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BUILDING ON TEACHERS' BELIEFS TO SUPPORT INQUIRY PEDAGOGIES. LOOKING FOR SYNERGIES BETWEEN TWO EUROPEAN PROJECTS

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Abstract

This paper refers to several International Projects of the 7th European Framework in which the authors are actively involved. The first European project referred to is the PRIMAS project (Promoting Inquiry in Mathematics and Science Education across Europe), which has the overall objective of promoting inquiry-based learning in Mathematics and Science at different educational levels across Europe

Closely connected to the PRIMAS project, the MaScil European project (Mathematics and Science for Life) intends to support the use of inquiry activities embedded in setting or sceneries related to the world of work, as a way to provide a sense of purpose and meaning in the science and mathematics taught at school.

The main objective of this paper is to bridge 'the foundation' of these two projects and build on previous results from the former one to inform and take decisions in MaScil in our National context.

Keywords: inquiry-based learning, mathematic education, science education, teachers' beliefs, professional development, situated learning.

1 INTRODUCTION

In the European educational context, recent reports [1] highlight a declining interest in science and mathematics at school, with a potential negative impact on students' education as literate citizens and detrimental impact on their future choice for scientific careers. This trend can be considered as a threat to our societies' capacity for innovation and development [2], [3].

Reports by expert groups have claimed the necessity of a renewed pedagogy in schools to raise standards of scientific and mathematic literacy and to overcome deficits in science a mathematics teaching in regards to the knowledge society that 21st century is requiring.

Among others, research identified that one of the key areas to be addressed is teacher pedagogical practices, which are said to influence pupils' attitude to science and mathematics learning [3], [4]. The key relationship between teaching methods and students' attitude to science and mathematics learning has been repeatedly reported [5], and it is explicitly addressed by the European Union in its call for proposals within the 7th FP Capacities Work Programme, Science in Society:

> *'Falling interest in key science topics and mathematics has been linked to the way they are taught from the earliest age. Therefore, greater emphasis needs to be placed on the development of more effective forms of pedagogy; on the development of analytical skills; and, on techniques for stimulating intrinsic motivation for learning science'* [6], p. 18.

Transmission-based pedagogies where students are considered as passive receivers and reproducers of information do not support the development of those skills and competences. Society is currently demanding critical thinkers, able to efficiently select and use information, solve problems, adapt to new situations, and keep on learning in an increasingly complex and rapidly evolving society. Therefore, there is an urgent need to support those teaching approaches which foster students' active learning in science and mathematics, and which promote not only conceptual understanding of key curricular topics, but also the acquisition of skills and competences. Inquiry Based Learning (from now *IBL*) is the pedagogy being promoted as a key approach to address these challenges [5].

Some existing research states that *IBL* effectiveness has not been established yet, among others reasons, because it is difficult to have a reliable measurement of it [7]. Evidences gathered from empirical studies are deeply linked to a vast variety and a wide understanding of what *IBL* is or should be. However, in last years it seems that there is a more consensus than disagreement about *IBL*

benefits and effectiveness. The benefits of applying these methodologies in day-to-day teaching are widely recognized and accepted by the research community. Thus for example, results form different meta-analysis shown the benefits of inquiry based education such as high effects of learning outcomes, positive effects on concept learning, development of transferable critical thinking skills, significant domain benefits, improved achievement, and improved attitude towards science subjects [8], [9].

Although IBL benefits have been clearly identify, inquiry-based education' in daily teaching practices in classrooms is far from being achieved ([10], p.1). Inquiry based pedagogies have not already been rooted in day-to-day teaching practices, and a widely and accepted successful implementation is far from trivial. Different reasons are behind this situation [99] and a thorough analysis of these factors is beyond the scope and extension of this paper. Conditions and constraints which might favour, or hinder, a large-scale implementation of inquiry-based Mathematics and Science education have been identified and described by Dorier and García [11]

This study emerge from the perspective of some Spanish teachers engaged in professional development courses delivered from an international project which is aimed at promoting IBL in Science and Math across Europe. We present and analyse some results of teachers´ beliefs on the status of IBL, attitudes towards professional development courses, some factors hindering the implementation of IBL, and current teaching practices. These results will be very valuable and informative to build on them, and to inform other European projects. Also to guide and facilitate decisions for further delivery and implementation of professional development courses, providing a rich picture of important issues regarding the implementation of IBL.

