; designing, analysing, and trying out tasks with learners; observing and analysing task implementation in the classroom; and using theory to explain teachers' experiences (Watson & Mason 2007). Through the above approaches teachers and prospective teachers challenge existing knowledge and perceptions of teaching and learning they had developed as students themselves and recognize the potential of inquiry and experimental teaching. In general, tasks have been recognised as important resources in mathematics and science teacher education that are conceptualised in different ways by teachers (Remillard 2005) and also transformed through the process of designing and implementation (Henningsen and Stein 1997).

The dynamic character of tasks as amenable to changes is strongly related to the process of inquiry in learning and teaching. Our theoretical approach prioritizes the issue of inquiry in students' learning considering as important "… to abandon efforts to teach by inquiry in favour of teaching for inquiry"

(Settlage 2007, p. 204), that is to say, to help students' practice and develop the skills of inquiry. Jaworski (2006) proposes three forms to address the inquiry practice: inquiry in mathematics; inquiry in teaching mathematics; and inquiry in researching the process of using inquiry in mathematics and in the teaching of mathematics. In this study PTs are engaged in all these forms of inquiry practice through working with tasks and resources as students, transforming these tasks in the process of designing for teaching, observing the process of inquiry based learning through students' engagement with the tasks and researching the inquiry process in actual teaching. In this perspective, tasks are considered as means for making links between theoretical ideas and research-based findings to the actual teaching of mathematics and science.

The situation becomes more complex when the tasks refer to realistic and workplace contexts that pose prospective teachers new challenges related to the adaptation of these tasks in the school context, to classroom management and to the process of making links between the context and the underlying mathematical and scientific concepts and processes (Ainley, 2011; Roth, Mc Ginn & Bowen, 1998). In this direction, research in science and mathematics education indicates the need of a situational perspective in integrating inquiry in teaching (Crawford 2007; Friedrichsen and Dana 2005; Hogan and Morony 2000; Nicol 2002; Windschitl 2004) and promoting teachers' professional development (Borko, 2004). WoW may function as a source of valuable situations, meaningful contexts for mathematics and science teaching, as they can support learning through interaction in the social and material world (Derry and Steinkuehler 2006). Research evidence concerning teaching and teacher education on the basis of WoW contexts is rather limited.

Since Mascil tasks are not content specific and are based in vocational and WoW contexts, it is important to explore what kind of issues may emerge as regards the integration of these tasks into curriculum and teaching through PTs' engagement in designing, implementing and reflecting. Prospective teachers have to cope with more complex situations both at the level of defining their mathematical or scientific goals and at the level of managing the use and transformation of the tasks in the classroom. Our study aims to contribute in understanding this complexity.

3 The context of the study

Our perspective in this study is country-specific as we refer to three postgraduate courses in Greece and target-group specific as the participant teachers are prospective teachers who are going to teach in secondary general and vocational school mathematics, applied science and engineering subjects. The first and the second course are parts of a two-year master's programme in mathematics education offered in the Department of Mathematics of the University of Athens (UoA). This programme is offered mainly to mathematics graduates. The third course is part of an one-year long post-graduate teaching certificate program that focuses on teaching and

learning issues, models, strategies and tools that can be applied in different secondary school subjects. This programme is offered for all higher education graduates in the School of Pedagogical and Technological Education of Patras (ASPETE). As the teacher educators are the members of the Greek Mascil team, during the academic year 2013-2014 they encouraged PTs to use Mascil classroom tasks or develop their own in the same spirit as part of their teacher education activities. Below, we provide in section 4 a description of the methodology of the study including a brief discussion about the context of each course, the teacher education tasks and the process of data collection and analysis. In section 5 we present some preliminary findings while in section 6 we summarize emerging issues for mathematics and science teacher education.

4   Methodological issues

4.1 The context of the courses

The first and the second course emphasize theoretical issues in mathematics education and familiarize PTs with main research findings. An ultimate goal of the two courses is the linking of these findings to the actual teaching through different actions such as reading and discussing research papers, designing and analysing tasks, conducting didactical interventions in groups of students, designing and teaching a lesson in the classroom and analysing students' work on the basis of research findings. Instructional practice in the teacher education sessions aim to support PTs' reflections on their experiences with the use of the designed tasks in teaching as well as to link emergent issues with existing research. A distinct feature of the second course is the integration of technology in the teaching and learning of mathematics. In this course, the cycle design-implementation-analysis is based on tasks addressing a pedagogically sound use of technology for the teaching and learning of mathematics with an emphasis on the role of tools and context in students' conceptual understanding. We note that the first course is offered in the winter semester and the second one in the spring semester.

The third course focuses on teaching and learning issues, models, strategies and tools that can be applied in different secondary subjects. It emphasizes interdisciplinary and visual approaches in teaching. Its main goal is to prepare PTs for classroom teaching and lesson design based on an inquiry approach.

4.2 The teacher education tasks and PTs' engagement

Concerning the first two courses, the PTs were asked to collaborate in groups and prepare an account on designing, implementing and evaluating a teaching intervention with a focus on students' mathematical thinking. Initially, they had to select a Mascil task, or to develop their own. By reading research papers in mathematics education related to IBL and WoW as well as to students' understanding of specific mathematics concepts related to the task, the PTs

were engaged in the process of defining their teaching/research goals and transform their tasks accordingly. Their designs were discussed in the course and the final versions of the tasks were used in the classroom or outside the classroom with small volunteering groups of secondary school students. Finally, the analysis of the interventions and the PTs reflections were presented in the course. As regards their main aims, one difference of the two courses concerned the integration of IBL and WoW in PTs' activity in their teaching intervention. In the first course, the WoW was seen as a context of the task and the PTs were asked to focus on IBL in analysing students' mathematical thinking and make connections to mathematics education research. In the second course, the PTs were directly asked to explore how the WoW was connected to IBL and students' mathematization of the problem. This change was due to the fact that when the second course was offered (spring semester) the teacher educators had already had an initial experience through their participation in Mascil and they had started to form a clearer view of the program's critical questions and challenges such as the making of connections between the WoW and mathematics and science teaching in schools.

During the third course, PTs from different disciplines were asked to study curriculum documents and textbooks in their field and identify units showing elements of integration of mathematics and science with other disciplines and/or the WoW. They had also to read a number of papers referring to the meaning of interdisciplinarity and how it can be connected to the WoW. For their final assessment they had to create their own video or select one from the internet which would be used as a basis for designing a scenario for teaching a specific unit of mathematics or science. PTs prepared written accounts of their scenario and the related tasks, its uses with students, as well as their arguments for their choices. Similar approaches and examples had already been discussed in the course. Some PTs applied their scenarios in the classroom.

4.3 Data collection and analysis

Fourteen PTs in the first course, eleven in the second and a hundred and twenty five in the third worked with Mascil tasks or other in the same spirit. The data consisted of: (1) PTs' written accounts in which PTs had to describe the rationale of their designs and their experience from their implementation, (2) the material constituting the PTs' designs for their teaching interventions (scenarios, worksheets, power point presentations, etc.), (3) selected videos from the course discussions, and (4) PTs' journals. For the data analysis, we adopted a broadly data grounded approach (Straus and Corbin 1998) focusing on qualitative content analysis of students' design and implementation on classrooms in terms of how inquiry realized, how the WoW has been integrated and what aspects characterized PTs' tasks. Moreover, in order to capture the evolution of PTs' design of tasks integrating IBL and WoW, we concentrate on examples selected from their work.

5 Findings

5.1 PTs' design and implementation

5.1.1 PTs' design and implementation in the first course

Here, we focus on the work of one group of PTs who participated in the first and second course. This group worked on the same task designing different types of intervention in the two courses. The task was transformed by the PTs according to the requirements of each course, but our common focus on the integration of IBL and WoW allowed us to view comparatively the designs they created and thus to capture the potential differences in the ways they addressed the integration of IBL and WoW in their teaching. The classroom task was chosen by the PTs from the Mascil site and concerned the covering of a backyard with circular pave-stones that leaves the minimum uncovered area. It is an optimisation problem and the aim is to find the configuration of circles with the maximal density. As regards the WoW, arranging objects in this way is a skill needed in many professions and everyday life situations. As regards IBL, students have to: (a) model the problem from the real world to the mathematical world, (b) identify possible solutions through the use of geometry, (c) select the best solution and (d) interpret the outcomes and reflect on the appropriateness of the solution.

The PTs transformed the context of the task and referred to the work of an architect/designer of exterior places. The problem was formulated as follows:
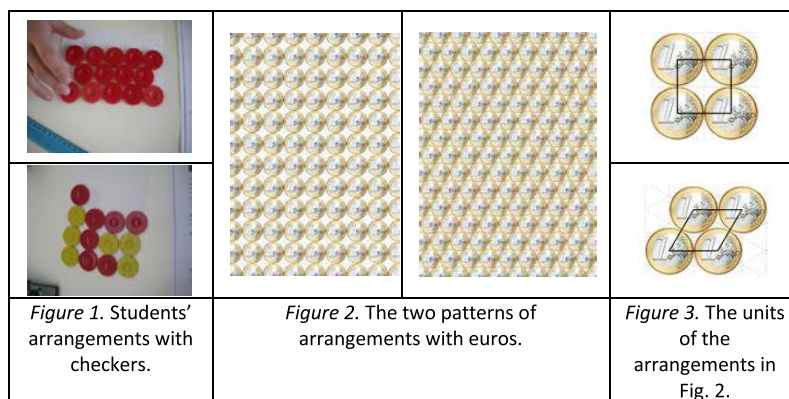
"You are working as an architect/designer of exterior places. One of your clients has a rather difficult taste: he doesn't like vertices; therefore, he would like his backyard to be covered with pave-stones in the shape of circular discs. He also wants the pave-stones to cover the maximum possible area, so as the grass that grows between the stones is as little as possible. Your job is to find a configuration for the circular pave-stones that leaves the minimum possible empty space between them".

The PTs designed the following teaching sequence in four phases:

Phase 1 (Experimenting with different arrangements through the use of circular objects): The students are given a sheet of paper and a number of particular circular objects (coins, backgammon checkers etc.) (Fig.1). Different pairs of students are given circular objects with different radius. The students are expected to experiment with different configurations and to realise that each one of them is based on a pattern created by a particular unit (a polygon) that can be seen as extended to the infinite plane.

Phase 2 (Recognizing the pattern in each arrangement): The students are asked to explore two particular arrangements through a model based on euros (Fig. 2) by focusing on the centre of the coins for each one of these, draw the polygons that are formed with vertices the centres of the coins and identify the

emerging. The students are expected to design various patterns generated by repetition of polygons and, through this, to identify the structural unit of the pattern.

Figure 1. Students' arrangements with checkers.	*Figure 2*. The two patterns of arrangements with euros.	*Figure 3*. The units of the arrangements in Fig. 2.

Phase 3 (Calculating the percentage of the covered area): The students are asked to calculate the percentage of the area that is covered with coins for each one of the various patterns in their previous arrangements. The students are expected to: (a) conclude that this percentage depends on the type of arrangement and (b) identify that the percentage of the covering does not depend on the length of the radius.

Phase 4 (Proving the conjecture of the best arrangement): The students are given the pictures shown in Fig. 3 and they are asked to compare the uncovered areas when the unit of the pattern is a square and a rhombus, which have equal sides. Then they are asked to justify which arrangement is the best.

The task was implemented for two teaching hours in one class of 16 year-old students (10 boys, 22 girls) in one experimental upper secondary school in Athens. The implementation took place in the context of the Geometry course and the students worked in groups of three to five. Basic concepts needed for being engaged in the task (e.g., calculation of the area of various shapes such as polygons, circular sectors) had already been taught and the lesson was conducted by the group of the PTs. PTs wanted to investigate: "*(a) the process of modelling and possible students' difficulties with the mathematical concepts and (b) the students' dispositions towards IBL*".

5.1.2 PTs' design and implementation in the second course

In their new design, the PTs kept the same problem and teaching sequence but integrated the use of digital tools in all phases and they transformed the questions of the students' worksheet accordingly. In particular, they designed dynamic geometrical figures (with Geogebra) to be distributed to the students in each phase with the aim to provide further opportunities for students to engage in experimentation and to enhance IBL. Below, we provide two examples.

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Example 1: In the first step of the phase 1 of the activity the students are engaged in exploring the arrangement of a specific number of equal circles through the use of Geogebra (Fig. 4). By moving the circles freely in the plane the students are expected to identify potential solutions of the problem at the perceptual level. In the next step of the same phase, the students are provided with a slider for changing dynamically the radius of the circles with the aim to recognize if and how the changes in the radius influence the best arrangement. Also the number of the provided circles on the screen is not enough for covering all the available space so as to trigger students' attention to the fact that the pattern can be potentially extended to the infinite plane.
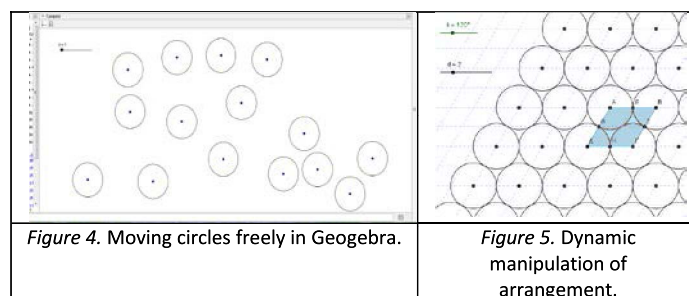

| Figure 4. Moving circles freely in Geogebra. | Figure 5. Dynamic manipulation of arrangement. |

Example 2: In the last phase of the teaching sequence the PTs designed an arrangement that can be manipulated with the use of two sliders (Fig. 5). The first slider changes the angle created by the lines linking the centres of the equal circles and the second one its radius. Through dynamically changing the values of this angle the students can observe the way that the area of the figure changes in relation to the angle. By comparing the different arrangements, the students are expected to realise that in each pattern a circle is created by the different parts of the pave-stone within the unit of a pattern (the rhombus or the square). This realisation can help them to recognise that the best solution to the problem corresponds to a rhombus with angles 60 and 120 degrees. Then they can be engaged in proving this conjecture based on their existing knowledge of geometry.

The task was implemented with one group of two 16 year-old students since it took place near the end of the school-year and there was not enough time for the organisation of an intervention in the classroom setting. Before students' engagement with the task there was an introductory phase during which the students were familiarised with the available tools and functionalities (e.g., designing basic geometrical figures and polygons, defining circular sectors, measuring areas). PTs' goals in this case were: *"(a) to describe the mathematization of the problem by the students including constrains and opportunities for meaning generation and (b) to analyse how inquiry and WoW appear in students' activity"*.

5.1.3 PTs' design and implementation in the third course

Phase 1. The philosophy of Mascil was discussed with so as to study the extent that such philosophy is present in the school curriculum and textbooks. The analysis of their reports shows that their reference to connections of content to the WoW usually had a general character, while existed educational approaches dominated their references, e.g. cross-curricular teaching, the method of project, etc.. PTs often referred and suggested actions like specialists' visits in classrooms and students' visits at outdoors places and factories.

Phase 2. Students designed scenarios that aimed to link teaching and the WoW. On the basis of given examples they were asked to create or inquire appropriate video for connecting the WoW to the curriculum. For example, PTs watched the video in the following link (http://thefutureschannel.com/videogallery/an-engineer-and-her-robot/) and started to design students' tasks. Almost all PTs were involved in inquiry, searching for available resources and teaching materials. Three characteristic examples are presented below:

Example 1: The scenario of a PT, who was a mechanical engineer, is based on a video (https://www.youtube.com/watch?v=Zrp0RC3XTpw) explaining how a homemade windmill works and produces electric current as well as how can be constructed. The idea of this scenario is not strongly connected to the WoW, while the PT seems not to be able to discern the WoW from the practical activities. Its main task poses the question "What type of studies or professional knowledge should a scientist have in order to participate in a project aiming to construct a wind generator?" which is related to the WoW but in a general way.

Example 2: The scenario of a PT, who was a pharmacist, is based on a video (http://www.youtube.com/watch?v=3a4lwvve9A8) that presents how a Nuclear Magnetic Resonance center works. The main idea is interesting and it is accompanied by detailed worksheets for the students with differentiated questions for a group of physicists, a group of biologists, and a group of chemists. It also suggests a final common task, where all groups have to work together on a protein, and a chemical compound that is attached to it in order to contribute in the completion of this process. It includes analytic design and description of implementation, but it is extremely specialized and probably time demanding and unrealistic for applying in the classroom.

Example 3: The scenario of a PT, who was an electrical engineer, is also based on a video showing the installation of solar panels on the roof of a house in Greece (http://www.youtube.com/watch?v=SPGY9eqSvR0). The complete scenario can be found in the Mascil repository. The task asked students to propose how solar panels will be installed on a flat roof of a house taking into account a number of factors. The PT had professional experience on this type of installation. He implemented his scenario in a classroom of 10 students, 11th grade of a vocational school.
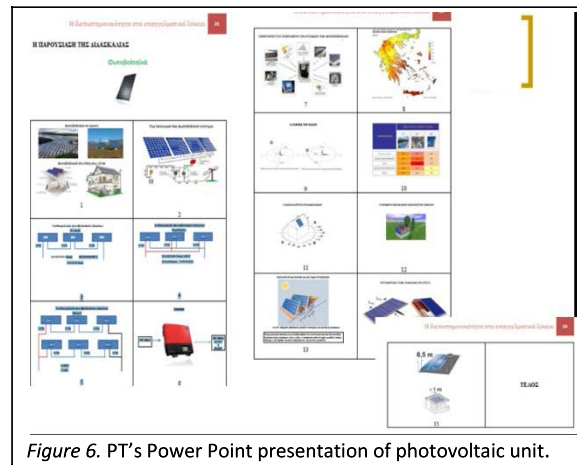
Figure 6. PT's Power Point presentation of photovoltaic unit.

In the first teaching period, the students watched the video and the PT presented different information about photovoltaic units through a power point presentation (Fig. 6), while during the second teaching period the students worked in three groups on the questions of the task. The PT was able to handle the task satisfactorily and had established good communication with the students. However, only one of the groups managed to proceed to the first set of questions. The others met difficulties with the basic mathematical knowledge like the calculations of the sides of a right triangle and the trigonometry and were reluctant to follow and try teacher's suggestions. They also met difficulties even with the simple arithmetic calculations. Their interest was mainly around practical issues, e.g. companies, programs for business financing.

5.2 PTs' reflections

In the first course, the PTs were enthusiastic about their collaborative engagement in the design and implementation of the teaching intervention and they felt that their knowledge about teaching and classroom reality was enriched. In their presentation in the course and in their journals' accounts they referred to: their expectations in relation to students' mathematical activity, the mathematization process and its connection to the mathematics content; difficulties in classroom management inherent in IBL teaching approaches and the importance of linking research to teaching. Some characteristic extracts from their power point presentation are the following: *"how can we take into account the authenticity of the context in our design and teaching?", "it is difficult to manage classroom interaction if you are the only teacher in the classroom", "the students find difficult to understand the language in this type of problems", "it is difficult to follow your plan concerning the duration of the intervention"*.

In the second course, the PTs felt again that they had a chance to design an innovative teaching intervention and they reported that their knowledge about integrating the use of digital tools in their teaching was widened. In their presentation in the course and in their personal accounts of their work the PTs

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reflected on their experience and indicated the new elements of their knowledge about integrating IBL and workplace contexts in mathematics teaching as follows:

(a) The complexity of the cycle design-implementation-analysis in practice when it concerns the integration of IBL and WoW in the classroom of mathematics. The PTs appreciated the difficulty to make links between the original task and reality. Based on their experience with the task, they recognised that if the backyard had been designed to have a specific shape the problem could become rather demanding for the students in terms of mathematical exploration. The PTs mentioned in their final report: "*A realistic problem connected to a particular workplace provides a challenge for the students to explore it. However, students can be trapped as they have to take into account the real constraints as it was the case with the borders of the backyard that it was too difficult for the students to manage … thus, what we learned from this experience is that design, implementation and analysis are too difficult and complex in practice*".

