Schumacher, Fabian; Wilde, Matthias

When prospective biology teachers visualize their beliefs about teaching and learning by drawing it, is it more than a reproduction of their experienced school lessons?

European journal of educational research 10 (2021) 2, S. 799-811

Research Article doi: 10.12973/eu-jer.10.2.799

European Journal of Educational Research
Volume 10, Issue 2, 799 - 811.
ISSN: 2165-8714
https://www.eu-jer.com/

When Prospective Biology Teachers Visualize their Beliefs about Teaching and Learning by Drawing it, is it more than a Reproduction of their Experienced School Lessons?

Fabian Schumacher
Bielefeld University, GERMANY

Matthias Wilde*
Bielefeld University, GERMANY

Received: April 4, 2020 ▪ Revised: July 8, 2020 ▪ Accepted: March 20, 2021

Abstract: Professional teaching competence is significantly influenced by beliefs about teaching and learning. Prospective teachers start their teacher training with quite persistent beliefs about learning processes. These beliefs are mainly influenced by the way they experienced their own lessons as a student at school. Previous biology lessons at school might be linked to the imagined biology lessons of prospective teachers. We interpret these future lessons as a representation of their beliefs about teaching and learning. The present study investigated how prospective teachers remembered their previous biology lessons as well as how they imagine the lessons they will conduct in the future. The drawings of 181 prospective biology teachers in Germany (Mage = 22.1; SD = 3.6; 64.1 % female) were analyzed using the Draw-a-Science-Teacher-Test Checklist (DASTT-C). Results of the study indicate that the lessons they experienced were mainly teacher-centered, whereas the lessons they imagined were mainly student-centered. Results of a chi-square-test indicate that there is no connection between these two drawings of biology lessons. This suggests that experiences from one's own schooling may have no connection with the way prospective teachers would like to teach in the future. The results of this study might be used as a basis for further studies examining the development of prospective biology teachers' beliefs about teaching and learning.

Keywords: *Teacher beliefs, constructivism, teacher-centered, science teacher education, prospective biology teachers.*

To cite this article: Schumacher, F., & Wilde, M. (2021). When prospective biology teachers visualize their beliefs about teaching and learning by drawing it, is it more than a reproduction of their experienced school lessons? *European Journal of Educational Research*, *10*(2), 799-811. https://doi.org/10.12973/eu-jer.10.2.799

Introduction

For more than two decades now, science education research has demanded a constructivist and student-oriented approach to biology lessons to ensure successful teaching processes (Treagust et al., 1996). However, the findings regarding the implementation of this approach in German biology classes are based on little research (Fischer et al., 2003). Presumably, these experiences at school influence the formation of beliefs about teaching and learning (Jones & Leagon, 2014). Thus, it can be assumed that prospective (biology) teachers start their teacher training with preconceptions about the teaching and learning process (Dann, 2000; Pajares, 1992). Beliefs about teaching and learning influence the way one teaches (Baumert et al., 2004; Jones & Leagon, 2014; Luft & Roehrig, 2007). As a result, they are an important object of investigation in teaching-related research (Kervan et al., 2021; Prawat, 1992). Several instruments for ascertaining prospective teachers' beliefs about teaching and learning have been developed. Generally, quantitative questionnaire surveys or qualitative interviews are conducted. In the present study, the Draw-a-Science-Teacher-Test Checklist (DASTT-C) was used (Thomas et al., 2001). This instrument has participants imagine their future lessons and draw them on a sheet of paper, which serves as a means to analyze their beliefs about teaching and learning.

In this study we were interested in the experienced and the imagined future biology classes of prospective biology teachers. To obtain comparable data, we used the DASTT-C and modified it by adding a further section in which the students drew their experienced biology lessons.