2 BACKGROUND

2.1 Some crossnational European projects and Inquiry-based learning

Probably, the most worldwide accepted, disseminated and cited definition of inquiry in Science education is that proposed by National Research Council, [12], p. 23:

> *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 already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations and scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work.*

This definition is often used jointly with the five features characterizing inquiry-based learning as expressed by the National Research Council: students create their own scientifically oriented questions; students give priority to evidence in responding to questions, students formulate explanations based on evidence; students connect explanations to scientific knowledge, students communicate and justify explanations [9]. As stated in [9] the existence of such definitions does not exclude the co-existence of different interpretations of inquiry-based learning, (p. 781)

Although inquiry based pedagogies are claimed to be student-centered, teachers also play a central role in the successful implementation of inquiry-based education in Science and Mathematics classrooms. Research claims that one of the key areas to be addressed is teacher pedagogic practice, which is said to influence pupil attitude to science and mathematics learning [2], [4].

As one indicator of the relevance of these renewed pedagogies we could have a look to the number of projects funded by the European Commission within the FP7 framework, focusing on various ways to foster inquiry based approaches in Mathematics and Science education. These projects bring together recognized researchers and practitioners in the field of Mathematics and Science education, from institutions such as universities and colleges, teacher's networks, and policy makers.

PRIMAS and MaScil are two examples of these projects. They are oriented to increase and undertake the development of inquiry based learning pedagogies in Mathematics and Science across Europe. A wider perspective of inquiry-based Mathematics and Science learning and teaching has been developed within the consortiums of these two projects (Fig. 1) This approach has been deeply

discussed and refined in order to obtain a wider interpretation a theoretical groundwork which guide each of the multiple actions carried out from these projects.

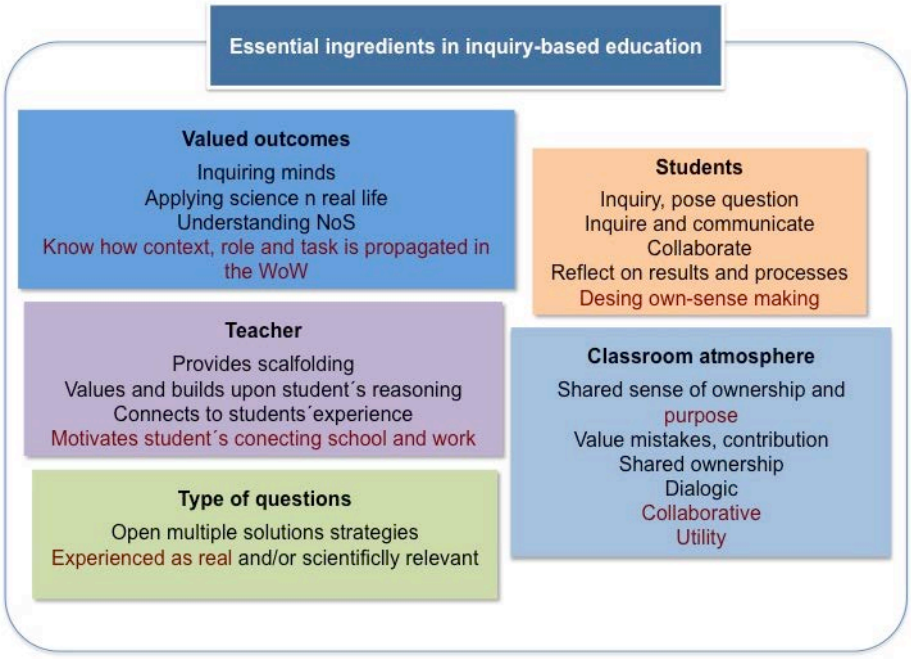

Fig. 1 Multi-faceted perspective of IBL (Adapted from: Black (PRIMAS); Brown (MaScil) [11] [13]

Accordingly to this scheme, *IBL* is considered as a multi-faceted teaching and learning culture, which recognizes that inquiry processes play a central role for learning. But also emphasizes that students are active players, that a social context is needed for this meaningful learning, and that learning have to be sustained by meaningful contexts.