(b) The critical role of the visual representations provided through digital tools in favouring students' engagement in conjecturing-inquiring-proving. The PTs appreciated the use of technology in influencing students' activity to more exploratory directions (*"The digital tools helped students to work with the problem visually, to make conjectures and prove them. When the students formulated one conjecture through the use of the tools, we asked them to prove it algebraically so as to strengthen their findings"*.

(c) The PTs' role as teachers in the intervention. The PTs were able to reflect on their own interventions to the group of students justifying their choice with references to the students' lack of familiarization with the functionalities of the software (*"In contrast to our previous intervention in the classroom, in this case our role was more directed because students were not familiar with the use of the software"*.

In the third course, despite the fact that PTs did not manage to provide scenarios that successfully linked content to the WoW, they were involved in an inquiry-based design of teaching scenarios. At the beginning, they complained that it is difficult to find a good video to use in their teaching. Finally they managed to produce plans of scenarios and tasks based on videos, that certainly were much more interesting than the usual routine teaching and felt a degree of satisfaction. However, their arguments for the value of their videos and scenarios reveal limited awareness of how school knowledge can be meaningfully connected to the WoW. However, some of the PTs came up with findings that showed that the school content is presented in a conventional form with small fragments of connections between subjects and the WoW and identified these missing elements. A characteristic extract from a PT's journal follows: "*The subject, Electrotechnology I, which we teach in the 11th grade, involves many topics related to other subjects, like physics and mathematics, and also to our everyday life. Specifically, when we talk about real technological establishments, e.g. solar panels, in our teaching, reference*

to the co-operation of electrical engineers, civil engineers and economists, as well as meteorological knowledge, whose participation is important for a successful establishment, is absent. These important aspects are omitted from their textbooks and the subsequent teaching." In another assignment the PT reports: "*I studied 9th grade biology curriculum and school textbooks. DNA helix is one of the most important topics. However, the school context presents the knowledge isolated from the importance of this knowledge for science, for specific workplaces, and professionals like criminologists. Identification of DNA in detection of crimes is a crucial procedure. Such a context could add students' meaning making concerning DNA.*"

## 5.3 Interpretation of PTs' activities

5.3.1 Commentary on the first and the second course

As regards the first course, in the initial part of their work the PTs read papers about IBL and students' geometrical thinking. In the design phase, the PTs had difficulty to link the theory and research to their intervention, but in the process of the course they realised its importance and were able to ground their research goals on existing research findings. However, the link between content specific studies and IBL was rather vague both in the design and in the analysis of the intervention. For instance, the arrangement of circles was seen by the PTs mainly as a way of covering a potential infinite plane rather than as a 'real' context providing constrains and limitations. Thus, in the design of the task and its implementation the PTs did not take into account the possibility to engage students in working with a model of a backyard whose sides have specific lengths. The targeted learning aim posed by the PTs concerned students' identification of the least uncovered area within the arrangement of four intersecting circles that constitute the unit of a particular arrangement. In their personal accounts of the implementation of the task, the PTs mentioned that their main aim was to help students conceptualise that a specific polygon created within circles (i.e. the unit of the arrangement) underlies the covering of the whole plane. As one PT put it:

"We wanted the students to understand the generalization to infinity, that is to say, the group of four circles is actually the constituting element of the whole (plane) that can be covered in the same way".

Also, IBL was not always evident in PTs' attention to classroom events in the analysis of their intervention. Overall, their main focus was on the modelling process and its relation to mathematics content as well as on students' motives to be engaged in inquiry. In their analysis and reflection the PTs seemed to pay attention to students' conceptual difficulties while IBL was investigated through students' written responses in a questionnaire given to them after the classroom intervention. Also the connection of the task to the WoW was rather weak as it remained only at the level of attributing the role of

a designer to the students. This is probably related to the nature of the original task and to the directions given by the teacher educator.

Figure 6.
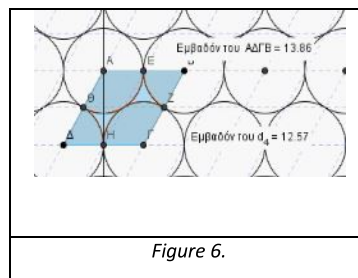
As regards the second course, at the initial part of their work the PTs read papers about the relation between school mathematics and workplace mathematics. Some of these papers were presented in the class and in the discussion followed issues about the tensions inherent in the connection between school mathematics and WoW emerged. As mentioned earlier, the PTs decided to keep the same problem in their design but to integrate in all phases the use of digital tools. In their analysis, they provided a detailed account of students' engagement in IBL in terms of horizontal and vertical mathematization emphasizing the role of the digital tools in meaning generation. For instance, in the initial part of their exploration in phase 4 to answer which arrangement was the best one (i.e. based on a square or a rhombus) the students conjectured that a square and a rhombus have the same area. One PT intervened and asked the students to test that conjecture. One student had the idea to design the height of the rhombus and realised that there is a difference between the two areas (Fig. 6). Then, through dynamically changing the angle created by the lines linking the centres of the circles the students were able to observe that the height was decreasing and, as result, the area of rhombus was decreasing. Finally, the students continued to prove this finding through their existing knowledge of geometry. In their analysis the PTs concluded: *"We conclude that the use of tools here helped students' vertical mathematization".*

As regards the WoW, the PTs in the second course appeared to be more sensitive in integrating aspects of WoW and the context of the problem in their implementation of the task and the respective analysis. For instance, after describing students' experimentation to construct perceptually a conjecture for the best arrangement (phase 1), they enriched their analysis by referring also to one student's making of links between his experimentation and the real context of the problem (phase 2). Particularly, after selecting the first arrangement (figure 2) the student commented that this choice is better *"if there is not an economic problem"* implying that this type of arrangement would be more expensive since more circular pave stones need to be used. Overall, the PTs kept an open eye to the emergence of the workplace throughout the students' activity. In their analysis they mentioned that the students worked from the beginning having in mind one particular ('real') backyard and often they expressed concerns about the accuracy of their

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covering. For instance, the students wondered if particular arrangements they tested were appropriate for backyards of different shapes. Thus, through this kind of students' experimentation the PTs realised that the problem could become rather complicated for the students if the backyard had specific dimensions (e.g., a rectangle with specific length and width) since in this case the best arrangement could be different according to the shape of the available space.

5.3.2 Commentary on the third course

Engaging PTs in inquiry based activities especially in courses with large groups is a demanding issue. A few of them produced scenarios similar to the examples that had been discussed in the course. However, through the organized tasks of this course PTs obtained experiences of inquiry for their own teaching design and managed to find sources and materials in order to produce innovative teaching scenarios. Not all of them, though, managed to develop inquiry based activities for their students. WoW is easily taken to be a practical activity or an everyday application in science teaching. The learning goals of their scenarios usually were general, while tasks required general knowledge with weak connections to the WoW and to the meaning of specialists' contribution. This seems to be PTs' main difficulty, on one hand to identify appropriate contexts for connecting the WoW with the school content and on the other the development of meaningful tasks promoting curriculum learning through the use of the WoW. In terms of classroom implementation, basic knowledge needed for tackling tasks that use situations related to the world of work, when is distant from current teaching, creates obstacles in students' successful engagement. PTs are not always able to support inquiry learning, even if inquiry tasks are involved in their designs. Finally, the use of videos in classrooms attracts students' attention and adds authentic aspects of the WoW that are missing from described contexts of the WoW.

The analysis of their scenarios revealed a number of limitations in terms of the presence of WoW, although their ideas were generally interesting in terms of teaching. The scenarios' context was often too broad, while the suggested videos were not always closely related to the learning of aimed concepts. In terms of inquiry, PTs' scenarios put limited emphasis on how students are involved in inquiry based learning. Tasks coming along videos usually were of a general nature and not closely connected to the context.

6 Emerging issues

In the three courses, the PTs seemed to have developed their professional learning about integrating IBL and WoW in mathematics and science teaching. The integration of WoW appeared to be more difficult for the prospective teachers than designing IBL tasks and developing a more inquiry stance in teaching. This is expected as the introduction of the WoW in teacher education courses is new while IBL is an approach that is more broadly supported

throughout their studies. The use or resources is another issue that emerged in all the three courses. PTs used research-based resources (e.g., research papers), hands on materials (e.g., coins, in the first course), digital tools (e.g., dynamic environments, in the second course) and internet resources (e.g., videos, in the third course). To identify or develop these resources and to explore their possibilities in mathematics and science teaching was not easy and required support from the teacher educators. However, PTs started to recognise their role in supporting mathematical and scientific inquiry and make learning meaningful.

Our findings pose new questions related to the nature of teacher education that promotes the integration of IBL and the WoW in the teaching of mathematics and science. PTs' courses need to be enriched with more specific examples of IBL activities related to the WoW. Normal curriculum and teaching neglect this dimension and PTs have to be enculturated in the teaching of mathematics and science that is meaningful for life and work. Teacher educators are demanded to offer clear guidance in order to support PTs to relate content knowledge to specific workplaces and life activities. This issue highlights two challenges that teacher education need to address: what school mathematics and science are necessary for life and work, but also what is the mathematical and scientific knowledge embedded in real life and work situations that can be involved in classroom teaching.

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6.4 Track 4: Professional learning communities

Using video recordings of ones own lessons – supporting teachers by coaching lesson development -

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1 The concept

1988 the Federal/State Commission for Educational Planning and Research Promotion (BLK) initiated a program called SINUS with the goal to increase the efficiency of teaching science and mathematics. This and various follow-up projects had the objective to realize sustainable development of lessons. In the process it became clear that it was less difficult to develop material such as tasks and problems, which are characteristic for a „good" lesson, than it was to change the scripts of teachers in order to influence their concept of teaching.

Two examples from the SINUS-program serve to illustrate how video recordings of one's own math lesson may be used to achieve sustainable professionalization. The findings are discussed based on theory and empirical data.

1.1 Example 1: About the possibilities to reason and argue in math lessons

Initiated by a teacher's question, coach and teacher together develop a unit, plan lessons and carry them out in class. Sharing the responsibility for this process, coach and teacher use the recorded lesson to reflect and evaluate the teaching habits and methods.
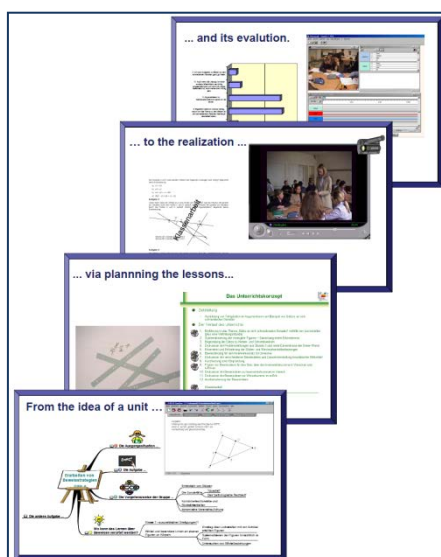

Figure 1

1.2 Example 2: A teacher: „I would like to analyse the quality of my teaching in a more differentiated way. Who can help?"

Again initiated by a teacher's question video-recorded lessons are used for evaluation. In contrast to example 1 this time the lessons is taped first. Based on the recording, coach and teacher discuss and analyse aspects of mathematical and didactic content. The coach supports the teacher in her/his process of reflecting upon her/his own lesson and in developing a course of action. First objectives and measures are agreed upon and put into practice by the teacher. The coach continuously supports the process of analysing, reflecting and helps to determine the next step. It is her/his responsibility to ensure stability to developmental process.
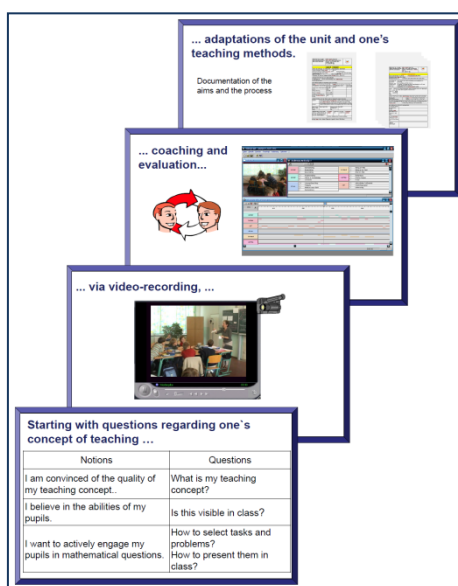

Figure 2

The exemplary processes shown above also serve to describe and reflect the role and the responsibility of the coach. Form the results a qualification module was derived to professionalize coaches and enable them to accompany and support teachers adequately in terms of content and didactics. The competencies that are deemed necessary for a successful coach will be described.

2 "Video-coaching" – Concept of qualification

The concept based on Approach discipline-specific and pedagogical coaching by Fritz Staub

2.1 Objectives and areas of expertise in focus: Acquisition of necessary competencies required of coaches:

- general pedagogical skills
- specific didactic content knowledge
- advisory expertise (in regard to advising individuals as well as groups)
- evaluation competence
- technical skills
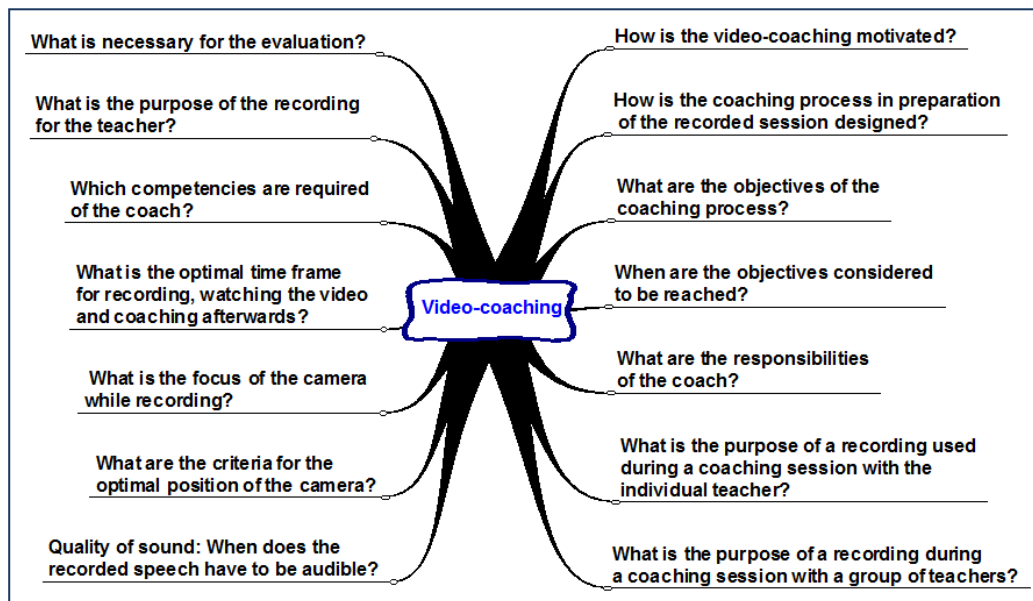
2.2 Video-coaching – vital aspects

Figure 3

2.3. Structure of the qualification process – alongside with the coaching process
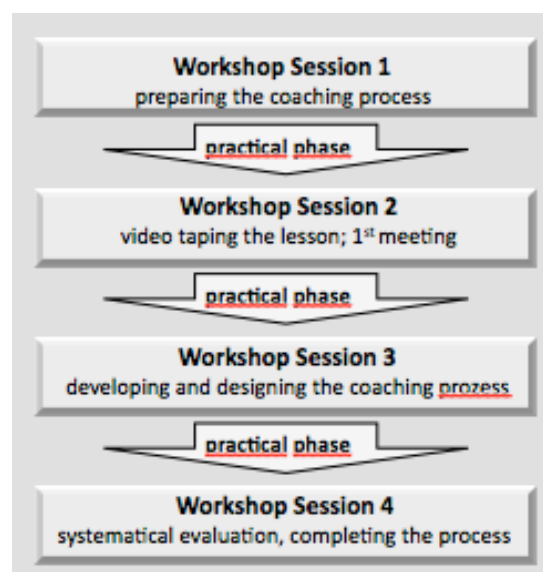

Figure 4

2.4. Achieving sustainability (based on the criteria for effective training by Lipowski, 2012)

- offer long term opportunities for active learning
- amplify pedagogical content knowledge and diagnostic skills of teachers focusing on the learning process of children
- foster awareness of self-efficacy
- effectively coordinate and align phases of input, trial and reflection
- focus on criteria for effective teaching methods
- provide feedback for teachers
- work in professional learning communities

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Teacher PD in the Czech Republic and implications of mascil -

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1   Historical background of the Czech education system development

The Czech Republic has had a long and strong tradition in the field of teacher education and their professional development for ages. Having started in the 16 century. Jan Amos Komensky (Comenius) (1964), an innovator, who called for universal education for all children of any social level, introduced textbooks in the native (Czech) language with pictures, examples and activities from real life, applied effective teaching based on the natural gradual growth from simple to more comprehensive concepts, supported lifelong learning and development of logical thinking opposing empty memorization, presented and supported the idea of equal opportunity for children, opened doors to education for women, made instruction universal and practical etc. His practical educational influence was threefold:

(1) he was both the teacher and organizer of schools;

(2) he formulated the general theory of education which was detected in works of Bacon, Descartes, Rousseau, Pestalozzi and others and summarized *Didactica Magna* (Great Didactics, approx. 1631);

(3) he influenced the subject matter and method of education, applied series of textbooks of a new type, e.g. *Janua Linguarum Reserata* (The Gate of Tongues Unlocked, 1631), *Orbis Sensualium Pictus* (1657) where illustrations to the work of teaching (relating to the world of work from the MaSciL point of view) were first published.

Followed by numerous others, e.g. Marie Teresie, G.A. Lindner, his principles have been applied in all successful (Czech) education systems, last but not least in Tomas Bata vocational schools where employees of the shoe producing company were prepared. All the above positive implications were unfortunately deformed and not developed in the period of socialism, i.e. 1948-1989. But it is necessary to explain that many enthusiasts were keeping high standard of teacher profession even in these times.

One of the sources which the intentions of the Czech Republic and other developed countries in innovations in educatio resulted from, was the International UNESCO Commission Report ´Education for 21 century Learning: the treasure within Vzdělávání pro 21. století Učení je skryté bohatství (Delors, 1996).

The report summarizes the lifelong education is based on four pillars which form the basis for setting the education curriculum and define how education should be understood:

- To learn to know, i.e. unify sufficient general knowledge and detailed knowledge in the field, benefit from education occasions within the course of life, to learn to learn.

- To learn to act, i.e. to acquire work competence, accept various situations, work in teams, act under different social conditions and work activities.
- To learn to live together, i.e. to develop understanding of other people, accept the idea of mutual dependency, manage conflicts reflecting values of pluralism and mutual understanding.
- To learn to be, i.e. to develop own personality and ability to act with autonomy, independent judgment, personal responsibility, to use the personal potential.

New orientation in education in the Czech Republic is reflecting the above mentioned four pillars. It mainly includes mastering methods how to learn, how to use new information and communication technologies, how to avoid overloading by information, to learn how to process information, change it into knowledge, how to apply knowledge, to think critically and evaluate information, how to work independently and in teams, how appropriately react to different opinions, understand mutual correlations, solve problems, act on independent judgments, how to take responsibility for own decisions etc.

New curricular concept based on these principles pays emphasis on key competences, acquiring attitudes and values, strengthening integration of learning and inter-subject relations, higher rate of differentiation and implementing new topics. Taking into account the transformation of primary education in the Czech Republic and new Framework Education Programme for Primary Education (RVP ZV), the pre-service teacher preparation at the Faculty of Education, University of Hradec Kralove, was substantially innovated.

After the Velvet revolution in 1989 events in the Czech Republic evoked changes in all spheres of the society and the system of education has been changed reflecting not only professional but also social aspects, e.g.