* **Corresponding author:**
Matthias Wilde, Bielefeld University, Faculty for Biology, Didactics of Biology, Germany. ✉ matthias.wilde@uni-bielefeld.de

Literature Review

Teacher beliefs

The actions of prospective teachers are guided by assumptions and mental processes (Dann, 2000). Many of these pre-conceived notions originate from their own experiences as students at school and from their formal university education (Kleickmann, 2008). These experiences help them to build mental models of how they should interact in a given environment (Norman, 1983). These mental representations about teaching and learning in a specific subject are also referred to as beliefs (Krauss et al., 2004; Pajares, 1992). In the present study, we use the term *beliefs* as the overarching term of these mental models. Clandinin and Connelly (1987) have determined a large number of different definitions of these beliefs. Therefore, it is necessary to formulate a theoretical classification and definition of the understanding of beliefs that is used here.

In our study, *beliefs about teaching and learning* are regarded as a part of the professional knowledge of teachers (Dann, 2000; Kleickmann, 2008). According to Baumert and Kunter's (2013) model of professional competence, there are three different components of this professional knowledge: general pedagogical knowledge (PK), content knowledge (CK) and subject-specific pedagogical content knowledge (PCK) (Baumert & Kunter, 2013; Bromme, 1992, 1997; Shulman, 1986, 1987). Subject-specific beliefs in this study are regarded as a part of the PCK in the taxonomy of professional knowledge of teachers (Magnusson et al., 1999). These beliefs about teaching and learning serve as a framework or a conceptual map of the general understanding of teaching and learning in a specific subject (Borko & Putnam, 1996; Bromme, 1992; Kleickmann, 2008; Krauss et al., 2008).

When it comes to the beliefs about teaching and learning, affective and cognitive aspects as well as opinions and knowledge are all intertwined. Magnusson and colleagues' (1999) model describes beliefs about teaching and learning as a form of (rational) knowledge that is based on one's own (subjective) teaching and learning experiences (Kleickmann, 2008).

In the present study, our definition of beliefs about teaching and learning includes the knowledge aspects of Magnusson et al. (1999) and the component of subjective beliefs by Richardson (1996) and Pajares (1992). Based on Kleickmann et al. (2010), we understand beliefs about teaching and learning as subjective perspectives on learning in the subject and include epistemologically validated knowledge as well as subjective convictions.

Origin and organization of beliefs

Prospective teachers' beliefs about teaching and learning are strongly influenced by their experiences (Jones & Leagon, 2014; Kleickmann et al., 2010). Richardson (1996, 2003) has identified various sources and influencing factors in the development of beliefs. For subject-specific beliefs about teaching and learning, two major influencing factors can be found (Richardson, 2003; Woolfolk Hoy et al., 2006): one's own experience as a pupil in a subject at school such as biology classes and one's formal academic education at university.

Prospective biology teachers do not start their teacher training at university without prior beliefs, as the notions they hold about good and standard practice has already been influenced by the education they received as students at school (Jones & Leagon, 2014; Kagan, 1992a, 1992b; Woolfolk Hoy et al., 2006; Pajares, 1992). These experiences may influence their notions of what constitutes good or bad teaching (Pajares, 1992) such as whether and how teachers can activate their students (Stofflett & Stoddart, 1994). Hence, these experienced biology classes have a significant influence on the development of one's beliefs about teaching and learning (Huibregtse et al., 1994; Jones & Leagon, 2014; Kagan, 1992a, 1992b).

According to the concept of anticipatory socialization, the experiences prospective teachers gain during their own school time and their university education constitute a framework for teaching and learning (Kohli, 1986). The beliefs formed during these times have a socializing effect on their actions in school and can have a greater effect than the formally gained PCK (Kagan, 1992b; Klinghammer et al., 2016). All interactions between teacher and student are strongly influenced by beliefs about teaching and learning (Koballa et al., 2000).

Currently, two general frameworks for teaching and learning can be distinguished: student-centered constructivist and teacher-centered transmissive approaches (Norton et al., 2005; Reusser & Pauli, 2014). In accordance with the designations of the original test instrument (Thomas et al., 2001), we use the term *teacher-centered* as a synonym for the transmissive and *student-centered* for the constructivist approaches. Teacher-centered approaches result from transmissive beliefs and are based on behaviorist learning theories (Dubberke et al., 2008). In this approach, learning is understood as the transmission of knowledge (e.g., Skinner, 1971). Learners are mostly passive (Dubberke et al., 2008; Kleickmann et al., 2010). Teachers with transmissive beliefs do not often provide learners with opportunities to actively engage in the subject matter (Dubberke et al., 2008). By contrast, student-centered approaches stem from constructivist beliefs that are based on active learners (Drechsel, 2001). Teachers tend to create learning opportunities that are individually attuned to the students (Buelens et al., 2002; Marsch et al., 2009). Encouraging students to formulate their own ideas and to reflect on their own way of learning are characteristics of a constructivist learning environment (Reinmann & Mandl, 2006).