2.1.1 Promoting Inquiry in Mathematics and Science Education across Europe: ***PRIMAS***

PRIMAS (*Promoting Inquiry in Mathematics and Science Education across Europe)* is a European project that has the overall objective of promoting inquiry-based learning in Mathematics and Science at different educational levels. To reach this objective, an international team of researchers from 14 institutions and 12 countries share a common interest in order to offer a more widespread uptake of inquiry-based learning. This project began in 2010, and during its lifetime, has aimed to effect change across Europe in the teaching and learning of Mathematics and Science by supporting and focusing on different target groups (teachers, multipliers, students, parents…) and through the development of many resources and the implementation of different support measures. These include: teaching materials, professional development courses for teachers, professional development materials for teachers, support for teacher and professional development facilitators, a great variety of dissemination actions such as conferences, communication with school authorities, events for parents and students, outdoors activities, etc.

2.1.2 Mathematics and Science for Life: ***MaScil***

Connected to the PRIMAS project, the MaScil European project (Mathematics and Science for Life) brings together 18 partners from 13 countries. This project aims to promote a widespread implementation of inquiry-based education in Math and Science in primary and secondary schools. MaScil is a dissemination project, which provides an intervention model for a wide spreading and implementation of inquiry-based learning. Our research question is 'How will different dissemination strategies work in different contexts? (www.mascil-project.ue/research_details.html) [13]. MaScil partners have adopted the former multi-faceted approach of *IBL* (Fig. 1) enriching the former scheme in order to integrate the concept of the 'World of Work (WoW, from now on)'. MaScil project intends to support the use of inquiry resources embedded in setting or sceneries related to WoW, as a way to provide a sense of purpose and meaning in the science and mathematics taught at school, also trying to increase students' motivation and interest towards careers in Science and Technology. These resources can point out to the WoW through different ways (e.g. using specific workplace contexts or by giving students a task or a role that somehow reflects a practice setting in a workplace)

The large-scale implementation of a professional development programme on *IBL* is a major challenge shared both by PRIMAS and MaScil. In Spain, professional development centres (depending on the Regional Ministry of Education) has been identified as key network. It offered the organizational structure to deliver courses to teachers. Our national team worked intensively with the Regional Ministry of Education, and with directors and science advisors of these centres, and with key actors within the Andalusian Society of Mathematics Teachers. This collaboration resulted in the identification of key teachers that acted as multipliers and in an extensive offer of courses by many teachers' centers in the region, which ensured the success of PRIMAS. Within MaSCil, official networks of professional development centres will also be considered. But MaScil will also explore the delivery of professional development courses in *blended learning* and/or *e-learning* settings, setting up communities of practice and using a teacher communication and professional development virtual learning environment (VLE) (http://teacher-communication.mascil-project.eu), which at this moment is under development. Consortium partners will decide the balanced weight of face-to-face or distance education, taking into account differences in each country teaching and learning culture, teachers and multipliers availability, and previous experiences and result from projects such as PRIMAS. Using a VLE will increase the opportunities to form international communities of teachers and the possibility to reach a higher number of them nationally.

2.2 Teacher´s beliefs

Within the PRIMAS and MaScil projects, teachers are considered as the key actors in promoting and enacting IBL practices to address the declining students' interest in science and mathematics through the use of these pedagogies.

Research has pointed out deep connections between teachers' beliefs and practices [14]. As cited by Maass and Artigue: 'task of preparing teachers for inquiry teaching is much bigger than the Inquiry-based learning in Mathematics and Science technical matters… the matter must be addressed… at a level that includes central attention to beliefs and values' (Anderson, 2000 cited in [9]). Educational research has also pointed out the impact that teacher attitudes and beliefs have on innovation and changes in curriculum and has also been reported that any professional development course should be built upon teacher views and practices to be successful. In terms of professional development, research findings clearly suggest that starting from teachers' beliefs is crucial for a professional development program to be really transformative [15].