- general development towards democracy and information and knowledge society transformed the existing structure of the educational system;
- new competences were defined which reflected the new learning content;
- new teaching methods, organizational forms, ways of evaluation were introduced;
- new relations between elements participating in the educational process were set; subjects as Humanities, foreign languages, Informatics, Environmentalistics were emphasized;
- learner´s responsibility for his/her own education, creativeness and motivation were required;
- economic aspects of education and competitiveness had to be taken into account;

- and last but not least the call for lifelong education appeared (Šimonová et al., 2009).

These features are slowly but steadily being included into the new educational system and curricula, which are hardly to be imagined without the ICT implementation. Both the learners´ and parents´ interest in the quality of education sharply increased but has been slowly declining since. Foreign languages and humanities belong to fields where learners´ interest and attention are paid to; on the other hand, science and mathematics are on the opposite side. To change this state and support learners engagement in these demanding fields is one of the MaSciL targets for the Czech education system. Such a new approach does not only mean adding new aids, methods, forms to the existing ones; it requires revision of the whole system and active Maths and Science teachers using attractive and efficient teaching methods may support substantially to the process (Bílek, 2005).

2 Czech education system: traditional versus new approach

For decades the pupils´load covered compulsory subjects (mother tongue, foreign language(s), Maths, Physics, Biology, Chemistry, Geography, later on e.g. ICT, environmentalistics, music, art, physical and technical education etc.), facultative subjects (reflecting learner´s interest) and after school activities, so any field of interest could be included in all three areas. The long-time intention of education and development of the Czech education system (2007) was approved in May 2007.

As previous documents, it was based on the National Programme of Education Development in the Czech Republic (called White Book), from analytical-conceptual materials prepared by the Ministry of Education ´Czech Education and Europe: strategy of development of human sources in admittance to EU´ (1999) and discussions of Ministry of Education with regional deputies, social partners and other resorts. It has become the tool of longitudinal horizon of development for the period of 7 - 10 years, which is worked out in detail for the period of 3 - 6 years. The longitudinal intention in objectives of strategic changes in education again emphasizes changes on the order of current school priorities (forming attitudes, developing skills and knowledge, key competences which mainly include tools and technologies and mechanisms of learning, work with information, critical thinking, communication and social skills). It understands further social development in realization of lifelong learning for everybody and gradual change of our society into the learning society.

New concept of the education content then contains following objectives (Dlouhodobý záměr vzdělávání a rozvoje vzdělávací soustavy ČR, 2007):

- Transition from acquiring of large amount of facts to the development of key competences for life.
- Strong emphasis on instruction of selected fields, topic, mainly:

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- foreign languages,
- information literacy,
- citizen literacy.

- Inner differentiation and individualization of education reflecting special needs of children.
- In professional education the development of study programmes with wider professional profile.

Just the development of information literacy and information and communication technologies implementation has become a key field where changes in objectives and learning content were applied on all levels of education. New factors having influence on the dissatisfactory situation were identified:

- Limited equipment of schools with technologies, mainly limited access to the Internet.
- High expenses of the Internet access in schools.
- Low average level of computer literacy of teachers and low will or limited conditions to overcome this state from teachers´side. Thus the efficiency of information and communication technologies is limited even in those schools which are equipped with technologies.
- Insufficient conditions in personal state of IT development in schools.

As mentioned above, the indispensable precondition of success is consistent implementation of the information literacy development into the prepared state programme and framework education programmes.

In the new approach on the state level the National Education Programme (NEP) works as a basis of Framework Education Programmes (FEPs) which are reflected in School Education Programmes (SEPs) on the school level. The Framework curriculum for primary and lower secondary schools then includes not only compulsory subjects (Languages, Maths, Biology, Chemistry, Physics, Music Education, Physical Education etc.) but also educational areas, it means e.g. Maths and its applications, Man and his world, Man and Nature, Man and Health, Man and world of work etc. On the lower secondary level Maths and its application is taught six hours per week, while Man and Nature, which covers subjects matters of physics, chemistry, biology and geography, has 22 hours per week as minimum. Above all, several cross-curricular topics are included, e.g. Education towards democracy, Education to personality and social development and adaptation, Environmental education, Media education, Education of EU and global citizens, Multicultural education etc. Several new topics appeared – Financial literacy, Ethics education.

3 Teacher training in the Czech Republic

Being based on a long tradition, and in the contrary to Bologna process requirements, the master level education is required for any teaching position in the Czech Republic. The ways how to reach the qualification may differ in relation to the level of education the teacher works (Kohnová et al., 2012).

3.1 Pre-service teacher preparation

Teachers for primary school (grade 1 – 5) study at faculties of education for 10 semesters structured in 5 academic years being specialized in a foreign language (mostly English or German), physical education, arts, music, ICT, environmental education etc. They reach M.A. degree.

Teachers for lower secondary schools (grade 6 – 9) also study mainly at faculties of education for 10 semesters structured in 5 academic years being specialized in one or two major general education subjects. Both groups of teachers can study either three-year bachelor study programmes followed by two-year ones for M.A., or five-year study programmes as M.A.

Two ways to reaching the level are provided to upper secondary school teachers (grades 10 – 13): (1) teachers of general education subjects are prepared in master study programmes – M.A. (commonly in two subjects), either combining the three-year bachelor and two-year master study programme, when the theoretical and practical preparation is included; (2) teachers of vocational (professional) subjects often have the professional degree in the field taught, or relating to (engineer, M.Sc.) which is supported by additional pedagogical study (1-2 years, or bachelor pedagogical study programme B.A.).

The teacher training is an obligatory part of pre-service teachers´ preparation. The primary school teachers have the training in each year of their study (totally it is nine types of training, e.g. teaching in blocks in the first grade, training as teacher assistant, teaching in alternative schools etc.). Lower and upper secondary school teachers have training in six subjects, i.e. observation of experienced teachers, running and continuous teaching etc.). Within the training students

- have four weeks of teaching at primary or secondary school, 50:50 at each level is optimum, but exceptions can be discussed and accepted by the responsible teacher - didactician;
- send the timetable to the responsible teacher , including number f lessons, school, subject and dates of training, immediately after the beginning of training;
- teach 24 lessons in one subject, i.e. totally 48 lessons in both subjects (for the supervising subject teacher at the school where the training is held this is maximum to be paid);
- is trained in both subjects in the same institution;
- write the training diary containing preparations for lessons, observation reports, analyses reports, list of other activities they participated in the

school etc., and the supervisor evaluation in the questionnaire form and decision whether to s/he recommends to give the student credits for the training.

- gets acquainted with necessary documents and relating administration, safety regulations, learners´ evaluation programme BAKALÁŘ.

3.2 In-service teacher professional development

The in-service teacher professional development includes both the field and didactic preparation. Faculties (teacher training faculties, faculties of science, faculties of arts etc.), methodological centres, education institutions, companies and other entities prepare teacher training courses. Despite the career development system is still missing in the Czech Republic (being under preparation for ages), the courses have to be accredited by the Czech Ministry of education. Teachers attend them mainly in their leisure time without any reimbursement, or on cost of school which receives small financial support for such activities from the Ministry of Education, and the final decision on recognition is made by the headmaster, i.e. it may differ in two schools.

Totally, three main types of professional development are provided to pre-service and in-service teachers:

- study towards reaching qualification requirements;
- study towards reaching further qualification requirements;
- study towards widening the professional qualification reached before. MaScil project is supporting this field.

At the Faculty of Education, University of Hradec Kralove, new courses for teacher PD (in-service teacher education) were prepared for accreditation of Ministry of Education, being based on materials created within the MaSciL project. Courses focus on all three levels of teacher profession, i.e. the primary, lower and upper secondary school teachers. The main objective is to explain the participants principles and application of inquiry-based instruction in Maths and Science on each level of education, mainly focusing on topics Maths and its applications, Man and Nature, Man and Health, Man and world of work. The courses aim at forming and developing knowledge and practical skills in inquiry-based instruction in each subject and perform possibilities how to use the ICT in the inquiry-based instruction. The course content is structured in eight lesson of prime instruction and twelve hours of self-study including the teaching practice of the participant. To receive the certificate, course participants have to write and defend a seminar work presenting the design of the inquiry-based task (experiment) in the subject they teach. After finishing the course, the graduates´ feedback will be collected, i.e. they will evaluate the course they attended from the point of professional content, work of lecture and organization.

Samples of course topics for primary school teachers:

1) IBL principles in relation to the Framework education Programme.
2) Methodology of the IBL implementation to the primary school curriculum.
3) The level of IBL and examples for preparation, evaluation and realization of the process of instruction on the primary school level.
4) Confirmation inquiry as the first level of IBL - applications to instruction.
5) Structured inquiry – applications to instruction.
6) Guided inquiry – applications to instruction.
7) Open inquiry – applications to instruction.
8) The use of ICT in IBL.

4 Future concept and expected results

Taking into account rather low interest in the in-service teachers professional development courses organized by tertiary institutions in the Czech Republic, we hopefully expect teachers´ approaches to be changed in case of newly designed courses based on MaSciL project concept. The planned institutionalized teacher professional development guaranteed by the Ministry of Education is to support this result.

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Professional qualification of teacher tandems conceptually combined with lesson development -

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The concept

Teacher trainers, who educate teachers and accompany and support processes to enhance lesson quality and curricular development, need conceptually appropriate qualification modules. These modules have to address mathematical content knowledge and pedagogical knowledge. Additionally they have to bear in mind the continuous enhancement of lesson and curricular quality.

The exceptionally diverse teaching staff of Berlin, teaching primary levels from grade one to six, makes it necessary to develop qualification modules for teachers that cope with that diversity. The teaching staff differs in various areas: mathematical content knowledge, pedagogical content knowledge as well as experiences in teaching on a primary school level.

Taking this necessity for teacher in-service training and educational policies (issued by the state) into account, the German Centre for Mathematics Teacher Education (DZLM) designs training concepts which focus not only on professional qualification in terms of mathematical content knowledge, but also on the didactical implementation in the classroom. To ensure sustainability and a continuous process of improving lesson quality, the training modules call for teachers of primary schools to work in tandems. The qualification program allows them to act as experts and multipliers not only within their school but also within their school district. Working within a professionalized teaching community is also part of the qualification program. Since August 2012, department one (primary school level) and department A (multiplier and teacher qualification programs) of the DZLM in cooperation with the Berlin's Senate Department for Education, Youth and Science have designed several qualification workshops for teacher-tandems of Berlin's primary schools. The mathematical contents from a didactics perspective are:

- Stochastic in primary school: data, frequency and probability
- Geometry
- Practical problems: scaling and measuring
- Numbers and arithmetic operations

The courses have been conducted these since February 2013. The poster presents the concept which serves as the basis for the mathematical and pedagogical qualification modules which address not only qualified teachers of mathematics but also those who majored in different areas but teach mathematics nonetheless. The poster gives an overview of all workshops offered currently. Each of the qualification modules is designed as an in-service training program and is scheduled over one school term. It consists of

four workshop sessions and three practical work phases - one in between each workshop session.

Illustration: Workshop "Stochastic in primary school: data, frequency and probability"

The workshop "Stochastic in primary school: data, frequency and probability" serves as an example to illustrate how content knowledge and pedagogical (content) knowledge may be professionalized in order to stimulate and support lesson and curriculum development.

During this course participants were immersed in a learning environment in order to:

- develop and prove their understanding of stochastics and its different stages of development in mathematical education,
- work in and as part of professional learning communities and
- develop (in cooperation with their trainers) teaching materials, that may be used in class by themselves and their colleagues.

Overview Workshop sessions

Session 1: Introduction – Stochastics in primary school, descriptive statistics

developing a professional learning community (PLC)

Session 2: reflecting the practical phase; combinatorics;

working in and as a PLC – objectives, ways of cooperation, process

Session 3: reflecting the practical phase; coincidence and probability

working in and as a PLC – objectives, ways of cooperation, process

Session 4: reflecting the practical phase; stochastics in primary school – in the overall course of mathematical education grades 1 through 6 reflecting PLC and considering further implementation in school and school district

Three practical work phases

Phase 1	Phase 2	Phase 3
Gathering and presenting data carry out a mathematical exercise to deepen understanding development, implementation and documentation of a lesson PLC: document the process, analyze the cooperation within the school	Combinatorics carry out a mathematical exercise to deepen understanding development and implementation of a specifically designed learning environment, documentation and reflection PLC: mutual in-class visits, exchange of ideas and observations; present experiences to other colleagues	Determine, illustrate and compare probabilities carry out a mathematical exercise to deepen understanding development and implementation of a designed learning environment, documentation and reflection PLC: mutual in-class visits, exchange of ideas and observations; strengthen the PLC: phrase objectives and plan further steps

Impressions and examples

How to deepen and expand content knowledge

Each session is followed by corresponding tasks for the practical phase. Literature and bibliographical references are provided on a Moodle-platform.

Figure 1 explaining probabilities http://kira.dzlm.de

How to deepen and expand pedagogical knowledge

Units and tasks are developed, tested and evaluated focusing on the contents of the workshop. The process is documented.
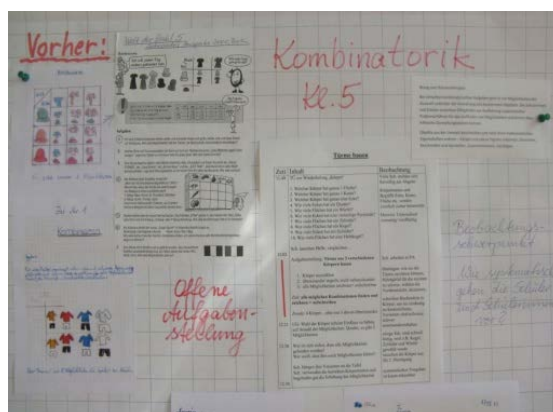
Figure 2 example of document

Professional learning community (PLC) at work

Figure 3 sharing results of a practical phase

Figure 4 documentation of a mutual in-class visit

All courses are evaluated by the DZLM. Some crucial results of these evaluations are presented on the poster.

Figure 5 Feedback after a workshop session
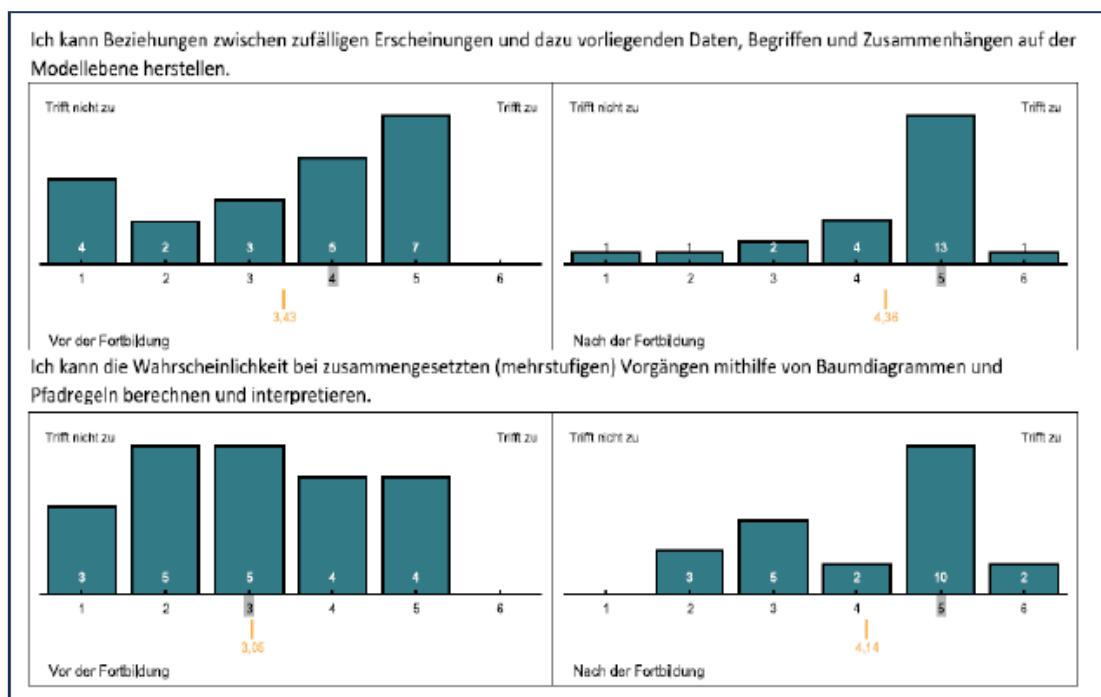
Figure 6 self-assessment with regard to mathematical learning objectives
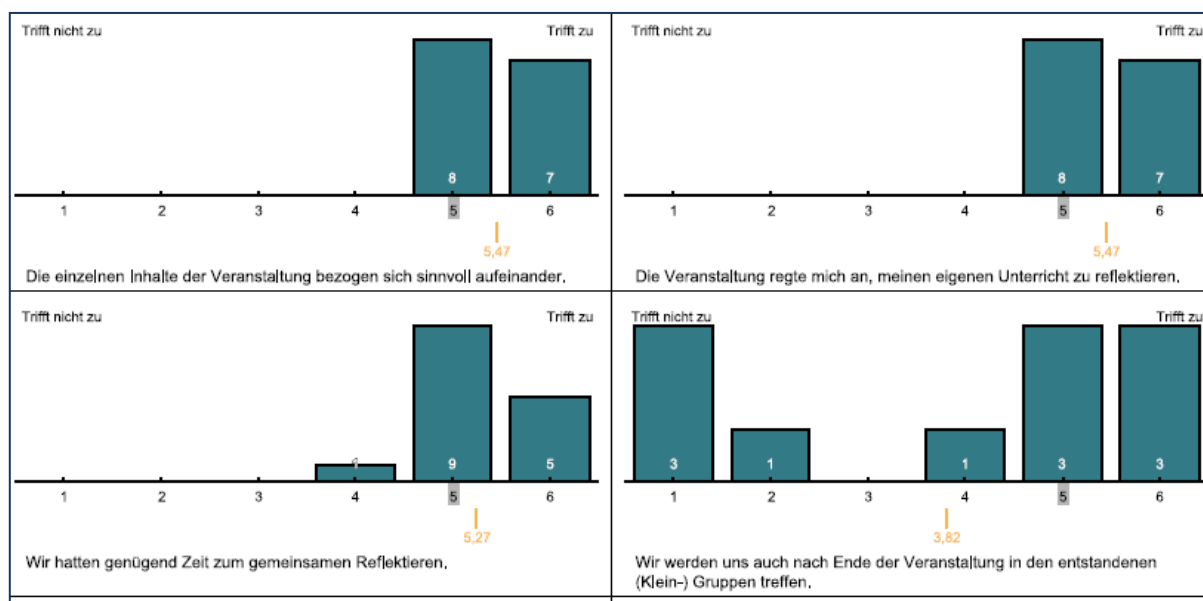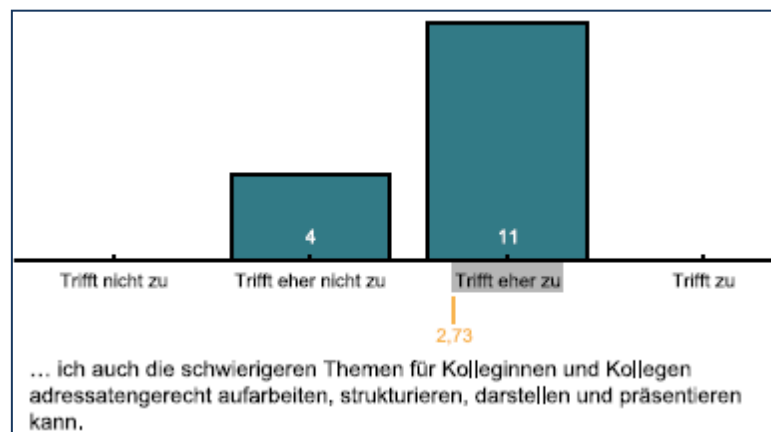
Figure 7 and 8 concept design of PLCs – how to continue the cooperation

The concept presented, plus the experiences with implementation and results of the evaluations could be the foundation of a (trans-)national exchange aiming to develop and design qualification measures, to ensure their sustainability and thereby contribute to the systematic enhancement of lesson and curricular development.