The data of prospective teachers' beliefs about teaching and learning at the beginning of their university education are based on little research. The few existing studies from the German context have found that prospective biology teachers start their teacher training with mostly constructivist beliefs about teaching and learning (Brauer et al., 2014; Markic & Eilks, 2007; Markic et al., 2006).

Several studies have investigated the learning environments and the influence they have on the beliefs of prospective teachers in science (biology secondary-level: Da-Silva et al., 2007; physics secondary-level: Fischler; 2000; Klinghammer et al., 2016; chemistry secondary-level: Koballa et al., 2000; elementary-level: Southerland & Gess-Newsome 1999). Jones and Leagon (2014) emphasize the need to conduct country-specific analyzes, as beliefs are always affected by country-specific experiences and cultures. Likewise, it is important to assess the beliefs for the specific subject, as there may be different forms of learning culture (Koballa et al., 2000). However, Dorfner et al. (2017) summarize in their review that the learning environments in secondary-level biology classes have been scarcely investigated in Germany (Fischer et al., 2003).

Methodology

Research questions

Prospective biology teachers usually acquire certain beliefs about teaching and learning during their own school time as school students (Jones & Leagon, 2014; Kleickmann et al., 2010). Consequently, at the beginning of their teacher training they have often already developed quite persistent beliefs about teaching and learning (Pajares, 1992; Woolfolk Hoy et al., 2006). The formation of these beliefs appears to be significantly influenced by the perception of one's previous learning environments as being mainly teacher- or mainly student-centered.

In our study, we sought to investigate the connection between the experienced learning environments of prospective biology teachers with the imagined learning environments of their future lessons. We evaluated and classified the learning environments of their biology lessons at school by interpreting the participants' drawings and descriptions thereof. We also investigated what the participants imagined their future learning environments in their biology lessons would look like by having them draw a visual representation thereof as well as write answers to prompts asking what roles the teachers and students play. These drawings function as windows providing insight into the beliefs they hold regarding teaching and learning (Al-Balushi et al., 2020; Thomas et al., 2001). In the present study, we view teacher-centered drawings as a representation of transmissive beliefs and student-centered drawings as a representation of constructivist beliefs. Our research questions were:

Q1) What type of biology lessons did the students experience in their own biology lessons at secondary school?
Q2) What type of biology lessons do the students imagine teaching in the future?

Prospective teachers start their teacher training as insiders with assumptions about learning and teaching (Pajares, 1992). These beliefs are based on the lessons they experienced at school (Huibregtse, et al., 1994; Kagan, 1992a, 1992b). This lead to the third research question:

Q3) Do the biology lessons prospective teachers experienced at secondary school correlate with the imagined biology lessons they want to teach in the future?

Instrument

The instrument Draw-a-Science-Teacher-Test Checklist (DASTT-C) by Thomas et al. (2001) was originally used to assess the beliefs about teaching and learning of prospective elementary teachers. Several recent studies have also used this method to assess the beliefs of science teachers (Al-Balushi et al., 2020; Alkış Küçükaydın & Gökbulut, 2020; Buldur, 2017; Klinghammer et al. 2016; Markic & Eilks, 2008; Minogue, 2010). It is based on drawings of the imagined learning environment in future science classes (Weber & Mitchell, 1996). Specifically, participants are asked to draw a picture of themselves as a science teacher (in our case, as a biology teacher) at work and to describe their drawing in writing.

In order to measure the influence of prior school experience on preservice teachers' beliefs about teaching (Thomas & Pedersen, 2003), we added another aspect to the established instrument. The students were also asked to draw their experienced learning environment in their secondary biology lessons at school. The approach of this test was equivalent to the established part.