Thus, understanding teachers' beliefs about professional development courses related to *IBL* approaches can inform us how teachers are likely to adopt and implement this methodology.

Taking into account this framework we aim to analyse how Spanish teachers of Mathematics and Science education perceived some features of *IBL* before they engaged in professional development courses as learners and multipliers. Through this study we try to provide an overview of teachers' beliefs about usefulness of professional development courses, some difficulties and hindering factors for IBL, attitudes towards IBL implementation, etc.

Herein we report some initial results and comment some items, which will be analysed and discussed, from our National perspective.

3 METHODOLOGY

3.1 Instrument

The questionnaire has been developed by experts of the 7th FP European Project PRIMAS, in order to outline the initial working conditions (study on teachers' beliefs and attitudes towards IBL and classroom practices) and the final impact of the actions carried out within the project. It is based on previous instruments and includes some items adapted from the PISA study, early works and previous research [8] [16]. This questionnaire had been developed bear in mind our multi-faced understanding of *IBL* (Fig. 1)

The questionnaire has three main sections. The first one gathers general information of personal data, such as gender, years of experience, educational stage (teaching at primary, secondary or high school) and subjects taught in the last two years. It uses codes to enable correlations with other latter data (post-questionnaire, students' questionnaires, case studies…) in an anonymous way.

The second and third sections include 92 items related to different aspects. The second section intends to classify the current teaching practices of the participants into three categories: traditional teaching, slightly *IBL* oriented and strong IBL oriented, according to the classroom culture and atmosphere, the teacher's predominant role in the classroom and students' usual role in daily lessons. The third one deals with issues related to what are the teachers' motives and expectation when enrolling in professional development programs. The second one focus on what are the features, requirements and effects of Inquiry Based Learning according to teachers' perspective, obstacles and hindering factors of IBL implementation.

After each statement, participants selected from a Likert-type scale (1=completely disagree, 4= completely agree; or 1=never, 4=always). This scale does not allow to choose from a neutral response. Depending on the categories the four-point scales reflect frequencies or agreement (never or hardly ever, in some lessons, in most lessons, in almost all lessons and strongly disagree, disagree, agree, strongly agree). The questionnaires also include one opened question: *What are the problems you face when teaching the subject?* Responses to this question will be use in a further qualitative content analysis to get a deeper and richer insight.

The questionnaire was originally written in English to ensure the participation and representation of the 12 countries involved in the PRIMAS project, and was later translated into the different national languages, looking for reliability and the preservation of the original meaning associated with any item.

Because we did not know teachers´ background in relation to *IBL* previously they were engaged in PD courses, we considered necessary to include a very brief text summarizing some of the key features of *IBL* in order to take the potential multi-faceted perspective views into account, but trying not to give enough information which could be used to orientated or 'over-guide teachers´ responses. We introduce the following text (translated into Spanish) at the beginning of the questionnaire:

> '*Inquiry-based learning (IBL) is a student-centered way of learning content, strategies and self-directed learning skills. Students develop their questions to examine, engage in self-directed inquiry (diagnosing problems, formulating hypothesis, identifying variables, collecting data, documenting their work, interpreting and communicating results) and collaborate. The aim of IBL is to stimulate students to adopt a critical inquiring mind and develop an aptitude for problem solving*'

3.2 Sample

Participants in this study were part the PD intervention carried out in the aforementioned teacher's centers.

Without intending to be representative of the whole Spanish country, the sample serves the purpose of the PRIMAS project by providing a picture, which contributes to illustrate a wide range of national contexts within Europe. The questionnaire was administered to 237 in-service Spanish teachers from different areas of the South of Spain. From this sample, 57% of participants were female and 43% male. In relation to the subjects taught, 70% of participants were mathematics teachers and 30% were science teachers, Grouping teachers in regards to the level they taught, the following distribution was obtained: 43% of teachers are involved in a "ten years and younger" level, 21% from ten to fourteen years and 36% in 14 years and older

In our national level, we aware that this sample could be not enough representative because our sample are not randomized. Without claiming to be representative of the Spanish population of teachers, we considered that it is meaningful to illustrate variety of cases and contexts among the 12 participating countries and for our national context could be a '*snapshot*' in regard to our potential teachers for oncoming PD courses delivered from MaScil. Therefore, this data will be very valuable for our National consortium bear in mind that a similar number of teachers, with similar background will be enrolled in PD programs delivered from MaScil project, (this assumption must be corroborated once the base line study, which is currently under development, were carried out).