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Competencies in Mathematics and Science Education (CMSE): A programme promoting in-service teachers' professional development -

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1   Introduction – the starting point of CMSE

The Austrian Ministry of Education set up several measures as reaction to the low results in international student assessment studies like TIMSS or PISA: On the level of systematic monitoring, one strategy was to implement educational subject specific standards to change the focus of the educational system from input to output orientation (Weiglhofer, 2007; Haagen-Schützenhöfer and Hopf, 2012). Another initiative launched was a project to support Innovations in Mathematics, Science and Technology Teaching (IMST: Innovations in Mathematics and Science Teaching).

The programme Competencies in Mathematics and Science Education (CMSE) is one strand of the IMST project dedicated to instructional innovations and teachers' professional development. CMSE was established by the Regional Centre for Didactics of Physics at the University of Graz in 2010. The core idea is to simultaneously intervene at the teacher and at the student level by providing a support system of teacher trainers and science education researchers. At the student level, CMSE aims at the improvement of students' subject specific competencies in Mathematics and Science subjects (Krainer and Senger, Andreitz, 2013; Mathelitsch, 2013). In order to achieve improvement on the students' level, this programme was set up to support science and mathematics teachers from different school types in implementing teaching innovations in the field of subject specific competences. The framework of CMSE was designed to initiate professional learning communities among the participating teachers. The aim is to support them to shift their teaching practice from input orientation to output orientation by integrating the concept of subject specific competencies in their instructional practice.

2   Operational levels of CMSE

Classroom or school projects proposed by the teachers themselves function as the vehicle for the sustainable changes aimed at the level of teachers and their professional development as well as at the level of students' subject specific performance, interest and motivation. The philosophy behind this approach is clearly bottom-up and makes sure that teachers are not doomed to apply in their instructional practice what external experts like science and mathematical educational researchers define as solutions and strategies for problems and challenges arising from very individual and local school and teaching settings. The IMST philosophy can rather be summarized as "help for self-help". Challenges are addressed joining the profound expertise of

teachers about their individual schools and teaching contexts together with external experts. So to speak the teacher always functions as promotor being part of the solution.

On the student level these classroom projects are designed to promote the progression of a clearly defined set of subject specific competencies within one school year. However, to also promote professional development, the teachers do not only carry out their projects as teachers, but they take a dual role as teacher and researcher conducting action research (Dorner, M., Langer, E., Mathelitsch, L. and Rechberger V.; 2014; Altrichter et al., 2013) on their teaching interventions (cf. Figure 1).

Teachers start with analysing their actual teaching practice which is the starting point for setting innovative goals for a change. Innovative school projects function as vehicle for these intended changes. The school project is the subject of the action research carried out by the teachers. Within this process, teachers work in small focus groups, where they analyse and reflect their teaching practice and their innovations guided by their coaches. These two components, the self-reflexive cycle initiated by their dual role (cf. left part of Figure 1) as well as the meta-reflection and guidance in the focus group (cf. right part of Figure 1) empowers them as reflective practitioner and contributes to their professional development, which retroacts on the implementation of the chosen innovation and in the long run on their teaching practice in general.
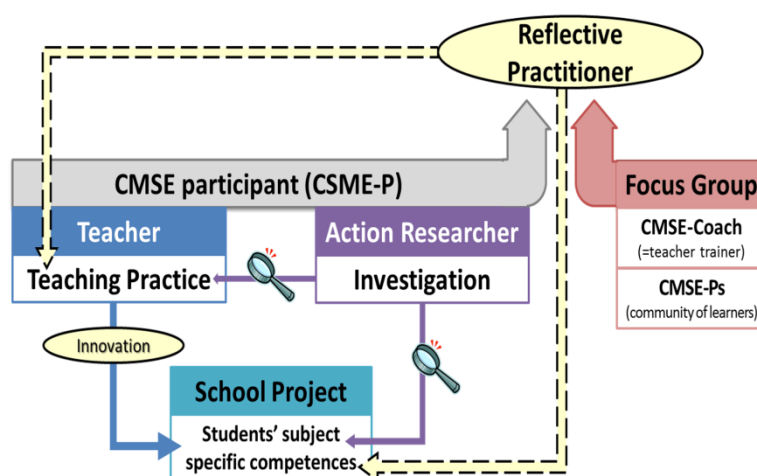
Figure 1: Empowering participants as reflective practitioners

3 The concept of CMSE compared to conventional professional development courses in Austria

The added value of the CMSE concept compared to conventional professional development courses is manifold: Firstly, teachers have to apply for their participation in CMSE themselves. They have to submit a proposal in which they outline a classroom or school project that aims at implementing a teaching innovation related to subject specific competencies. Projects can be carried out in STEM subjects and with students at all age levels, from primary

up to upper secondary level. The project submissions are reviewed by external educational experts from the German speaking community and by CMSE staff (cf. Figure 2). The teachers get feedback to their proposals and are finally chosen based on the output of this double review. Only 20 projects per year can be accepted for the programme. This is about half of the number of applied projects.
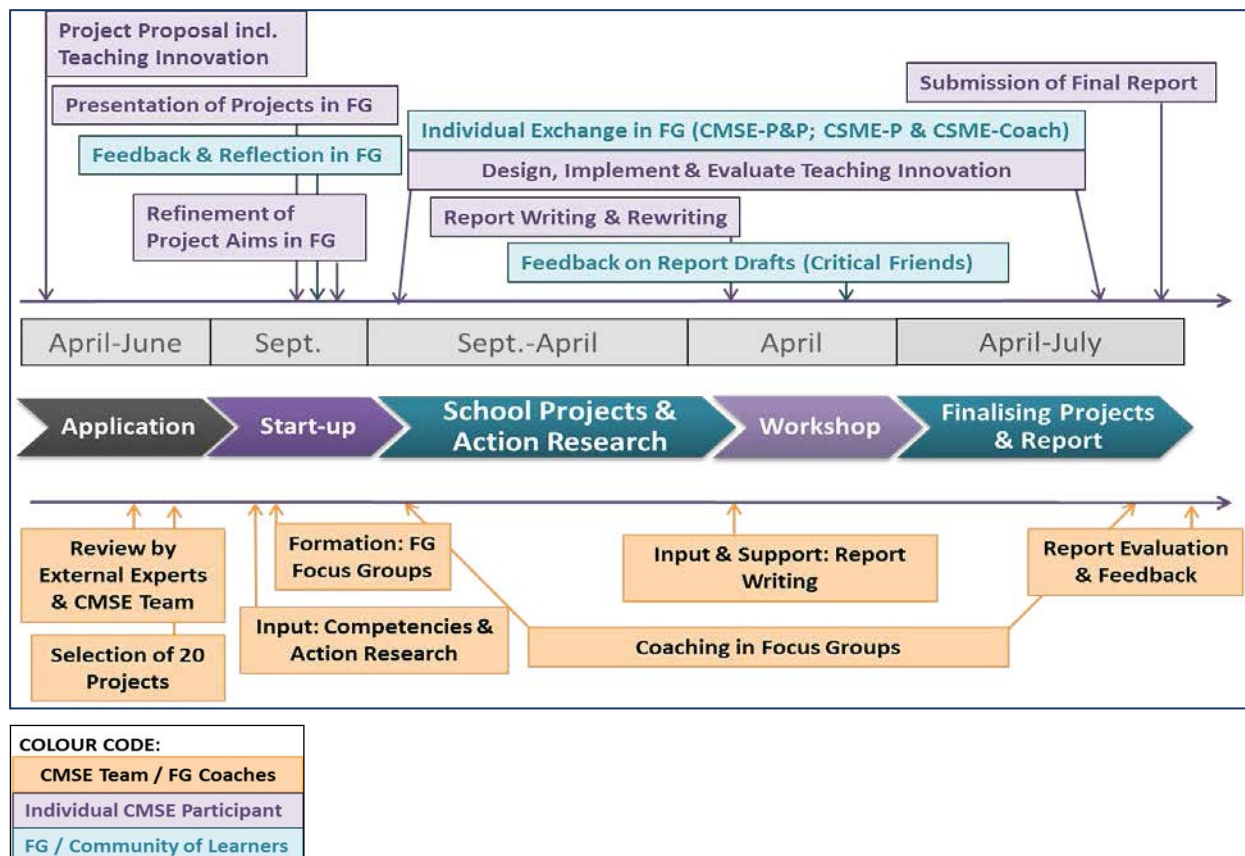
Figure 2: Structure of the CMSE programme

Secondly, teachers do not only get input from teacher trainers as in conventional PD courses, but they work on their individual teaching practices, carrying out action research on their teaching innovations. This process is guided and accompanied by teacher trainers in small focus groups. So, CMSE directly intervenes at the teaching practice.

Thirdly, CMSE is a long term measure contrary to conventional PD courses in Austria which usually last from half a day up to two days. Contrary, in the CMSE programme teachers are supported for one year. All CMSE participants meet two to three times a year for face to face meetings lasting for two to three days (cf. Figure 2).

Additionally, the structure of CMSE does not only allow teachers to form communities of learners but explicitly supports and promotes the exchange of ideas and experiences, common reflection work and mutual support among teachers. CMSE teachers work – depending on the focus of their school

projects – together in small communities of practice, which communicate and exchange between the face-to-face meetings via different modes.

Finally, the role of the learning communities is also essential in the phase of writing the project report (cf. Figure 2). Each teacher has to document his or her school project, evaluate it and at the same time reflect on his or her teaching practice and its development during the teaching innovations and interventions carried out. Members of the established learning communities take the role of critical friends, promoting their colleague's reflection process and support them during the task of report writing.

4 The structure of interventions during a CMSE cycle

The following section focuses on some stages within the CMSE cycle.

4.1 The start-up workshop

After succeeding in the application phase, the CMSE participants meet for the first time at the end of September at the start-up workshop (cf. Figure 2), which lasts for two days. The aim of this start-up is to make participants familiar with the IMST philosophy and to provide them with new impulses for their projects. The start-up begins with a presentation of all five topical programmes of IMST including the introduction of very successful projects of the last project year. This phase of the start-up is to accustom the participants.

After this very general introduction and overview phase, each topical programme group works together in their topical programmes for the rest of the start-up. In the CMSE workshop we treat organisational issues concerning project management, followed by input on subject specific competences, competence models as well as aims and benefits linked to a competence oriented instruction. After that CMSE team members work with the participants on their individual project aims, fine tune them and deduce a first rough set of evaluation strategies.

The second day of the start-up is dedicated to the formation of focus groups. The focus groups are proposed by the CMSE team. Each focus group consists of four to seven participants and is coached by two coaches. In the focus group each participant presents his current working version of the project, focusing on project aims, corresponding instructional measures and first ideas about evaluation. Within this session the participants get feedback and hints of the focus group coaches and of the other participants.

4.2 Collaboration in Focus Groups

After the start-up the teachers are supported by their focus groups in the implementation of their project. The focus group functions as "critical friend", supporting each other in the project implementation and with reflection work. The focus group operates in different modes. There are interim face-to-face meetings of some or all group members with the focus group coaches,

materials and interim reports are exchanges or participants visit each other in their schools. In this phase, when the project is carried out on the level of instruction, the teachers operate in a dual role, as teachers but also as action-researchers, investigating their own teaching practice as well as the teaching output in terms of their students' competences. This action research work carried out in combination with the reflection work done, promotes their development as reflective practitioner, which again is supposed to influence their teaching practice on the long run.

4.3 The writing workshop

The final phase of the CMSE year is dedicated to writing a final report (cf. Figure 2) which describes the project, starting from the teachers' motivation, the aims pursued by the innovative school project, the interventions carried out as well as the design of the evaluation and its results. This final report is prepared by the implementation of various scaffolding strategies during the year. In addition, all CMSE participants and coaches meet in April for three days. There, the participants get specific input on data analysis and academic writing. The most of the time of this workshop is however dedicated to individual counselling and support. At this stage the professional communities play a crucial role. Participants support each other by reading their drafts and giving feedback as critical friends.

5   Experiences of the first years of CMSE

Evaluation on the level of teachers and on the level of students was carried out for each year of the CMSE project. Results of the first project year showed that it seems to be difficult for teachers to focus on one subject specific competence they intended to promote in their teaching. Some teachers were so enthusiastic about their projects that they got lost in the plentitude of goals they wanted to achieve. While in the first project year the focus groups were formed according to school types, in the second year of the project the focus groups were build according to competencies which the individual projects focused on. This kind of group formation turned out to be essential in order to establish effective communities of learners.

In this second year, exchange did not only take place between teachers teaching the same subject at the same type of school, but also involved teachers from different school types and levels (from primary level, to upper secondary level) and from all science subjects as well as mathematics. This turned out to be an additional benefit for all participants. The heterogeneous learning communities did not only help to initiate the exchange between different science subjects and subject cultures, but they also established and supported mutual understanding.

Within the year teachers participate in CMSE, they get the opportunity to cross boundaries of subjects, subject cultures and school types. This change of perspective does not only help teachers to learn from each other but also to

develop mutual understanding for the needs and challenges of their colleagues. This insight into other school types and/or subjects is likely to facilitate students' problem when progressing from one school type to another.

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Professional Learning Communities: What are the important questions for an educator to ensure a sustainable community? -
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1 Introduction

The Educating the Educators conference was aimed at connecting international researchers and practitioners engaged in teacher professional development in mathematics and science education. This paper was presented by an Australian mathematics educator who works at a university and also for an institution that provides professional development for teachers. The presentation focused on the questions that educators might need to ask to ensure they provide meaningful professional development for teachers. Meaningful professional learning needs to improve both mathematical content knowledge and mathematical pedagogical knowledge and promote the development of sustainable professional learning communities. Attendance at this international conference provided an opportunity for an Australian mathematics education teacher educator to talk with international researchers and staff involved in teacher education centres from many different countries. Responses continue to be sought to questions such as:

- What are the features of successful concepts and professional development (PD) and does this change depending on the country?
- What are the similarities and differences in expectations of participants in the international professional learning communities?
- What are the needs and experiences of the different target groups - teachers, Principals and teacher educators?
- Which pitfalls have to be avoided in the provision of successful and sustainable professional learning communities?

2 Context: An example from Melbourne

According to Cole (2012): "Professional learning is the formal and informal learning experiences undertaken by teachers and school leaders that improve their individual professional practice and the school's collective effectiveness as measured by improved student engagement and learning outcomes" (p.4). As a mathematics educator I have been providing professional development to teachers for more than twenty years (See for example, Pearn, 1999). Professional development is usually in response to requests from schools and could vary from a single session of 1.5 hours to up to 10 days a year for several years. Over this time some professional learning communities were formed and sustained until changes of school personnel resulted in them being abandoned. Key to the sustainability of successful learning communities appeared to be strongly linked to the length of time the mathematics educator was actively involved in providing ongoing professional development and

whether the ongoing professional learning was embraced, and supported, by the school leadership team as well as all teachers in the school.

Currently the author is employed in two part-time positions. One position is as a mathematics education lecturer at The University of Melbourne where she teaches in the postgraduate programs of Master of Teaching and Master of Education. She is also a Senior Research Fellow for the Australian Council *for* Educational Research [ACER] Institute which provides professional development for teachers and educators both locally and internationally. While these appear to be two separate learning communities, being part of both communities has had a positive and important impact on both the teacher educator and the learning communities with which she has been associated.

To assist with the implementation of the Master of Teaching program at the Melbourne Graduate School of Education school-based university-based lecturers are employed as Clinical Specialists to support students undertaking the Master of Teaching courses (Teacher Candidates). As a Clinical Specialist the author links university theory and classroom practice while supporting Teacher Candidates who are based in schools two days a week for an extended period before undertaking block placements. A key part of the Clinical Specialist role is to build an ongoing relationship with the Teacher Candidates, the university and the Partnership School Group communities that include teachers, students and parents. It has taken many years to build the trust of the school communities so that as a Clinical Specialist the author is seen as part of the learning community as 'a respected and critical friend'. Building trust with all groups within the school community has taken a considerable amount of time and involved providing professional development for staff and information nights for parents.

As a Senior Research Fellow at Australian Council for Educational Research the author provides professional learning for experienced teachers on behalf of the ACER Institute. The content of programs and workshops are based on both research, and classroom experiences, in primary and tertiary classrooms. Much of this professional learning is in response to tenders commissioned by the Department of Education and Training (previously known as the Department of Education and Early Childhood Department) that offers learning and development support, services and resources for all Victorians, from birth through to adulthood. The author has been responsible for the writing and implementation of professional development programs such as: *Effective Mathematics Teaching in Primary Classrooms*, *Effective Teaching of Number in Secondary Classrooms* and *Leading Conversations about Student Work*. In 2013 four intakes of an eight-day program, *Leading Numeracy,* was presented for the Bastow Institute of Educational Leadership.

As a mathematics education lecturer and Clinical Specialist at the university, information gained from the professional learning communities, impacts on the courses I provide, the research I conduct, and the professional learning I deliver to experienced teachers through the ACER Institute. As a Senior Research Fellow at ACER, information gained from my writing and

presentation of professional development for the Department of Education and Early Childhood Development [DEECD] impacts on the classes I present at the university.

3 Professional Development Programs

This section will focus on recent professional development programs presented by the author on behalf of the ACER Institute for the Department of Education and Early Childhood Development [DEECD]. In all of these programs teachers attending courses were encouraged to attend with other colleagues from their school or a neighbouring school. Our work has confirmed that the maximum impact is achieved when several teachers (either from a single school or neighbouring schools) take part in a Professional Development program and form a 'learning community'. We have also found that these learning communities are sustainable when the whole school community has a common aim, teachers are supported by the Leadership team, and all members share the experience and passion of being involved in a clearly defined project.

Two professional learning programs were specifically designed for classroom teachers and supported by the Department of Education and Early Childhood Development [DEECD]. Teachers were encouraged to attend with at least one other colleague from their school for the two programs: *Effective Mathematics Teaching in Primary Classrooms* and *Effective Teaching of Number in Secondary Classrooms* so that they could share their learning in their school. As the titles suggest *Effective Mathematics Teaching in Primary Classrooms* was a professional learning program designed for Victorian primary mathematics classroom and *Effective Teaching of Number in Secondary Classrooms* was a professional learning program designed for Victorian secondary mathematics classroom teachers to support them to build their capacity to improve student learning outcomes in mathematics. Another course for secondary teachers was offered that focused on the effective teaching of Algebra but was presented by other consultants. There was an expectation that teachers would share their learning with colleagues on their return to their schools. There was no evidence that this actually occurred.

The *Leading Conversations about Student Work* professional learning program was designed for school leaders to encourage and develop peer-to-peer collaboration and accountability in the analysis of student work. Schools were given a grant by the Department of Education and Early Childhood Development [DEECD] to support their attendance and included time required to plan, engage and evaluate the moderation process. This program encouraged participants to implement new or enhanced moderation processes in their schools through a developed understanding of assessment and moderation. It also supported the teachers' ability to lead quality conversations about student work within their school communities. Two teachers from each school were expected to attend and Principals were expected to actively support their staff by "giving them the authority to implement new or enhanced

moderation processes in their schools". The presenters offered further support in the form of school visits and professional development sessions in schools.

4 Professional Learning: Catering for different needs and starting points

A new Australian curriculum has recently been introduced. This replaces previous curriculum offered by the individual Australian states and territories. One of the General Capabilities in this new curriculum is Numeracy where Numeracy: "encompasses the knowledge, skills, behaviours and dispositions that students need to use mathematics in a wide range of situations. The Numeracy learning continuum identifies the related mathematical knowledge and skills, and contextualises these through learning area examples" (ACARA, 2014). One of the difficulties mathematics educators face when delivering professional learning is the fact that the terms 'Mathematics' and 'Numeracy' are used interchangeably by teachers, schools, and school systems in Australia.