Data Collection

The participants received two pre-structured pages. On the first page was a square where participants were asked to draw the biology lessons they experienced as students. On the second page, they should draw the biology class they would like to teach in the future. Below both images was an opportunity to briefly explain the drawing. The participants were given approximately 15 minutes to complete the test.

Sample

The opportunity sample consisted of 181 prospective secondary school-level biology teachers from one university in North Rhine-Westphalia, Germany (M_{age} = 22.1, SD = 3.6; 64.1 % female; $M_{semester}$ = 2.64, SD = 2.23). The test was conducted during the beginning of a university lecture about learning and teaching biology in school. The assessment was conducted during the first lecture of the course titled "Introduction to Biology Education". Participation in the survey was a voluntary part of the lecture.

This was the first time these students were confronted with didactic topics in their biology teacher training at university, although the lecture is approximately 1.5 years after the start of their university education. At the beginning of their teacher training in biology, students take courses on the basics of biology. Didactic topics in biology are first taught in the examined lecture (Bielefeld University, 2020). Thus, it can be assumed that this was the first time that they had been confronted with topics about learning and teaching biology during their first phase of teacher training at university.

Data analysis

The drawings were rated using a 13-level dichotomous checklist. The checklist can be retrieved from the original publication by Thomas et al. (2001). One point was given for the presence of a characteristic and zero points for the absence of a characteristic of the checklist. The sum of the distributed values ranged between 0-13. The higher the sum values of a test, the more transmissive and teacher-centered the rater considered the drawing of the learning environment to be (Thomas et al., 2001). Three basic categories were distinguished: student-centered (0-4 points), undecided (5-6 points), and teacher-centered (7-13 points). Responses were classified as student-centered illustrations (see Fig. 1) if they showed various types of active teacher-student interactions. In these cases, the teacher is seen as a part of the pupils' spatial surroundings and includes him/her in the pupils setting instead of as a separate and superior actor; student-teacher interactions take place on the same level. In these drawings, no rows of desks are shown, but various activities such as experiments or activating methods instead. By contrast, teacher-centered illustrations (see Fig. 2) depict the teacher in front of the class. The desks are organized in rows and teacher and students can be clearly distinguished from each one another. Moreover, typical characteristics of this teaching style are illustrated (teaching from a chalkboard, step by step guidelines, etc.).

Of the total sample of 197 drawings, only 16 tests were not analyzed due to insufficient information being found in the drawings. Therefore, 181 tests were included in the reported results. Pearson's chi-square test was calculated in order to analyze the correlation between part one (experienced lessons) and part two (imagined lessons). To estimate the inter-rater-agreement, two researchers rated independently the two parts. In an interpersonal argumentative validation process, differing interpretations of the data were discussed and a second run was performed (Mayring, 2016). The inter-rater-agreement (Cohen's kappa coefficient κ) for the experienced lessons (κ = .88) and for the beliefs about teaching and learning (κ = .81) was good (Döring & Bortz, 2016; Wirtz & Caspar, 2002). The internal consistency of the scale 'experienced lessons' with Cronbach's alpha α =.75 and the scale 'imagined lessons' with Cronbach's alpha α =.69 turned out to be acceptable for group comparisons (Lienert & Raatz, 1998). If the pictures were ambiguous, the written prompts could be used as an aid to interpretation (Thomas et al., 2001). However, a triangulation of the data from the drawings and the short explanations had to be omitted, as the written answers were insufficient in quantity and explanatory power to evaluate them separately. This problem has already been mentioned in a previous study (Klinghammer et al., 2016).