4 RESULTS AND DISCUSSION

The analysis of data related shows that the majority of the Spanish teachers enroll in professional development programs as a source of personal and professional satisfaction and none of them do it because they feel obliged to (Fig. 3). These outcomes are aligned with the analysis of the Spanish

national context, where teacher professional development is recommended but not mandatory. Furthermore, these kinds of courses receive scarce social and professional recognition in Spain.

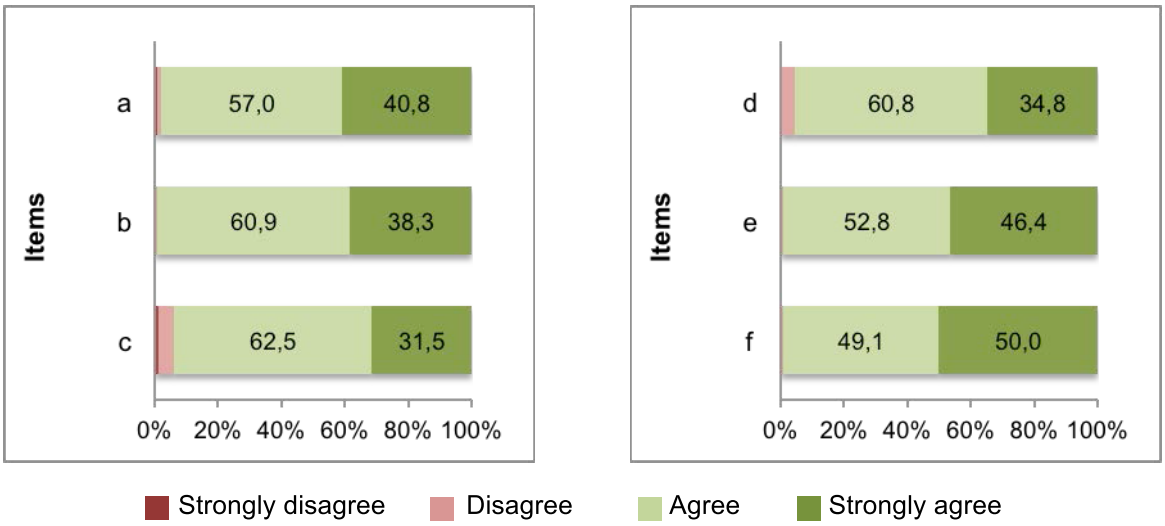

Fig. 2. Teachers beliefs about *IBL*. **Items:** (a) I would like to do more IBL to enrich my teaching practice; (b) I would like to implement more IBL practices in my lessons; (c) I would like to have more support to integrate *IBL* in my lessons; (d) IBL is well suited to approach students' learning problems. (e) *IBL* is well suited to overcome problems with students' motivation; (f) Students benefit from *IBL*.