The *Leading Numeracy* course was designed to support school and teacher leaders to create and sustain the organisational conditions that enable teachers to become effective numeracy teachers. The ultimate goal was to improve numeracy learning and standards of achievement for all students (Bastow, 2012). The development of the participants' knowledge of these change processes was intended to increase their ability to lead change to support whole school improvement and teachers' numeracy instruction.

The Leading Numeracy Program

In 2013 the *Leading Numeracy* course was offered over eight face-to-face days, with each of the four topics being delivered over two days. The overarching expectation was not only the inclusion of relevant numeracy/mathematics content for these topics but the focus on developing the leadership skills for all participants. The four topics included:

- Reviewing current numeracy achievement and teaching practice;
- Building teacher capacity in teaching numeracy;
- Building teacher capacity to link assessment with instruction;
- Enhancing teacher knowledge and building teacher capacity in numeracy instruction.

There were four intakes of *Leading Numeracy*, one program was offered in Semester 1 and three in Semester 2. The range of leadership skills and mathematical content knowledge of participants in each intake varied. Some participants had chosen to attend the course while others were instructed to attend. Those that chose to attend started building their professional learning communities on Day 1 while those that had been directed to attend reluctantly joined learning communities. Table 1 shows the range of participants' school types. The participants in Intakes 1, 3 and 4 were mainly from primary schools

and included participants from Special Settings such as Developmental Schools with small numbers of participants from secondary, middle years or P – 12 settings. The participants from Intake 2 were mainly from secondary schools.

Compulsory education in Australia starts at the primary level, usually when children are aged five. Depending on the state/territory primary education lasts six or seven years. Secondary school (called high school) starts at age 12 to 13 and continues until age 17 or 18. School grade levels are numbered Year 1 to Year 12, following the initial preparatory year or kindergarten year (see http://australia.angloinfo.com/family/schooling-education/). In Victoria the first year of school was called the Prep year but since the introduction of our Australian Curriculum the first year of school is now called Foundation. The Middle Years are usually from Years 5 to 8. Table 1 includes the participants' school type for 152 of the 153 participants.

Intake	Primary	Secondary	Middle Years	P - 12	Special Settings	Total
Intake 1	27	5	2	4	2	40
Intake 2	7	29	3	1	0	40
Intake 3	31	5	0	2	2	40
Intake 4	21	4	0	5	2	32
Total	86	43	5	12	6	152

Table 1: Participants' school type (n = 152)

While *Leading Numeracy* was advertised as a leadership program and some teachers were in leadership positions others were not confident that they would be in a leadership position in the foreseeable future. Participants also varied in experience from a new graduate to Principals.

There is now a set of professional standards for Australian teachers (AITSL, 2014). The four career stages (Graduate, Proficient, Highly Accomplished and Lead) in the Standards provide benchmarks to recognise the professional growth of teachers throughout their careers. The descriptors across the four career stages represent increasing levels of knowledge, practice and professional engagement for teachers. Progression through the stages describes a growing understanding, applied with increasing sophistication across a broader and more complex range of situations. The usual progression for Victorian teachers when the Leading Numeracy course was offered was to start at the Graduate level and then successively move through Accomplished and Expert levels before becoming a Leading Teacher. Typically, Leading Teachers are responsible for coordinating a number of staff to achieve improvements in teaching and learning. Their focus is on the introduction of changes in methods and approaches to teaching and learning. However, they will also be responsible for the management and leadership of a significant area or function within the school to ensure the effective development, provision and evaluation of the school's education program.

Table 2 shows the range of participants' level of responsibility in their schools for 151 of the 153 participants.

Intake	Graduate	Accomplished	Expert	Leading Teacher	Assistant Principal	Principal	
Intake 1	4	10	14	11	0	1	40
Intake 2	2	13	5	13	3	3	39
Intake 3	0	16	4	12	3	5	40
Intake 4	2	12	11	3	2	2	32
Total	8	51	34	39	8	11	151

Table 2: Participants' Positions of Responsibility (n = 151)

Table 3 includes the types of schools and participants' professional status of 151 of the 153 participants at the time of attending the Leading Numeracy course.

Position	Primary	Secondary	Middle Years	P - 12	Special Settings	Total
Graduate	4	3	1	0	0	8
Accomplished	29	14	3	5	0	51
Expert	17	6	0	5	6	34
Leading Teacher	22	14	1	2	0	39
Assistant Principal	4	4	0	0	0	8
Principal	10	1	0	0	0	11
Total	86	42	5	12	6	151

Table 3: Participants' positions of responsibility and school type (n = 151)

Some participants were the only person from their school, while others had groups of participants including the Principal. Learning communities were much stronger when there was a team of participants from a school or in the case of a small school, where teachers joined with another school or group of schools from their network. During the professional learning sessions opportunities were provided to occasionally separate into groups who were already leaders and those who were aspiring leaders e.g. when discussing characteristics of a Professional Learning Community. Combining more experienced leaders with the less experienced, was also beneficial although not always acknowledged. The most successful learning communities were those where the Principal accompanied, and supported, an aspiring leader.

In each intake participants exhibited a huge range of mathematical knowledge and skills. These ranged from very limited mathematical skills and knowledge to the highly skilled secondary mathematics teachers with university level mathematics. Sometimes it was the secondary teachers who struggled with simple mathematical tasks while some primary teachers exhibited very high levels of mathematical understanding.

Results from the Feedback questionnaires

There were two questionnaires for the participants to complete. One was given about half way through the course the second after the course was completed. Participants were asked to respond to statements using a five point Likert Scale where the responses ranged from *Strongly Disagree* to *Strongly Agree.* Scores for the responses ranged from 1 to 5 where 1 represented *Strongly Disagree* and 5represented *Strongly Agree.* Intake 1 completed their mid-term questionnaire first and changes were made to that program and subsequent programs accordingly.

Mid-course survey for Intake 1

In the mid-course survey given to the participants of Intake 1 there were six statements that focused on the Course Content. These included:

- *The course content has been relevant to my work;*
- *The course has been pitched at a level appropriate to my stage of development;*
- *I have had adequate opportunities to explore the theory and models central to the course;*
- *The learning activities have been carefully planned and well organised;*
- *The course materials and handouts have been of high quality;*
- *There have been sufficient opportunities for me to interact with other participants during workshops*.

Scores for all these course content statements ranged from *Strongly Disagree* (1) to *Strongly Agree* (5) with a range of means from 3.3 to 4.1. The lowest mean (3.3) was for the statement: *The learning activities have been carefully planned and well organised* with 60% of the participants saying that they *Agreed* or *Strongly Agreed*. The highest mean (4.1) was for the statement: *There have been sufficient opportunities for me to interact with other participants during workshops* with 83% of the participants saying that they *Agreed* or *Strongly Agreed* with the statement.

After consultation with co-presenters the decision was made to include two mathematical or numeracy tasks for participants to solve and discuss the underpinning mathematics in each workshop. Rich mathematical tasks were chosen that were appropriate for both primary and secondary settings. This increased the repertoire of mathematical/numeracy tasks that leaders could use with staff and students but also alerted participants to possible areas of

mathematics/numeracy they may themselves need to improve. Comparison of the results from Intake 1 participants showed that there was a change from a mean of 3.3 for the statement: *The learning activities have been carefully planned and well organised* in the mid-course survey to a mean of 4.1 in the final survey.

Final survey for all four Intakes

Despite reminders to complete the surveys only 83 of the 151 participants (55%) completed the final survey for their course. The results are shown in Tables 4 – 6 for three of the statements given in the final questionnaire to the participants of all four Intakes:

- *The course content has been relevant to my work*;
- *The learning activities have been carefully planned and well organised*; and
- *There have been sufficient opportunities for me to interact with other participants.*

In Table 4 the results for the four Intakes highlights the similarities in the scores for the statement: *The course content has been relevant to my work.*

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean
Intake 1	0	2	2	11	3	3.8
Intake 2	0	3	1	6	10	4.2
Intake 3	0	2	2	7	17	4.4
Intake 4	1	1	1	6	8	4.1
Total	1	8	6	30	38	4.2

Table 4: The course content has been relevant to my work (n = 83)

The graph in Figure 1 highlights the similarities in responses for the four intakes with 82% of the participants *Agreeing* or *Strongly Agreeing* that the course had been relevant to their work. As a mathematics educator I am concerned with the small percentage of participants who either *Strongly Disagreed* or *Disagreed* with this statement. The question for me as the facilitator: What could I have changed so that more participants thought the content was relevant for their needs?
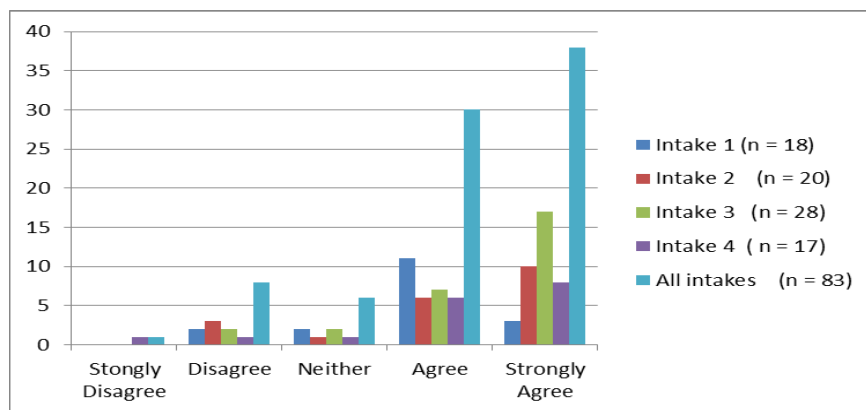
Figure 1: The course content has been relevant to my work (n = 83)

Table 5 shows that the participants from Intake 1 had scored this statement higher than they did for the mid-course survey with an overall mean of 4.1 compared to the mid-course survey result of 3.3. Overall, 87% of all the participants either *Agreed* or *Strongly Agreed* that the learning activities had been carefully planned and well organised.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean
Intake 1	0	2	2	10	4	4.1
Intake 2	1	1	0	10	8	4.2
Intake 3	0	1	2	12	13	4.3
Intake 4	0	1	1	5	10	4.4
Total	1	5	5	37	35	4.2

Table 5: The learning activities have been carefully planned and well organised (n = 83)

In Figure 2 the graph shows the similarity in the responses from all four groups. When asked to highlight the strongest features of the course one participant responded: "Giving examples of students' work and how to assess and improve their numeracy understanding. Practical activities." Another participant stated: "You always left each day with something you could take away from the day. Being able to listen to other people and their stories from their schools and having those professional discussions together."
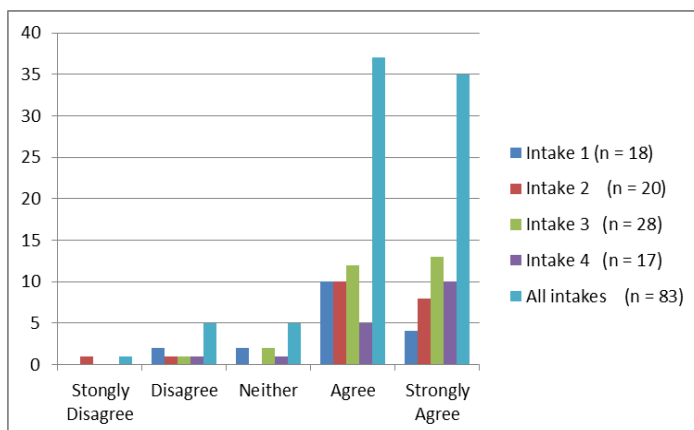
Figure 2: The learning activities have been carefully planned and well organised (n = 83)

The results in Table 6 show that 89% of the participants of all four courses *Agreed* or *Strongly Agreed* that were sufficient opportunities to interact with other participants. As one participant stated on the survey: "The strongest feature of the course was networking, and gaining ideas of implementation from other schools and professionals."

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean
Intake 1	0	0	2	12	4	4.1
Intake 2	0	3	1	5	10	4.2
Intake 3	0	0	2	2	24	4.8
Intake 4	0	0	0	1	16	4.9
Total	0	3	5	20	54	4.5

Table 6: There have been sufficient opportunities for me to interact with other participants (n = 83)

The graph in Figure 3 highlights the success of allowing the interactions of the participants at various times during each of the days. As stated by one participant: "The opportunities to network with other staff was invaluable as we were able to explore best practice across the region". As another participant stated: "The collective knowledge and skill of the participants was utilised to full advantage".

Figure 3: There have been sufficient opportunities for me to interact with other participants (n = 83)

Interestingly some participants thought there were not enough opportunities to interact with other participants as shown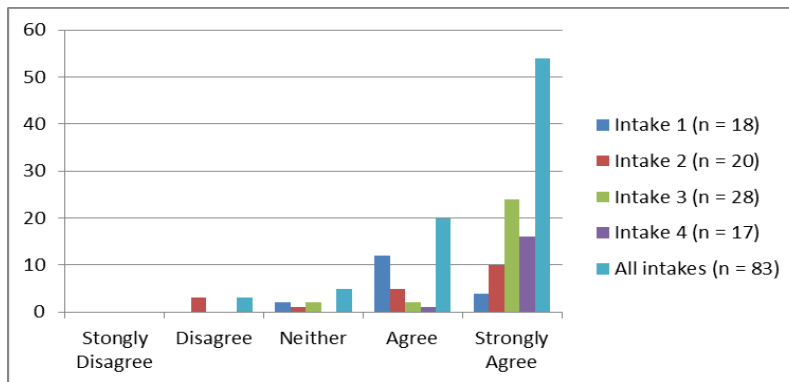 in the following comment by one participant: "More contact and sharing with the group would have been beneficial". Another participant also stated there was: "not enough time to talk with colleagues and peers".

Since the majority of the participants obviously thought there were plenty of opportunities to talk to their fellow participants it is difficult to know how to please those who needed or wanted more time to interact with their colleagues and what that might look like.

5 Conclusion

The ongoing experience with professional learning programs has shown that valuable learning occurs when participants include teachers from both secondary and primary school. While some participants in the *Leading Numeracy* course stated that they would have preferred separate courses for primary and secondary teachers there appears to be benefit for both groups to be included in professional learning programs so discussions about what happens at both levels can take place.

During the *Leading Numeracy* course teachers benefited from discussing their different pedagogical experiences and content-related expertise. In the *Leading Numeracy* course there were times when groups were separated and worked on modified tasks to cater for the different expectations of primary and secondary teachers. For example, when comparing student mathematical work samples, primary teachers analysed examples from primary students, and secondary teachers analysed tasks from Middle Years' students.

Both the content and process were constantly being modified to cater for the diverse range of learners. Experience in these learning communities has enriched the professional learning programs I offer for the ACER Institute and the courses I deliver at the University of Melbourne. For any professional learning programs that I offer, key questions I continually need to ask:

- "What are the needs and experiences of the different target groups: facilitators of learning communities, educators of teacher educators, and teachers in their everyday classroom practice?"
- "How will I know if I have catered for these needs?
- "Did I take into account the participants' previous experiences?"
- "Will the content of this professional learning encourage and support a sustainable professional learning community?

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Professional Learning Communities - the case of Learning study -
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Introduction

Here I will present one form of professional learning community (PLC), related to action research and lesson study, called Learning study (Cheng & Lo 2013; Marton & Pang 2003). Ever since Learning study was introduced in Hong Kong and Sweden some 15 years ago, thousands of teachers and a great number of educators from universities have been involved in Learning study and more than 50 articles in international journals, PhD-dissertations and books reporting on what teachers and/or students learn, have been published.

In my presentation I will focus on its specific characteristics, I will describe and discuss its contributions to the improvement of students' and teachers' learning. Finally, I will reflect on Learning study as a possible candidate for 'clinical research in education' (Bulterman- Bros 2008) and whether it has the potential to bridge the gap university - school practice.

Learning study in the landscape of PLC

However, I will start will orientating Learning study within the landscape of Professional Learning Communities (PLC). PLC is, in my interpretation, more of an umbrella term, which may encompass various approaches to professional development with some common features. The National Commission on Teaching & America's Future defines PLC in STEM (science, technology, mathematics) and states that the following criteria must be fulfilled: 1. There must be three or more teachers/prospective teachers and/or other administrators, 2. It could be interacting for varied purposes related to improving teaching, 3. It should not be a short-term experience (min. two weeks), 4. It must involve student and teacher learning, and last; there should be shared visions and goals and the collaborative elements are the core of the process.

PLC could have different purposes. It could be a component of or used as means for curriculum reform (e.g. in HK, and Singapore). It could also be a goal in itself; thus, to establish a community of learning and change the isolation of teachers' practice.

Theoretically the idea of PLC could be framed within theoretical orientations emphasizing learning as social and situated (Brown, Collins & Duguid 1989) and Wenger's notion of communities of practice (Wenger 1998). However, features of PLC also originate from Lawrence Stenhouse's rationales for teachers as researchers (Stenhouse, 1975), which Elliott (1991) specifies as a process of collegial, open and tolerant professional discourse rather than an individualistic or bureaucratic form of accountability. I would also situate PLC as a reaction to the often criticized top-down- approach common in reform

work. The failure to change the current practice into a more "reform-oriented"-practice, could be explained by the often used top-down approach, where the teachers have less influence on the process. The bottom-up-approach of PLC is thus seen as a more effective way to change current practice, since it involves teachers and is directly connected to their practice. With such a purpose, PCL runs the risk to be less teacher driven compared to Stenhouse's and Elliott's visions, however.

With the broad definition given above, various approaches can be classified as PLC. To give thorough and deeper description of different approaches of PLC is not in the scope of this presentation. I will concentrate on one of the most common (as regards numbers of articles in journals) and probably most well-known, the Lesson study, since it has many features in common with Learning study. So, Lesson study will here be used as a back-ground to explicate features of Learning study.

Lesson and Learning study- commonalities and differences

Lesson study has its origin and a long history in the Japanese tradition. Although, it goes back to the late 19th century, Lesson study became known to the West by Stigler and Hiebert in their books published in late 90s (e.g. Stigler & Hiebert 1999) but also by publications in international journals by Catherine Lewis (e.g. Lewis, Perry and Hurd 2004), Makoto Yoshida (e.g. Yoshida 2012) and Clea Fernandez, (e.g. Yoshida and Fernandez 2004) just to mention a few. The bulk of the literature on Lesson Study comes from the US and not from Japan (Cheng & LO, 2013) and my interpretation of how Lesson study is practiced in Japan, is that it could be seen as a broad approach to teacher professional development. Figure 1 tries to describe some common features among Lesson and Learning study, but also features specific for the latter. That which is put into brackets for Lesson study in the table are seldom explicitly reported on.

	Lesson study	Learning study
Observation classroom teaching and learning	x	x
Curriculum oriented	x	x
Learner oriented	x	x
Iterative	x	x
Content oriented	(x)	x
Theoretically framed	(x)	x
Systematic triangulation of student and classroom data	(x)	x
The nature of the object of learning and its critical aspects		x

Figure 1: Features of Lesson and Learning study

From figure 1 it can be seen that they are both iterative processes and learner and curriculum oriented. Teachers observing and reflecting on the lesson is another common feature. However, the content is not necessarily the focus in Lesson study. It is common that there is an overarching and common theme for the lesson study at the school (cf. Ermeling and Graf-Ermeling 2014). For instance, in a school I visited in Tokyo, the theme that year was 'the students should learn and appreciate to listen to each other, learn to learn from each other and interact in group discussion'. This was then applied in all subjects. Thus, it is not that the subject matter is not there. But the subject matter could sometimes be embedded in a broader focus and general goals.