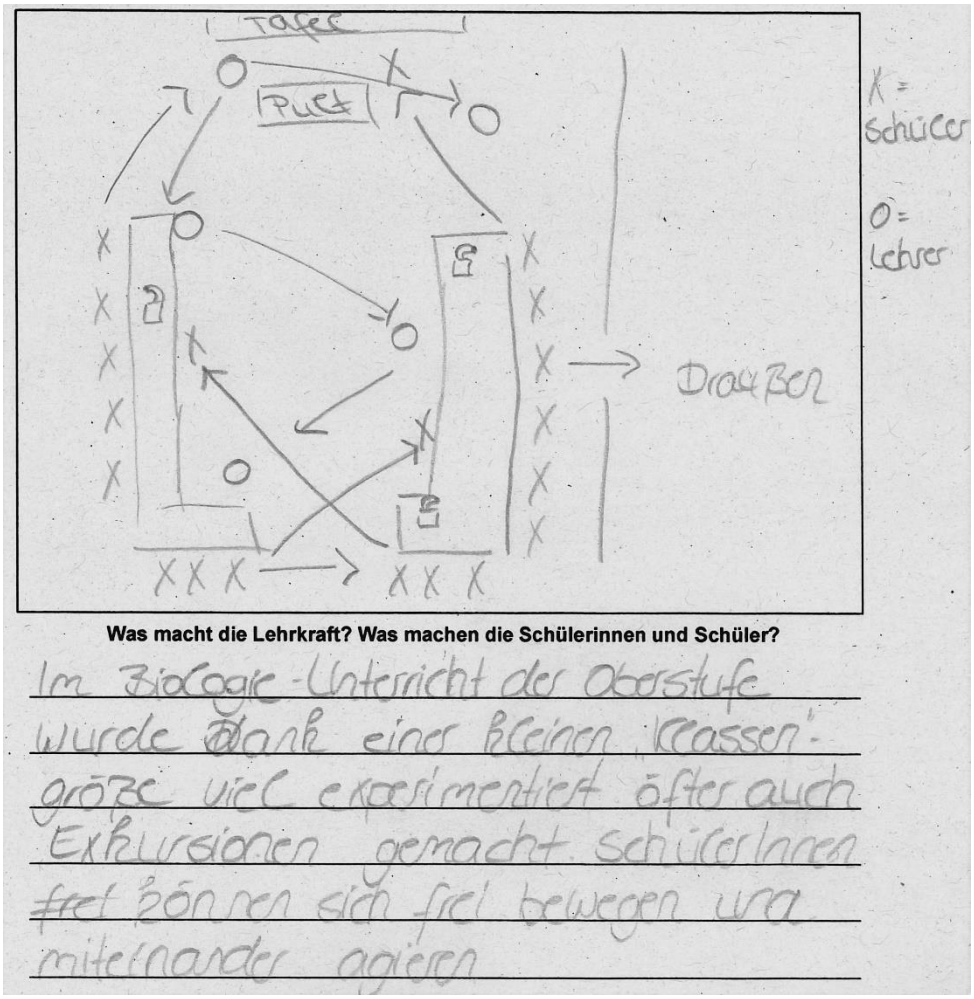

Figure 1. Student-centered drawing. Writing prompt: What is the teacher doing? What are the students doing? Answer: 'In biology lessons at the upper-secondary level, a lot of experiments were carried out—thanks to a small size—and excursions were often made. The students were able to move around freely and interact with each other'.