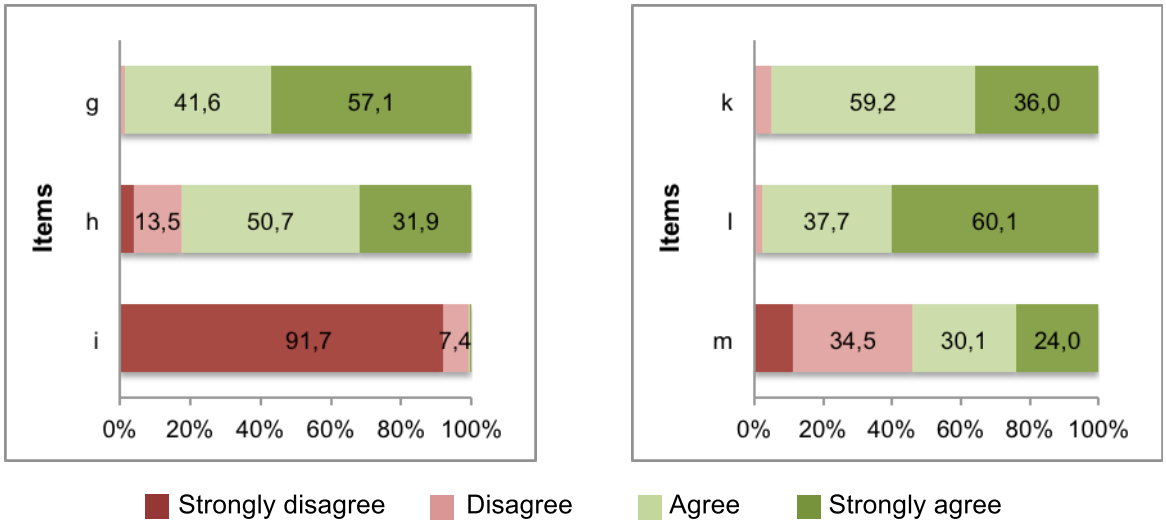

Fig. 3. Teachers' beliefs about profesional development programme. **Items:** (g) Through this programme I can attain greater professional satisfaction as a teacher; (h) Engaging in this programme can make me more confident in performing my role; (i) I am participating in this programme because it is compulsory; (k) I am really glad that I have the opportunity to take part in this programme; (l) This programme is necessary to update my repertoire of teaching methods; (m) This programme is necessary in order to update subject knowledge.

Other interesting feature of Spanish teachers' is that although most of them look at professional development courses as a mean to enrich their teaching repertoire (97.8%), there are a 54,1% of teachers that recognize they are looking for an improvement of their subject content knowledge thorough these courses (Fig. 3)

In relation to *IBL*, 45.3% of teachers affirm to be familiar with these pedagogies and 54.7% say that they do not know the fundamental principles of *IBL*. This split our sample in almost two equal groups. This result should be discussed a further more. By means of the analysis of some open questions, informal interviews and/or case studies carried out within the project, we have detected that sometimes teachers' views slightly differs from our multifaceted approach of what *IBL* should be. Thus, a question to be further investigated arises: *What are the main features that teachers select to*

decide whether or not they are familiar with the principles of IBL? Thus for example Marshal [10] has stated that *teachers often confuse teaching science by inquiry with teaching science as inquiry.* The first vision of teaching results in the so called "*activity-mania*". This approach often considerer activities as ways of entertainment and disconnected content-landend inquiry investigations. In these views some of our "ingredients" of multifaceted framework are missing.

This is a crucial starting point to have in mind once PD courses delivered from MaScil start. VLE could offer enough flexibility in order to deal instruction itineraries adapted to individuals depending on which group of views are learner-teachers .