Although it is sometimes argued that Lesson study is grounded in theory, in my interpretation, it is more often a general educational philosophy or theoretical orientations, like socio-cultural ideas expressed as a need for more communication in classroom, for instance. Whereas in Learning study a specific theory – variation theory – is used as an analytical tool when analyzing student learning and analyzing and designing the lesson. Variation theory has demonstrated to be a powerful tool for analyzing teaching and learning (Cheng and Lo, 2013). Variation theory proposes a specific view of learning and focuses on the relation learner and what is learned. It is used as a tool for teachers to identify the necessary conditions (critical aspects) for the learning of what is supposed to be learned (the object of learning) (See Marton and Booth 1997; Marton et al. 2015). Furthermore, variation theory is used when the teachers explore students' prior understanding and to what extent the object of learning has been achieved by the learners after instruction. The exploration of teaching and learning in the Learning study entails identifying what aspects of the object of learning are critical for learning and how to make it possible for the learners to experience them.

The object of learning and what is to be learned

By the object of learning we do not mean 'learning objectives' (Marton 2015). Learning objectives are general and common for a group of students in the same grade or students taking the same course. They are supposed to develop the same knowing among all learners. For example, in the Swedish national curriculum in mathematics grade in 3, one of the targets is: "Pupils [should] have basic knowledge of natural numbers and can show this by describing interrelationships between numbers and also by dividing whole numbers". However, this description does not say anything about what must be learned, for instance to "divide whole numbers" or "describe interrelationships between numbers". For thosewho can do this, this might be seen as trivial. Furthermore, as a teacher you can most likely determine whether the pupil has this capability or not. However, if you ask questions like: 'What does it imply to describe interrelationships between numbers?', 'What have you learned when you developed this capability?', and 'What do these particular learners have to learn in order to develop this capability?' you will probably find that he answers do not come immediately.

Framing teaching and learning in this way, exploring the concept and its nature alone is not sufficient, however. The meaning of the concept 'number' cannot be considered in isolation from the learner. For everything the students are supposed to understand/have knowledge about and so on, there are certain things that must be learned. If the learner fails, for example, to develop the capability to 'describe the interrelationship between numbers', from a variation theory perspective, this is framed in terms of "there is something the learner needs to learn, to be aware of or to discern in order to have this capability, but has not learned or discerned yet.

From the point of view of the ontological and epistemological underpinnings of variation theory, the object of learning cannot be taken for granted. If knowledge is seen as existing independently of the individual, its background and previous experiences, the situation and the culture, and if teaching is seen as transmitting knowledge, this is not problematic. Taking a variation theory perspective on learning and knowing implies to consider the relationship between the knower and the knowledge (cf. Dewey and Bentley 1949). Thus, exploring the object of learning and its critical aspects, those aspects that must be learned by the specific group of students, is the specific feature of Learning study. How the critical aspects can be identified and tested in Learning study is described and exemplified below.

Identifying what is critical for learning

Identifying the critical aspects of the object of learning is not an easy task, however. In a Learning study in grade 6 of decimal numbers, the object of learning was 'to understand that decimal numbers are dense' (Kullberg, 2010). Learning study always starts with mapping students' understanding by

studying their response to particular tasks. In this case one of the task was: "Are there numbers between 0.97 and 0.98? If so, how many and why?" Students' answers on the task were analyzed and categorized by the teachers before they jointly planned the first lesson.

Student answer	Class A Before/after lesson (N=19)	Class B Before/after lesson (N=17)
'Many'	1 / 4	4 / 16
One	4 / 0	5 / 0
Ten	0 / 9	0 / 1
No number	8 /4	3 / 0
Other	6 /2	5 / 0

Table 1: Numbers of different students' answer to the question "Are there numbers between 0.97 and 0.98?" before and after the lesson

As can be seen from table 1, very few of the learners in both classes had an idea of 'infinity' before the lesson (e.g. they gave answers like: "very many, "a lot of numbers", "it doesn't stop", "it goes on"). Except from "other answers" (e.g. I don't know, omitted answer) the most common answers were "there are no numbers" or "there is one number" (only!) From the table it can also be seen that the first lesson in the cycle contributed very little to the improvement of learning. Yes, we can even see that about half of class A answered "10 numbers" after they were taught. However, lesson 2 seems be more successful. After the lesson almost all of the students gave answers that we interpreted as they had some ideas about the density of decimal numbers (note! It was never said in the lesson that there are infinite numbers). So, what has happened in between?

In the post-lesson meeting after the first lesson (Class A), when the results on the post-test were reflected upon and the video recorded lesson was analyzed, the teachers came to realize that during the whole lesson, the rational numbers were talked about as decimal numbers only (e.g. "zero point ninety-eight"). They also realized that, even if the teacher tried to draw the learners' attention to the space between the numbers on the number line and asked if there were numbers between 0.97 and 0.98, the students had difficulties to find other numbers than for example 0.971, 0.972 ….. They also supposed that the fact that the numbers were represented as points on the number line, might have triggered the students to count the decimal numbers. This could explain why half of the class (9 of 19, see table 1) answered "ten numbers". So, the teachers made the conclusion that there must be something that is necessary to be aware of, to discern or to learn in order to understand that

decimal numbers are dense. However, they concluded, this was not made possible to learn in lesson 1. From carefully analyzing the lesson and students' responses to the task on the test, they anticipated that the following were critical aspects:

- interchangeable representations,
- the number as a part of a whole,
- the divisibility of parts

The identified critical aspects implied that the teachers anticipated that the learners had probably not discerned that a decimal number can be represented as a fraction *and* as percentage, and that they had not discerned that a number like 0.97 (although expressed as 'zero point ninety-seven', i.e. as natural numbers) denotes a part-whole relationship. Furthermore, they anticipated that it must be made possible to learn that, even if the decimal numbers (0.97 and 0.98) are represented as points on a number line (which happened in lesson 1), the interval between the two points/decimal numbers can be successively divided into hundredths, thousandths and so on.

These insights were the ground when they planned the second lesson (class B). Apart from bringing out the identified critical aspects, no other changes were made to lesson 2. They decided to use the same activities and arrange lesson 2 in the same way as lesson 1.

It must be noted that the teachers did not explain students' failure on misunderstanding, that they were not attentive enough in the lesson, or on some inherent deficiency of the learners. Instead, I would suggest, the theory helped the teachers to direct their attention, not to the concept as such only, but to the learners' understanding and experience of the concept also. The theory also guided the teachers how to make the identified critical aspects discernible. Variation theory states that an aspect is likely discerned if it is varied against a stable background. And furthermore, we do not learn by seeing sameness, but by experiencing differences. So, when the teachers planned lesson 2 with the aim of helping the learners to discern the critical aspects, they considered what to vary and what to keep constant; they decided about a pattern of variation, namely:

- To take *the same number*, but use *different numerical representations*
- To point to *the same interval* partitioned into *different partitions* (tenths, hundredths, thousandths)
- To relate *the same number* to *different wholes* (0.97 could be a part of different wholes)

So, after having identified the critical aspects, patterns of variation are used to help students to discern the critical aspects identified for specific object of learning.

Learning on three levels

In the knowledge synthesis of PLC, made by the National Commission on Teaching & America's Future in 2010, it is said that "few studies can on *a rigorous ground* support student learning outcomes related to teachers engagement in PLC, but the trend is positive". It might not be possible to directly related changes in learning outcomes that are robust, in the sense of statistical significance, to teachers' participation in PLC. However, evaluation of a number of Learning studies in Hong Kong indicates progress in student as well as teacher learning (Cheng & Lo 2013)

After evaluating the effect of teacher learning, National Commission on Teaching & America's Future points to effects important for teachers' professional growth:

Participation in PLCs can successfully engage teachers in discussion about content knowledge or knowledge about how to teach it (pedagogical content knowledge or PCK), positively impacting their understanding of or preparedness to teach content, or attitudes toward teaching methods. Participation in PLCs increased teachers' deliberation about students' mathematics or science thinking." (p. 8)

These are findings similar to what has been identified from studying teachers participating in Learning study, but specified by Cheng and Lo (ibid.) in that it concerns a common language to talk about teaching and learning, knowledge about the object of learning and how to teach it in a way that can promote learning:

Throughout the project, the teachers learned and used a common language - the jargon of variation theory - to talk about teaching and learning, referring to the object of learning (OL), critical features (CF), variation in students' understanding of the OL, variation in teachers' ways of dealing with the OL (V2), and using variation as a guiding principle of pedagogical design (V3). They learned to negotiate patterns of variation, to help students to discern critical features and together planned teaching activities that could best allow students to experience the variation patterns themselves. In doing this, they had to draw on their own experience and knowledge of teaching. (p. 20)

Our suggestion is that by the theory based inquiry, thus that there is an explicit theoretical framework involved in the process, adds values to Learning study.

Learning after Learning study?

So far, I have suggested what teachers can learn when they are involved in Learning study, but what happens outside and after participating in Learning study? Does the participation have any influence on what teachers do outside Learning study? In a current study we explore the long term effects of Learning study (Kullberg,et al., under revision). Before participating in three Learning studies, 12 mathematics and science teachers were asked to teach one lesson free of choice. One and a half year later they were asked to teach the same lesson again. That is, they taught the same topic. However this topic was

different from what they were teaching in the Learning study. When the two lessons, taught before and after the participation in Learning study were compared, we found common features among all the teachers. Namely, in lesson 2, all of them dealt with the relevant concepts and principles in relation to each other (i.e. simultaneously) and not one at a time. In the lesson before Learning study, concepts or features of concepts, were taught in sequence. For instance, one of the science teachers in the first lesson, first taught about 'pressure' and gave several examples and after that, later in the lesson, talked about 'force'. Thus, these concepts were taught after one another and in sequence. In the lesson, after the participation in Learning studies, these (pressure and force) were juxtaposed and compared. Similar was found among another science teacher. In L1 acids and acidic were first discussed on a macro level and then later in the lesson on a micro level. This was followed by a brief discussion about basic (and neutral) on a macro level. Lesson 2 was sequenced differently; acids and bases were handled *at the same time*, first on a macro level and then on a micro level.

We find these changes interesting and would suggest firstly, that the teachers demonstrated that they can handle the content in a different way after the Learning study and secondly, that these changes reflects what they had experienced in the Learning study, namely something that it is in line with variation theory, that says: In order to make the students aware of how things differ, are similar, or simply how they are related to each other, it is better to deal with them together, in relation to each other, rather than after one another. That is exactly the way the teachers did after participating in the Learning study, but not before that.

Is Learning study research?

Finally, I will take Learning study a bit further by suggesting that Learning study could be more than just PLC and teacher professional development.

The gap between theory and practice, between university based research and school practice, has been discussed a lot. The dominating rational is that research is something researchers do at the university, and results from research can be transformed as recommendations to practitioners. This way of thinking is not un-problematic, I think. The researcher at the university may have other interests and other questions than a teacher at school has. It has been suggested that the gap can be overcome if teachers are involved in the research process, not as objects of research, but as subjects and become part of the research process. It has been argued that Lesson and Learning study have features that is in line with that which was advocated by the British educationalist Lawrence Stenhouse, who argued that teachers must be implicated and take part in producing knowledge that is the scientific ground for their professional work (Elliott 2012).

In an article in The International Journal of Lesson and Learning studies, the Swedish educationalist Ingrid Carlgren (Carlgren 2012) describes Learning

study as one form of clinical research. Clinical research is in analogy to medical clinical research. The use of teachers' experiences and tacit knowing in the knowledge-producing process, the iterative process of specification of theory, and the uniqueness of the learning problems among different groups of pupils, are central aspects of a particularistic clinical research process, she says. In comparison with Lesson study, the Learning study "is more focused on constructing knowledge concerning objects of learning as well as teaching-learning relations. Teachers are included in the research as interpretative professionals making professional sense of particular educational events" (p. 1).

Learning study as research, does not imply research *on* teachers. If an academic is involved in the process, he or she has the same interest and the same object of research as the teachers. So, in Learning study as research, there is a shared object of research. They are dealing with the same problem, but with different expertise and experience.

However, the quality of the research depends on several factors. Except for other requirements for good quality of research, the quality of the collaboration within the team, the extent to which the process is followed, the extent to which the focus of research is on the everyday reality of teachers and to the extent to which the research is reflected upon and shared with others, for example, are important.

So, my final suggestion and conclusion is: Learning study implies possibilities for students' learning, teachers' learning and researchers' learning.

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A study of collaboration between mathematics teachers and mathematics education researchers: insights into developing professional learning -

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1 The importance of collaboration between teachers and researchers as a means for professional development

Within the socio-cultural perspective, teachers' professional development is conceived as "learning in practice" (Jaworski & Goodchild 2006). Learning is seen as change of participation in communities of teaching practice, realized through reification and requiring the alignment of the participants with the norms of these communities (Wegner 1998).If alignment is achieved critically, then inquiry becomes one of the norms of the practice, reflection constitutes part of the teachers' professional actions and the community of practice turns into a community of inquiry (Jaworski 2006, Jaworski et al 2011). The reflective interaction between inquiry and professional development indicates the critical character of the collaboration between teachers and researchers (Jaworski 2008).

2 Investigating the collaboration between researchers and teachers; Methodology and case studies.

In this study two groups of people collaborated. The first consisted of two researchers of mathematics education (rA and rB) while in the second group there were three secondary mathematics teachers (tA, tB, tC) with distinct roles in the different phases of the community's development. The teachers acted either as "internals" (teachers) or as "externals" (researchers) of the teaching practice, while the researchers participated as "externals" of the teaching practice and "internals" of the research practice.

Study 1: Identification and management of students' mistakes by the teachers and the researchers. The study was carried out with 13 years old students (7th grade) in teachers' tA and tB classes. Lesson transcriptions and their analyses by both teachers constituted the basis of a reflective and inquiring circle of discussions between the teachers and the researchers.

Study 2: Investigation of the content and the form of collaboration among the community members. Teachers tB and tC planned and taught a lesson regarding the solution of quadratic equations. Critical reflection was developed in analysing lesson transcripts (design and implementation phases) and discussing decisions and outcomes of the experience.

Study 3: Investigation of the teachers' questioning. This activity was viewed as a professional development activity for the community members. Lesson transcripts coming from four teaching sessions in high school classes were analysed. Teachers tA and tC identified representative episodes of their questioning that seemed to indicate construction of mathematical meaning. Selected episodes, their analyses and personal notes concerning instances of reflective action by the community members constituted the data were exploited.

All the above procedures were mutually accepted by both the teachers and the researchers and can be summarised in figure 1.

Figure 1: Schematic representation of the methodology that was followed.

3 Results and Discussion

3.1 Teachers' professional learning

The teacher tA considered the dilemma of time as an obstacle and identified mathematical challenges that the students faced. The teacher tB maintained the high level of questioning connected with the desired learning goals. The teacher tC focused on the knowledge she gained as a researcher when looking into the members' identity, the research tools exploited and the alignment with the achieved norms of the community.

Overall, teachers managed to reflect on their teaching practices, doubt the effectiveness of these practices and started to reconsider their knowledge base regarding what is of importance in teaching.

3.2 Researchers' professional learning

From the researchers' perspective, two main issues were enlightened; the dynamic character of the interaction within the classroom shaped both by the teacher and the students and the difficulty of the teacher's transition from the teaching to the researching framework. Having these observations at hand, the researchers aim at developing academic knowledge based on the analyses provided by the teachers. At the same time researchers are interested in identifying the teachers' characteristics and actions with the ultimate goal the support of their professional development. Lastly, researchers understood that inquiring mathematics teaching is linked to the process of negotiating meanings among the members of the community.

4 Towards an effective community of inquiry

The collaboration that was developed between the researchers and the teachers gave rise to an emerging community of inquiry. The different perspectives enacted in the mathematics classroom gave rise to a dynamic and rich context of inquiry and reflection regarding mathematics teaching as well as the researching practice of all community members.

Acknowledgements

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Learning Communities in a STEM Education Network: scaling-up a talent development programme -

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1 Introduction

In many science and mathematics (STEM) classes, there are always some students who are eager and able to learn more than is offered to them in the regular curriculum. They finish their tasks long before their classmates. In many cases however, they are not challenged to go deeper into the subject matter. As a consequence, instead of paying more attention to the subject that they are motivated for, they only spend little time on it. This can result in a decrease of motivation, and in these students eventually finding school science and mathematics dull. Junior College Utrecht, a cooperation between Utrecht University and 27 secondary schools, has tried to provide a solution to this problem by offering these students and their teachers special 'STEM-talent programmes' in their schools and on the Utrecht University campus.

In order to encourage and support the more able students, science and mathematics teachers need to be equipped with suitable skills to promote talent development (Tabor 2007). For the professional development that teachers need for this, participating in a community of teachers is useful (Cochran-Smith and Lytle, 1999). Such a community, focused on promoting talent development can be formed within a school, but also in a network of schools in which a university can be involved. Such a community is inspiring and it enables the connected schools to set common goals based on research literature and to develop plans related to connecting secondary and higher education (Van der Valk 2014a). In addition, participation of a university provides opportunities to scale up the programmes developed by the schools. Moreover, expertise in teacher professionalization is available through the university.

1.1 Junior College Utrecht and its learning communities

Junior College Utrecht (JCU) is an example of one of these 'school-university networks', promoting talent development in science and mathematics. It aims to be a working place for improving the quality of science education. In 2004, Utrecht University invited schools from the mid-Netherlands region to join the JCU-network. At the time of the research (2014), a total of 27 schools are in the 'ambition' network of JCU.

The main idea of the JCU network is continuous and mutual learning within these communities: students learn from their teachers as well as from their peers; teachers learn from their students as well as from their colleagues. Schools learn from other schools as well as from the university. This idea of connected learning communities is elaborated in the main activities of the JCU-network: developing and implementing programmes for talented science

students and providing professionalization programmes for teachers and schools.

Macmillan (1976) describes a community as follows: "*Sense of community is a feeling that members have of belonging, a feeling that members matter to one another and to the group, and the shared faith that members' needs will be met through their commitment to be together.*" So, a community is characterized by four features: 1) participants feel a membership, i.e. loyalty and relatedness to the group, 2) there are emotional bonds between participants, e.g. by sharing experiences, 3) the participants have influence on the aims and the activities of the community, and 4) these activities fulfil common needs.

In JCU, learning communities have been realized on three levels: students, teachers and schools. The student learning communities consist of grade-11/12 students from the partner schools who meet each other in a STEM talent development programme. The focus of these communities is sharing interest in and enthusiasm for STEM topics. Guidance by STEM-teachers is a prerequisite for their success.

JCU teacher learning communities have been realized in the JCU professionalization programme. There, STEM-teachers from partner schools meet with each other and university staff, discussing topics like how to promote talent development and possibilities for using JCU material in regular classes (Van der Valk 2013). The teacher learning communities are guided by JCU-staff members. In addition, a learning community of JCU schools has developed wherein principals of partner school exchange their experiences with JCU student programme, with the teacher programme and discuss common goals.

The way in which the JCU learning communities have been involved in scaling-up talent development programmes has evolved since the start of JCU in 2004. The development can be described in two phases. During the first phase (2004 – 2012) the focus was mainly on the campus programme, developing innovative teaching material orienting students to recent STEM research, and on its nation-wide dissemination. In the second phase (2013 – now), the focus is on implementation of talent development programmes in partner schools, followed by dissemination to other schools in a later stage.

1.2 Central issues of this paper

The aim of this paper is to learn some lessons from the strategy Junior College Utrecht has followed for scaling-up the results of the innovation it strives to achieve, using professional learning communities on different levels of its network (students, teachers, schools). Therefore, the central questions of this paper are:

- How can a school-university partnership successfully implement talent development for senior secondary school students and scale this up to its partner schools and nation-wide?

- What can be the role of the learning communities in this process?

2 Phase 1 (2004 – 2012): a talent development programme at a university campus

When the JCU partnership started in 2004, upscaling was an aim for the longer run yet. The main issues for JCU were (1) developing a STEM campus programme suited for talented grade 11/12 students, (2) convincing STEM teachers in the partner schools of the importance of talent development and involving them in JCU activities and (3) fostering the network of JCU partner schools.

The cohort of grade-11 students that was selected for JCU was about 50 a year and each cohort spent two years in JCU. So, every year, the entire JCU student population consisted of 50 grade 11 and 50 grade 12 students. The students followed the campus programme two days a week. The JCU curriculum included the national grade 11 and 12 STEM syllabi which were taught on the campus at an accelerated pace and in a comprehensive way. The time saved by the acceleration was spent on the enrichment and more in depth exploration of topics and on research assignments. During the other three days of the school week, they studied the non-STEM subjects (e.g. languages, history) at their respective schools (Van der Valk *et al*. 2007).

For teaching the regular STEM syllabuses, eight senior secondary school teachers were selected from the partner schools, two from each subject: mathematics, physics, chemistry and biology. They adapted the methods for teaching the syllabuses to the talented group. They were the ones who had most contact with the students and appeared to be very important in fostering the student learning community. Moreover, as these teachers were teaching at JCU as well as at a partner school, their JCU teaching had a (modest) impact on the views on talent development in their home schools.

University teachers developed and taught enriching modules about their areas of STEM research. Two examples, that have been translated into English, are: 'The Dynamic Earth' (JCU 2011a) and 'The Molecules of Life' (JCU 2011b). The goal of these modules was to contribute to the bridging of the gap between secondary and university STEM education. These modules later became examples for a new (modular) STEM subject that was introduced nationwide from 2007 onwards (see section 2.2).

In the structure of the network, JCU held a central position, see fig. 1. Nearly all communication occurred between JCU as central partner and the individual schools. In the course of time, communication between partner schools was stimulated and did increase.
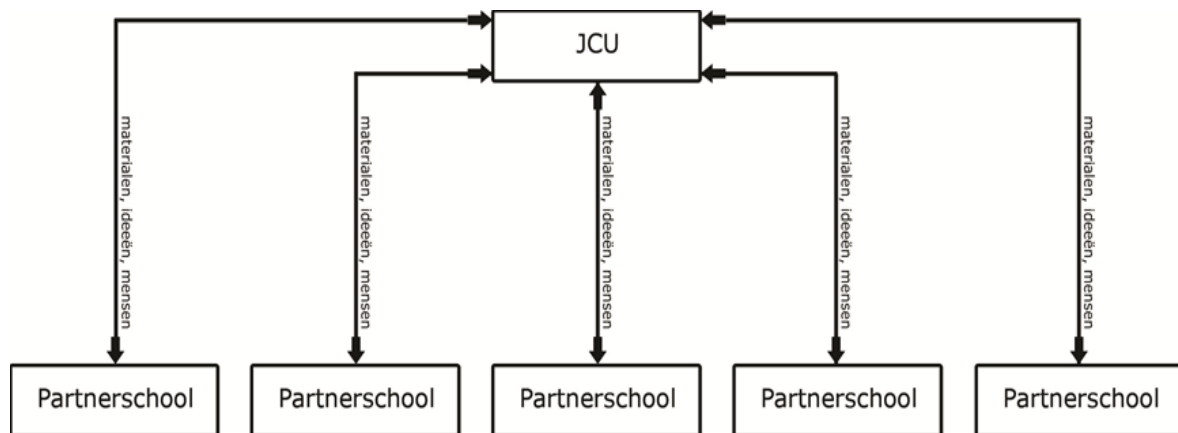
Figure 1: The structure of the JCU partnership: communication by exchanging material, ideas and teachers

2.1 Results of the JCU student programme

The student programme appeared to be successful. All stakeholders, the students, their parents, secondary schools and university teachers, school principals, and the UU Faculty of Science, appreciated it very much (Van Weert 2010).

Every student that participated fully in the JCU programme passed the national final examinations, on average with good grades for all subjects. In addition to that, they had also successfully studied several comprehensive STEM enrichment modules. The students felt empowered by JCU (Van der Valk and Pilot, 2013). The results of the JCU alumni in university bachelor (number of EC gained, study time) excelled, compared to students that had comparable curricula and final examination grades (Tromp 2014). For these alumni, the gap between secondary and university education seems to be bridged!

However, especially in the first three month of the programme, participating in the JCU programme appeared to be very demanding because of its different approach and for getting used to missing lessons at their own schools. Students, who had always been successful before, now sometimes failed tests. Most participants overcame these problems by being a member of the JCU learning community of like-minded students. The fact that they did not want to leave the community appeared to be a main factor in motivating them to go on and to stay in the programme. As a result students changed their study habits and developed academic competencies that helped them cope with the demanding programme. Eventually, about 8 percent of the students dropped out of the programme.

These results showed that there were two components in the JCU approach that were suitable for upscaling: (1) bridging the gap between secondary school and university STEM education, and (2) providing talented students with more opportunities to fully develop their STEM talents. For this upscaling, JCU used learning communities in which STEM teachers and principals of its partner schools participated.

2.2 Scaling-up: bridging the gap between secondary school and university

In 2007, a new STEM subject was introduced into the Dutch senior secondary curriculum: Nature, Life and Technology, (acronym: NLT). The general aims of NLT are "*to make science and mathematics education more attractive and challenging by offering students insight into new – often interdisciplinary - developments in science and technology, and to create coherence in teaching and learning the science and mathematics subjects*" (NLT, 2015). These aims corresponded very much with the aims of the enrichment modules developed by JCU, i.e. bridging the gap between senior secondary school and university STEM education. This was no coincidence, as staff members of Utrecht University were closely involved with developing NLT and had witnessed the success of the modules that had been developed at JCU.NLT provided an excellent opportunity for the upscaling of the JCU enrichment modules. JCU decided to adapt these modules for NLT by a three-step strategy (Figure 2).
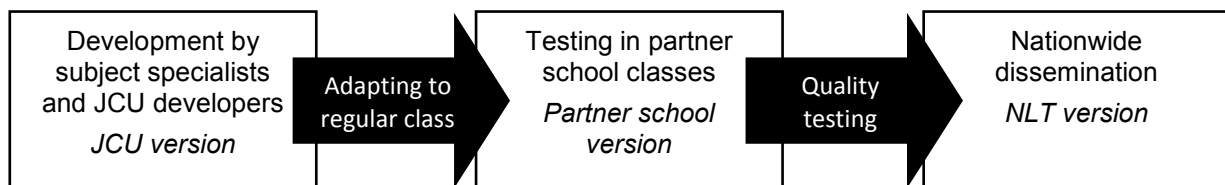

Figure 2: The JCU dissemination model

After developing and teaching a module, the university teacher and JCU staff adapted it to be taught again next year. For this, classroom experiences and students' evaluative comments were used. This way, the 'JCU-version' of the module was developed (step 1). The second step was to adapt the module for using it in regular education and to test it in partner school classes. For this, partner school teachers were invited to participate in adapting the modules to the NLT curriculum and test it in their classrooms. The teaching was followed by an evaluation and, if needed, by adaptation again. This second step implied a quality test that corresponded well with the development and dissemination strategy of the national NLT Steering Group (Eijkelhof, 2014), resulting in the eventual 'certification' of a module. This way, JCU realised the certification of fourteen modules. For these modules, upscaling was possible (step 3): disseminate the modules nation-wide for use in the NLT curriculum. By now, all schools that teach NLT, can use the JCU developed modules as optional teaching units, and many schools do. So, the upscaling has been successful. By the end of phase 1, there was no need for developing more NLT-modules anymore as about 50 NLT modules in total had been developed, by JCU as well as by other institutions.

The main effects of the development and dissemination of NLT modules by JCU were (1) the fostering of the cooperation of partner school teachers in the

JCU learning community and (2) a growing national recognition for JCU as an educational organisation for promoting talent development.

2.3 Scaling-up: STEM talent development

A self-evident way of scaling-up the JCU talent development programme would be to increase the number of schools and students participating in JCU. However, financial and organisational constraints impeded this. As a way to scale-up, JCU opted for increasing the attention for talented students within the partner schools.

To convince all partner school teachers that talent development in their classes is important, JCU started a learning community in which partner school teachers and principals explored what materials and methods, developed in the JCU programme, could be implemented. Teachers found it hard to use these materials and methods in regular classes. Testing was hindered by the fact that most of their brightest students were already in the JCU programme and therefore did not attend the STEM lessons in their schools. Nevertheless, discussions in the learning community and the success of the student campus programme convinced the teachers that it was worthwhile and possible (though not easy) to give students more opportunities for talent development in regular STEM lessons. In the community, the insight grew that talent development is not a task for individual teachers, but has to be organised by the school and by cooperation between the STEM departments. This insight had a significant effect on the schools' readiness to provide talented students of all grades in the school with opportunities to develop their STEM talents. It paved the way to starting school talent development programmes in phase 2.

2.4 Conclusions of phase 1

In phase 1, JCU has been successful in developing and teaching a STEM talent development programme to talented grade 11 and 12 students at the Utrecht University campus. It has successfully scaled-up its enrichment modules by fitting them in to a new curriculum, using a three-step dissemination model in which teacher learning communities played an important part.

Scaling-up the talent development programme by introducing it into the partner school STEM curricula appeared to require a change of views on talent development in the schools and in society, which needed much time. JCU succeeded in convincing partner school teachers and principals that promoting talent development to able and motivated grade 11/12 students is possible and also needed and that the schools have to play the main part in that.

Also in the Dutch society, views changed. The experiences and success of the JCU programme may have contributed to that. The Dutch Ministry of Education launched a national programme to promote talent development,

aiming at the 20% brightest students (OC&W 2011). This stipulated the need to admit more students to STEM talent development programmes.

This national programme made principals and teachers realise that they should start a talent development programme in their school. JCU staff realised that this may raise a need to bring back the talented students into the regular class communities. That might change the form of the JCU learning communities, but not result in their ending. Moreover, upscaling the number of participating students and inspiring all students in regular classes became new aims. These developments were reasons for a profound change of the design of the JCU programme in phase 2.

During phase 1, the structure of the partnership already had changed. It had started as was shown in Figure 1. By the working in learning communities, contacts between schools had increased and so the partnership evolved towards being a real network (Fig. 3).
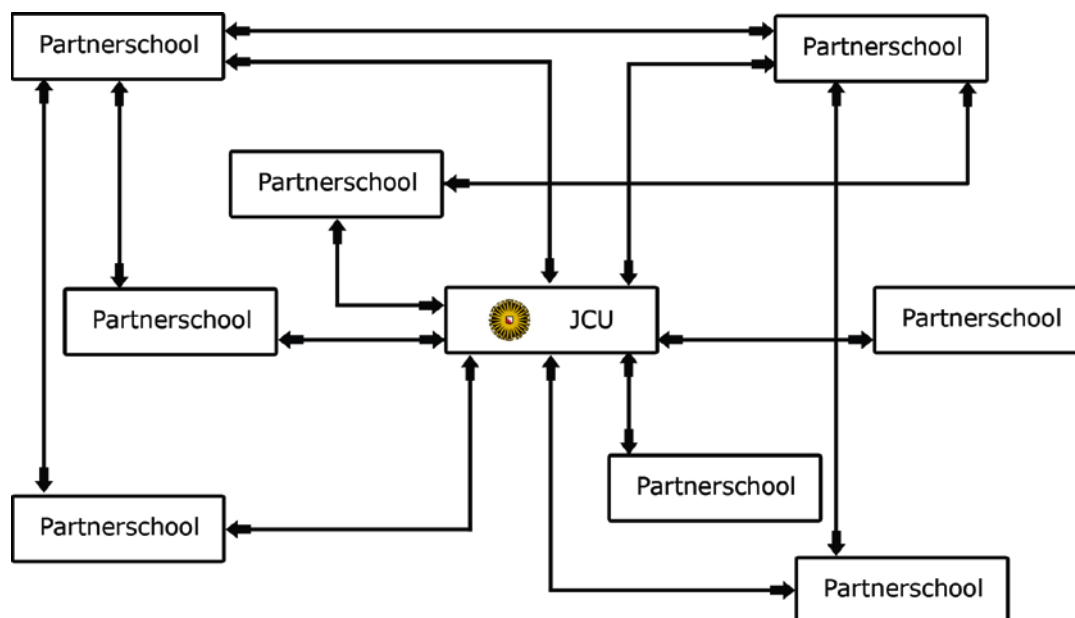
Figure 3: The JCU partnership as a school-university network

3 Phase 2 (2013 - onwards): realising a school - campus talent development programme

Since 2012, the JCU programme has been redesigned, focusing upon two main aims:

- Implement a school talent development programme that fits individual schools and that is connected to a common campus programme for students
- Increase the number of students in the programme.

Its revised student programme is named 'U-Talent Academy' (U-TA). This Academy has a school as well as a campus programme. It is expected to have an impact on the school as a whole, as is reflected in Figure 4.

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At the moment this paper is written, the U-Talent Academy has an experience of 1 ½ year. The first grade 12 students are about to finish the programme and to do the final examinations. So, only some initial results can be reported, that nevertheless show the strength of the learning community of JCU schools that has grown since the start of JCU.

Figure 4: The new model: a talent development programme on top of the regular curriculum, having impact on the school as a whole

3.1 Establishing the U-Talent Academy at school and on campus

In 2012, JCU developed a plan for a new design of the student programme, building on the insights gained in phase 1. JCU staff proposed to the partner schools and Utrecht University that the new U-Talent Academy (U-TA) for grade 11/12 students would have a combined school/campus programme. The campus programme would not include the regular STEM syllabi anymore, but only a big research project and enrichment modules orienting on university research topics. Instead of one group of 50 students being in the programme 2 days a week (as in phase 1), in phase 2 groups of 50 would be on the campus two days *a month*, making room for three more groups of 50 to participate, at the same costs.

The U-TA students would attend STEM classes in their own schools and, in addition, a U-TA school programme. The partner schools were free to design their own U-TA school programme. In the community of schools, they agreed that each U-TA school programme would include four activities: (1) preparation at school of modules of the campus programme; (2) enrichment projects; (3) community activities and (4) differentiation in regular STEM lessons.

The partner schools were offered three options: to leave the JCU partnership, to join the U-TA in 2013 or to join in 2014. JCU staff expected that 10 schools would choose option 1, but surprisingly, 23 schools opted for joining in 2013. Four schools joined in 2014 and one school decided to join the partnership of a more nearby situated university. This result shows that the new design was broadly supported in the partnership. All joining schools accepted the demanding task of developing a U-TA school programme.

So now, at the end of 2014, 27 schools are developing their U-TA school programmes and having fist experiences with that. JCU supports their STEM teacher teams by a teacher professionalization programme. Pairs of schools visit each other in order to learn from each other. Significant differences between the school programmes have appeared. E.g. some schools

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integrated it in a broader talent development programme (including non-STEM subjects; for all grades). Other schools developed programmes limited to STEM and/or to grades 10-12. Schools develop enriching modules about topics they are specialist in. However demanding, principals and teachers feel challenged to develop good quality U-TA school programmes.

Preliminary results show that a key factor in realising the U-TA school programmes has been the agreement about the four common activities in the school programmes. In particular, 'preparing students for modules of the campus programme' had a stimulating impact on starting the U-TA school programmes. Before each monthly module in the campus programme, students receive from their campus teacher a preparation assignment about the module that will be taught. In their school schedule, time must be allocated to do this assignment and a teacher must be present then to guide the students. This implied for schools that they really had to design and to schedule the U-TA programme. And starting the programme requested developing enrichment modules and community activities. Realising differentiation in the STEM lessons, however, has appeared to be hard. A bit of differentiation is realised in all schools, because students sometimes are absent in lessons when they do U-TA activities at school or when they attend the campus programme. But in most cases, students have to manage themselves how to catch up the lessons missed. Only few schools succeed in providing differentiated assignments, with e.g. compacted or comprehensive parts in it.

It is concluded that the aim of scaling-up by implementing talent development programmes in the partner schools in well under way, but it will take some years to develop well balanced U-TA school programmes. In a later stage, these can be disseminated to other schools or networks.

3.2 Scaling-up the number of student participants

It was planned that the U-Talent Academy would start in 2013 with 100 grade 11 students, being two communities of 50 students. In each following year, the number would increase with 50 students until the number of 250 is reached.

In 2013, the schools selected 104 students for U-TA and all were admitted to the programme. After some months, 5 of them dropped out, that is less than the 10% drop-out in stage 1. At the end of grade 11, all students expressed to enjoy the U-Talent programme, in particular the campus programme. The U-TA campus teachers, however, noticed that the community forming was less intensive than in stage 1, because the students now meet each other only once a month. This decreased community intensity probably was compensated by the students being in the school U-Talent community. For, many of them expressed to enjoy that community. However, the students of some schools found that the school programme activities need improvement. In the 2014/15 course, 99 students are in grade 12 and are preparing for the national final examinations.

In 2014, 144 students were selected and admitted to the programme (three groups). No one of them dropped-out until now (end of 2014).

The planned increase of the number of participants has been realised. But in fact, the upscaling has appeared to be bigger. For, the new design provided a solution for those candidates for U-TA participation that were not selected for the school-campus programme, be it for lack of places or be it for the campus programme being too demanding for them. Quite a few schools decided to admit those students to their school programmes, without participation in the campus programme. Thus, in 2013, 160 students more participated in the U-TA programme, be it partly. The 2014 numbers are not known yet. It can be concluded that the aim of scaling-up the number of participants of STEM talent development programmes has been reached by far.

4 Reflection on the central issues

The aim of this paper was twofold: a) to describe how a school-university partnership can successfully implement talent development programmes for senior secondary school students and scale these programmes up to its partner schools and nation-wide and b) to clarify the role of learning communities in this process of scaling-up.

We described the case of Junior College Utrecht in two phases: a first phase (2004-2012) during which a talent development programme at a university campus was developed and enrichment modules were disseminated to partner schools and schools nationwide; and second phase (2012-2015) during which the talent development programmes expanded to 27 schools that took responsibility for the development of their own talent development programmes, aligned to an enrichment programme at the university. This latter phase is still very much developing. Still, we can distil some conditions that need to be met for effective scaling up in a school-university network.

First, a school-university partnership needs concrete activities that function as a crystallization point for illustrating the issue clearly to all stakeholders. A clear crystallization point requires commitment between the stakeholders, and can function as a showcase of its main purpose. For example, in the case of JCU, the crystallization point in phase 1 has been a talent development programme at the university in co-operation with the schools. Students mentioned the strength of the student and student-teacher community very often. Its success demonstrated to teachers and school principals that some of their students benefitted greatly from an enriched and accelerated STEM programme as well as a strong academic community. This helped to raise awareness for the need of enrichment, community, etc. at the schools.

Second, school-university partnerships need to set common goals. For this to work, a constant dialogue between stakeholders in the community is needed. This requires that university staff members and school teachers & principals regularly communicate and on a basis of equality. It is also needed that the activities address the concerns of the university as well as the concerns of the

participating schools; this in turn requires a willingness to learn about these concerns and to come up with concrete solutions to these concerns. If this happens, the partners will not only experience influence in the activities of the school-university partnership, but the activities of the partnership will also serve the needs of its participants.

Third, if no talent development programmes are started in a school, it is hard to implement lesson material developed for the traditional subjects in a campus programme. However, new innovative curricula can provide opportunities for such lesson material, at the condition that it is adapted to the goals of such a subject and to the level of the students.

Fourth, relying fully on a campus programme has many advantages, but in the course of time, some disadvantages can come to the fore, e.g. focuses on the role of the university instead of focusing on the role of the schools. In a redesign, the part of the schools in the programme has to be enlarged. Within the school teacher communities, a leading teacher (e.g. the head of the science department) can take the role of educator, being educated by university staff (Van der Valk 2014a).