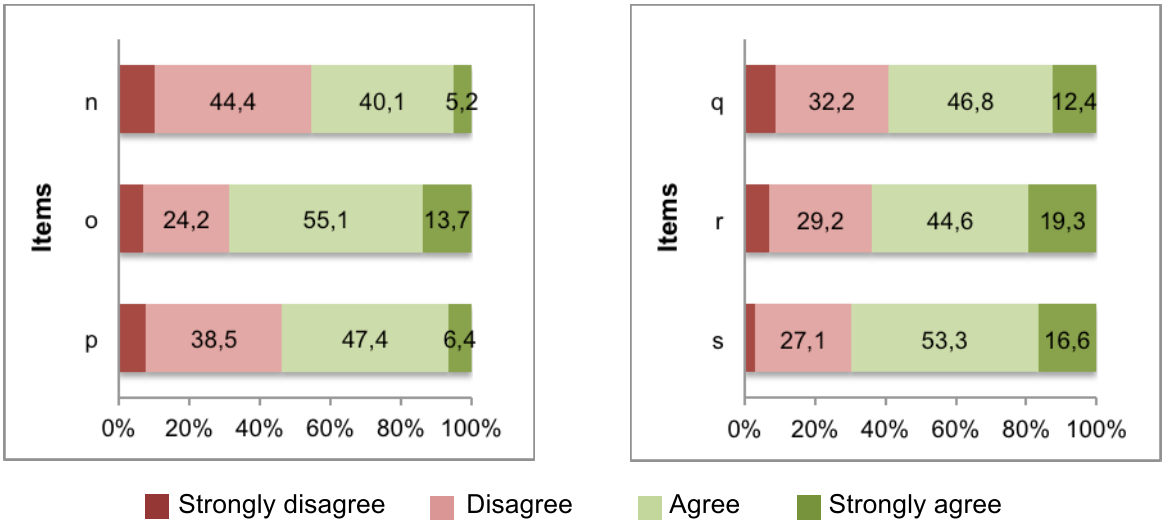

Fig. 3. Teachers´ beliefs about obstacles and hindering factors of *IBL*. **Items:** (n) I know about the principles of IBL; (o) IBL is not included in textbooks I use; (p) I think that group work is difficult to manage; (q) Curriculum does not encourage *IBL*; (r) I don't have sufficient resources such as computers, laboratories, etc.; (s) I have a lack of adequate teaching materials

The analysis of teachers' responses reveals the presence of those difficulties which hider a broad uptake of IBL For instance, 88.8% of teachers agree that standard text books are not align with these pedagogies and that there is a lack of teaching materials to support these approaches (69.9 %). Additionally, 63.9% explicitly highlights the need of extra resources such as laboratories, computers, etc. Over half of the participants (52%) express some concerns about classroom management when using *IBL* and agree that it is a time-consuming activity that does not always fit with the time allotted at school and the curriculum demands and even that curriculum does no encourage IBL (59.2%). All these difficulties are summarized under three factors: systemic restrictions, classroom management and resources restrictions.

Despite of that, most of the teachers (94.6%) look at inquiry based learning as an interesting approach to deal with some common learning problems and as an effective means to increase students' motivation (99.2%). They also recognize potential benefits related to the use of IBL in day-to-day teaching and the orientation towards the use of IBL show values close to 100% (orientation is measure by items a and b, Fig. 2). Nevertheless, they state that they would need further support to successfully integrate them into their daily practice (93%) (Fig 2.)

5 IMPLICATIONS AND FUTURE STEPS

Results in this communication are based on responses from teachers pre-questionnaires filled in before PD instruction was carried out. Almost 300 teachers participated in the professional development courses delivered from PRIMAS in Spain, most of them in Andalusia. A final report with a total sample of approx. 237 Spanish teachers size will be published elsewhere within a crossnational report. Within the whole consortium, these numbers has reached to approximately 1200 teachers, offering an opportunity to have a deep insight on the different categories of analysis.

The study carried out herein reveals teachers' positive attitude towards professional development and a positive orientation towards IBL implementation, and shows that they regards *IBL* pedagogies as an effective means to increase students' motivation and improve Science and Mathematics learning.

With this background, the PRIMAS project has promoted a wider use of IBL using a comprehensive strategy, which engages all the different stakeholders (students, parents, school departments, teacher centers and policy makers). Special emphasis is placed on teachers' professional development and on the necessity to equip teachers with the skills and resources required to effectively manage and guide IBL. Outcomes show that they need further support to efficiently integrate *IBL* into their day-to-day teaching. These results outline a highly receptive target group to keep on working within our professional development programs designed by MaScil consortium.

The challenges related to the lack of teaching materials and classroom management, for example, have to be tackled by sharing with teachers engaged in PD courses those experiences and resources of proven efficacy (MaScil is a dissemination project with strong developmental aspects) It is of course true that the tasks and materials must offer students the opportunity to make decisions for themselves, but the tasks and materials do not in themselves guarantee inquiry-based learning. Differences in teachers´ conceptions of inquiry and the inquiry-based learning multi-faceted nature sum up to the challenge of teacher training in these pedagogies. Resources and materials refined and developed in a setting of WoW and properly integrated in our PD courses might be help to face all these challenges and might have a synergic effect on teachers and students, sharing a perspective on teaching and learning that creates a new culture in the classroom of Mathematics and Sciences.

MaScil is working on it!

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