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Lesson Study as a tool for professional development: the context of counting problems -

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1 Introduction

In the last ten years there has been a growing interest in Japanese Lesson Study. Lesson Study experiences are reported from Hong Kong and Sweden (named Learning Studies), Germany, and the US and the Netherlands. In Lesson Study participating teachers choose a topic and plan lessons collaboratively, one teacher implements the lesson in class and student learning is live observed by all participants, and finally the observations are discussed. The focus is on student learning, and this creates teachers' awareness on mathematical knowledge of teaching and learning. Lesson Study is chosen as a professional development strategy because research shows that within a context like Lesson Study, changes in knowledge and beliefs are to be expected. The aim of this study is to investigate the effects of Lesson Study on Dutch mathematics teachers' professional development with the focus on counting problems. Counting problems (with permutations and combinations) are difficult for students; they feel uncertainty to solve this type of problems. In this study we choose Lesson Study alerting the mathematics teachers to focus on students' reasoning to set up counting problems. We relate the teachers' professional development in terms of external influences, classroom practices and internal knowledge, beliefs and attitudes.

2 Theoretical framework

2.1 Lesson Study

Lesson Study originates from Japan, where it is a leading approach for teachers' professional development. Teachers collaborate in a team with the intention to probe students' learning processes (Lewis, 2009; Saito, 2012). In a Lesson Study team, teachers, under the supervision of a process organiser, collaboratively improve teaching and learning assisted by an experienced teacher trainer in the field of study. First the team analyses the way they introduced a certain topic. Experienced problems are discussed and this leads to new student and teacher activities. In the next phase, the so called research lessons are planned. In the research lessons the new approach and activities are implemented in class by one of the participants while the others live observe the way the students learn. Then the different observations are discussed by the team. Finally, on the basis of these discussions the activities are revised, and the planning, implementation, observation and discussion is repeated as shown in Figure 1 (Stepanek et al.).
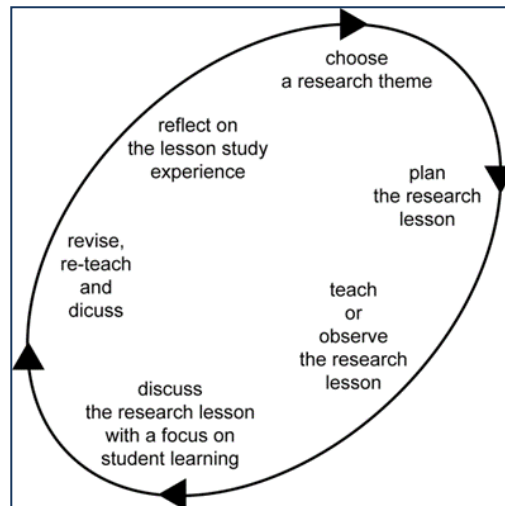
Figure 1: Lesson study cycle (adapted from Stepanek et al.)

Members of the Lesson Study team, and as much as possible colleagues and other interested persons live observe the research lesson the focus is on observing the students, not the teacher.

2.2 Teachers' professional development

In this study we focus on the content knowledge, curriculum knowledge and pedagogical knowledge aspects of Shulman, Shulman's (1987) Pedagogical Content Knowledge (PCK).The Interconnected Model of Teacher Professional Growth (IMTPG) as depicted in Figure 2, is used to analyse teachers' professional development.
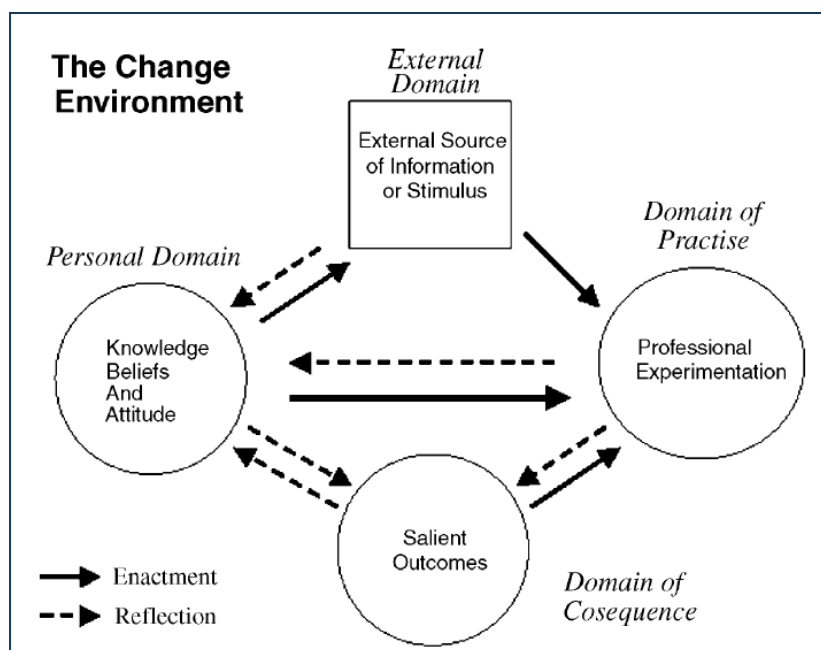

Figure 2: The Interconnected Model of Teacher Professional Growth

The IMTPG takes teacher change to be a learning process and suggests the mechanism by which this learning might occur: in recurring cycles through the processes of 'reflection' and 'enactment' in four distinct domains. Three of these domains are situated in the teachers' daily world, the fourth (the External Domain) is outside this daily world. Teachers' knowledge, beliefs and attitudes are situated in the Personal Domain (PD). The External Domain (ED) is where a teacher meets new ideas. In the case under discussion the ED consists of specific literature, the live observations and the discussions. The Domain of Practice (DP) involves all possible kinds of teacher classroom experiences, in this study the implementation of the research lessons. The Domain of Consequence (DC) focuses on the student learning results. This domain is coloured by teacher's expectations beforehand. Clarke and Hollingsworth emphasized the effect of a change in one domain as a sequence of changes in the other domains. They identified temporal changes named 'change sequences'. When the change is more than momentary, this is seen as professional growth and the associated change sequence is termed a 'growth network'.

3 Method

3.1 Participants and context of the study

The participants were seven Dutch mathematics secondary school teachers from different schools. Two of them participated three year in the Lesson Study team one of them participated two year in the Lesson Study team. Two members of the university completed the team: a mathematician of the applied mathematics department (the chair) and a researcher. The Lesson Study team met three weekly at the university. The teachers were given time (half a day weekly) from their school management to participate in the Lesson Study team. The first teaching of the two successive research lessons took place at the end of October 2013 with 28 students aged 15. The second revised teaching took place in another school two weeks later, with 24 students. The researcher distributed the scientific literature with regard to research outcomes related to teaching and learning counting problems. Particulars of the Lesson Study participants are shown in Table 1.

Work experience in		Degree + extra information
Ala	28 year	MSc mathematics + MSc education; mathematics team leader
Bill	2 year	MSc philosophy + MSc education, lower level to upper level high school
Cod	6 year	MSc technics + MSc education, mostly upper level high school
Don	20 year	BSc mathematics + MSc education, mostly upper level high school
Eli	2 year	MSc mathematics + MSc education, lower level to upper level high school
Fre	23 year	MSc mathematics + BSc education, lower level to upper level high school
Gus	3 year	MSc mathematics + MSc education, lower level to upper level high school

Table 1: *Description of the participants*

The first Lesson Study cycle consisted of several planning meetings but only during the last meeting teachers completed a learner report. The research lessons lasted 50 minutes each. The students were divided in groups - four students each – strong, middle and weak student groups.

3.2 Research instruments

The research instruments consisted of teacher leaner reports based on the video-taped Lesson Study cycle aspects: preparation, teaching and live observation with discussion / reflection and evaluation. The teacher learner report consisted of a combination of open, half-open, and closed questions about the learning outcomes, the context in which the learning experiences occurred, and the teachers' intention(s). This combination of the questions should provoke and support teachers to report in detail their learning experiences. The design of the learner report was inspired by the work of De Groot (e.g., Van Kesteren (1993)), and Endedijk and Vermunt (2013). We distinguished four versions of the learner report each tailored to address characteristics of a specific Lesson Study activity: collaborative preparation (P), teaching (T) or live observation with post-lesson discussion (O), and evaluation (E). In all learner reports the teachers were asked to highlight what happened and to describe **what** they learned and **from what** they learned: exactly what happened, who was involved, did you expect this and why, what were the effects on you personally, and did you design new plans based on this experience?

3.3 Procedure and data analysis

The learner reports of the seven secondary school teachers who participated in this study were collected between September and December 2013. The participants received instructions about the learner report. The participants reported a self-chosen learning experience by completing a learner report two times in a university meeting in the first Lesson Study cycle: firstly after the collaborative preparation and secondly after the teaching (of two successive research lessons), observations and discussions.

The analysis involved several stages. The data were structured and paraphrased in order to make these accessible. Teachers' written answers were marked by condensed statements representing what was learned and from what was learned. The 'what was learned' statements were categorized in aspects of mathematics teaching methods: 'not working', 'formulas - without student understanding', 'focus on one single context' and 'focus on different contexts'. The 'from what was learned' statements were categorized in preparation, teaching, observation, discussion and evaluation. The researchers summarized these results in: "What was learned" and "From what was it learned".

4 Results

Table 2 reports 'what' and 'from what' the teachers learned in the Lesson Study cycles in phases. The first column holds teachers. The second column reveals 'what' the teachers learned. The third column holds 'from what' the teachers learned in phases: preparation (P) continued by teaching (T1) or observation with discussion including preparation (O1) in the first Lesson Study cycle, and teaching (T2) or observation with discussion (O2) continued by final evaluation (E) in the second Lesson Study cycle. The fourth column shows aspects of teachers' growth network in terms of IMTPG domains.

	I learned that…	from..	IMTPG
Alan	… my students, with me being unaware, apply tricks and a difference between choosing and ordering	P	PD
	… when students see numbers in an exercise starting multiplying, without any meaning	O1	DC
	… students learn from acting out a counting problem	O2	DC
	… visualizations are important for student understanding	E	PD
Bill	… I should enrich lessons with pictures / systematic notes	P	ED
	… the teacher should help students tackling counting problems showing practical applications	O1	DC
Cody	… student need to count systematically as a basis to learn combinatorics	P	ED
	… the supposed importance of imagining instead of drawing pictures	O1	DP
	… enthusiast students have no idea whether their approach is correct	O2	DC
	… visualizations and plays are important tools to understand counting problems	E	PD
Don	… certain approaches need to be developed far for (students) to see that the chosen approach does not work	P	ED
	… it is hard to teach students by letting them discover	O1	DP
	… students are uncertain, unable to explain what they did	T2	DC
	… suitable practical examples are hard to find	E	ED
Eli	… students are not capable yet to systematically write out	P	PD
	… students first try to work everything out in mind before writing out any part and continue	O1	DC
	… there are many ways to look at a counting problem, students should be made aware - no more problems	E	ED
Fred	… the importance of systematic counting and the way to write this out, I will give more attention to that	P	ED
	… acting out a situation really helps students to understand the counting problem and the differences	O1	DC
	… students need to systematically write out all possibilities to feel certain: solution is correct	O2	DC
	… students should be able to switch the point of view, too different problems are not helpful	E	PD
Gus	… it is hard to predict student reaction on open questions	P	PD
	… open questions are helpful to reveal thinking processes, hard to relate concrete problems	T1	DP
	… different students learn completely other things	O2	DC
	… students should be able a visualization by situations	E	ED

Table 2: Teachers' learning activities in the two Lesson Study cycles on counting problems

At the preparations the teachers decided to start with thirteen different counting problems, asking the student groups to order them and explain their ordering (Batanero, Navarro-Pelayo and Godino's 1997). It proved hard to predict what difficulties students would encounter when dealing with counting problems. The students' arguments provided the teachers a lot of insight regarding their own view on what their students are capable of and how they can investigate student thinking processes in terms of ordering and

replacement. Almost all the teachers concluded in the evaluation of the first lesson that the chosen approach had not worked, but were very pleased with the conclusions they could take from it, resulting in an adjusted second plan with a focus on the visualization of the problems. None of the teachers had anticipated this to be a vital part of the lesson plan at the beginning of the Lesson Study. The teachers said no longer to use their previous approach with regard to counting problems but decided to focus on one single context stimulating students' imagination. In the second Lesson Study cycle the context 'offering five chairs to three people' was used in the first research lesson. A comparable situation of choosing three out of five people to be a chairperson, a secretary and a treasurer was used in the successive second lesson. When discussing the observations, the teachers became aware of the power of comparing situations in different contexts and of students playing out the situation.

Looking at the domains in the IMTPG, it becomes clear that the preparation of the Lesson Study made the teachers aware of the fact that students use tricks, highlighted in their textbooks, to solve counting problems. The teachers discussed their classroom practices of students' use of not understandable formulas (DP) being aware of students' lack of systematic counting and writing out (ED). The live observation reveals teachers' classroom experiences and student learning as well as the importance of imaging (DP). Teaching made the teachers aware of students' uncertainty and the positive effects of playing out (DC). The reflection and evaluation show teachers' awareness with the focus on carrying out the collaborative prepared lessons (PD) and the reasoning about teaching and learning strategies (ED).

This study in a Dutch Lesson Study context reveals the advantage of visualization and playing out counting problems. Our research outcomes show that the Lesson Study approach is a flexible approach based on daily complex and different classroom practices. Lesson Study promotes the focus on student thinking and learning, instead of the best learning materials or teaching methods. According to Saito key points and practices required to develop skills in observing and interpreting what happens in the classroom are also still largely unspecified. Models that specify the connections between the observable characteristics of Lesson Study and instructional improvement, would therefore be useful. The Dutch experiences demonstrate that it is advisable to limit the number of participants in Lesson Study teams. Too many participants hinder the quality of the discussions. Scaling-up the Dutch Lesson Study experiences is complex. Firstly, the school managers who are willing to stimulate the scaling-up of Lesson Study supporting teachers by giving time to plan collaboratively, to visit other schools and to reflect in the university meetings. Secondly, the Lesson Study experts who are able to organize the Lesson Study and distribute scientific literature to professionalize the teachers. Thirdly, the teachers themselves who are interested in searching their own classroom practices in collaboration with colleagues.

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Content focused peer coaching and the development of lesson plans about scientific inquiry -

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Background

Scientists, science teacher educators, and classroom teachers agree that students should hold knowledge about scientific inquiry, because scientific inquiry is seen as an indispensable component of scientific literacy (Abell, 2007; Lunetta et al., 2007). Based on this assumption several countries all over the world have implemented teaching standards for scientific inquiry (e.g. EDK, 2011; KMK, 2004). According to those standards scientific inquiry is defined as an active and idealized learning process modelled after the inquiry process of professional scientists. It is a content of itself, comprising reflective knowledge about scientific thinking, scientific methods, techniques of laboratory work like planning and executing experiments and the Nature of Science.

As learning outcomes are, at least in part, depending on the quality of classroom teaching, learning to create an inquiry-oriented lesson is a core part of science teacher education (NGSS, 2013; Windschitl, 2003). Frequently science teacher students as well as inservice teachers struggle with planning inquiry-oriented lessons (e.g. Schneider & Plasman, 2011). Among the reasons are unfavourable beliefs about scientific inquiry, little experience with scientific thinking and scientific methods in school and teacher education, insufficient knowledge about central terms like "hypothesis" and "experimentation", and at a more administrative level missing or insufficient teaching standards related to scientific inquiry that can be used to develop learning opportunities for future science teachers (e.g. Asay & Orgil, 2010; Gyllenpalm & Wickman, 2011; Hasse et al., 2014). Unlike the US (NGSS, 2013) in Germany exist rather general standards for science teacher education (KMK, 2004; GFD, 2005) that require educators on the university level to individually specify what science teacher students should learn to be able to plan and analyse inquiry-oriented science lessons. Furthermore, empirical data about successful teaching strategies fostering science teacher students' orientations and knowledge about planning inquiry-oriented lessons is small in number (e.g. Capps & Crawford, 2013).

Reflected experience in school-based learning environments is considered a key element for the transition from novel to professional teacher (Wanzare, 2007). A popular approach to enrich practice-based learning opportunities is mentoring by more experienced teachers, which can occur before, during, and after lessons (Schwille, 2008; West & Staub, 2003). Recent studies have shown that supported lesson planning is an effective learning opportunity for student teachers with respect to different indicators like self-reported changes

in concepts on teaching, or interdisciplinary and pedagogic facets of lesson quality (Kreis & Staub, 2012).

There is evidence that student teachers engage in unsolicited collaborative lesson planning with peers during school internships. Studies on teaching related collaboration between peers show promising effects (Lu, 2010). Van Driel, Beijaard, & Verloop (2001) recommend to use peer coaching to help develop science teachers pedagogical content knowledge towards a more reform oriented curriculum with scientific inquiry as a core element. In addition to reflection with more experienced teachers peer coaching about scientific inquiry could be helpful, because mentoring teachers encounter problems to adequately support science teacher students in planning inquiry-oriented science lessons due to their own uncertainty in this field (Fazio et al., 2010).

The intervention study KUBeX employs content focused peer coaching between pairs of science teacher students (Kreis & Staub, 2012) as an additional learning opportunity for planning and reflecting science lessons. In KUBeX we ask, whether and to what extent content focused peer coaching may contribute to the quality of lessons plans about scientific inquiry, especially experimental biology lessons. The findings of the project should contribute to the knowledge about processes and quality of science lesson planning between students. Moreover, findings should help to unveil the transition process from novice to expert teacher as an interaction of restructuring beliefs and adapting knowledge with the help of peers.

1 Methods

KUBeX is a bi-national collaborative project of three Swiss (Thurgau, St. Gallen, Zurich) and one German university (Weingarten). Participants are science teacher students who qualify as biology teachers for lower secondary level (N = 120). Within KUBeX impacts of an intervention are studied with regard to (a) science teacher students' knowledge, beliefs, and activities about content focused peer coaching in biology, (b) knowledge and beliefs about teaching scientific inquiry, and (c) quality of lesson plans of experimental biology lessons collaboratively planned and reflected. Research involves 1. quantitative analysis of content knowledge about experimentation and visual perception as contents of the planned lessons, 2. pedagogical content knowledge about scientific inquiry ("Orientation to Teaching Science", "Knowledge of Assessment of Scientific Literacy", "Knowledge of Instructional Strategies" and "Knowledge of Students' Understanding of Science" (Magnusson et al., 1999)), 3. prior teaching experiences, 4. qualitative and quantitative analysis of video recordings of peer coachings, and written lesson plans.

All participants take part in two successive workshops (2 x 90 min.) on pedagogical content knowledge with focus on scientific inquiry in biology. The intervention group additionally participates in two training workshops (2 x 90 min.) on content focuses peer coaching (Kreis & Staub, 2012). The control

group simultaneously receives an input, which does not interfere thematically. All workshops are fitted into the regular schedule and can be considered as ecologically valid. In a subsequent implementation phase, each science teacher student plans a biology lesson emphasizing methods of scientific inquiry within a standardized content ("visual perception"). Two students either of the control group or intervention group form tandems and discuss their initial lessons plans. Students' discussions are video recorded.

To analyse the quality of the peer coaching rubrics have been developed covering discussion topics, length and quality of discussion, and types of interventions chosen by the coach to elaborate the discussion. To analyse the quality of the initial lessons plans and lesson plans emerging from content focused peer coaching a rubric has been developed based on previously formulated requirements for teaching experimentation in biology taking into account relevant literature (e.g. Gyllenpalm & Wickmann, 2011; Schneider & Plasman, 2011; Börlin, 2012).

2   Findings

At present data of questionnaires and video recordings are analysed. As expected first results show little development of science teacher students' content knowledge. There is some preliminarily evidence that orientations to science teaching, and knowledge of instructional strategies increase. Peer coachings last between 10 and 50 minutes. Science teacher students discuss a variety of topics concerning pedagogical issues of the planned lesson like classroom and time management, uncertainties on content level ("How does visual perception work?", "Is a dissection a kind of experiment?"), and challenges of teaching inquiry. Some of the participants were not able to plan an experimental biology lesson focussing on methods of scientific inquiry. Progressions in lesson quality as a result of peer discussions can be found but don't come up regularly. Currently we analyse commonalities and differences of peer coachings between control and intervention group.

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