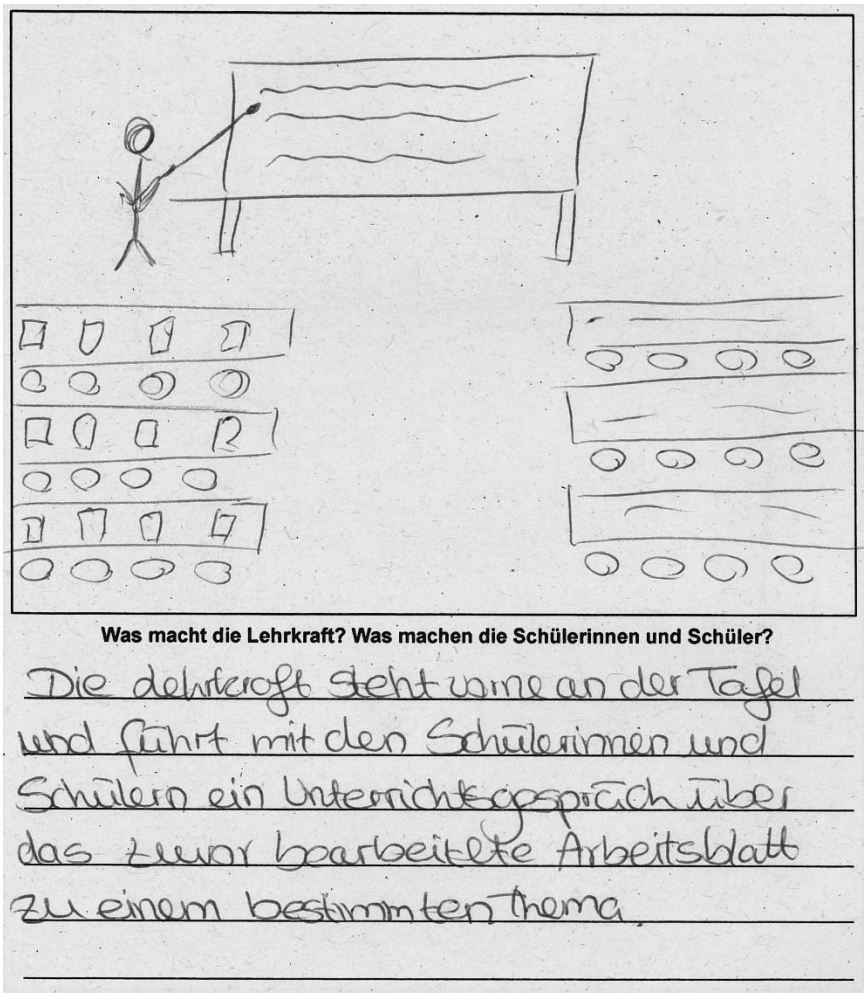

Figure 2. Teacher-centered drawing. Writing prompt: What is the teacher doing? What are the students doing? Answer: 'The teacher is standing in front of the blackboard and conducting a classroom discussion with the students about the previously finished worksheet on a specific topic.

Findings

First, we were interested in the type of learning environment the participants experienced in their biology lessons at school. According to Thomas et al.'s (2001) three-stage classification, 71.8% of the prospective teachers had experienced teacher-centered lessons. By contrast, only 9.4% of them drew classes that were classified as student-centered and 18.8% were assigned to the medium category 'mixed' (see Table 1). On average, the prospective teachers in this sample reported having experienced mostly teacher-centered lessons (M = 7.76, SD = 2.45).

Regarding our second research question, we assessed the participants' beliefs about teaching and learning by evaluating their imagined future biology lessons. The results showed that 59.1% of the drawings were rated as student-centered, whereas only 20.5% turned out to be teacher-centered and 20.4 % fell into the medium category. The mean value indicates that the drawings were mostly student-centered (M = 3.94, SD = 2.40).

For our third research question, we were interested in whether the participants' beliefs about teaching and learning were correlated with the type of learning environments they experienced in their biology lessons at school. We found no significant correlation between the two ($\chi^2 = 7.995$, $p = .084$, N = 181).

Table 1. Comparison of the DASTT-C response frequency distributions

Score	experienced biology lessons		imagined biology lessons	
	frequency	percentage (%)	frequency	percentage (%)
0	0	0.0	3	1.7
1	0	0.0	19	10.5
2	2	1.1	27	14.9
3	7	3.9	33	18.2
4	8	4.4	25	13.8
student-centered (0-4)	**17**	**9.4**	**107**	**59.1**
5	12	6.6	22	12.2
6	22	12.2	15	8.2
undecided (5-6)	**34**	**18.8**	**37**	**20.4**
7	16	8.8	20	11.0
8	33	18.2	10	5.5
9	43	23.8	4	2.2
10	27	14.9	1	0.6
11	9	5.0	1	0.6
12	2	1.1	1	0.6
13	0	0.0	0	0.0
teacher-centered (7-13)	**130**	**71.8**	**37**	**20.5**
Total	181		181	

Discussion

In our study, we were firstly interested in the nature of the biology lessons our prospective teachers experienced. Secondly, we were interested in what they imagined their future biology lessons would be like so we could see whether there is a correlation between the two. The students in this sample reported having experienced mainly teacher-centered biology lessons during their own school time. One possible explanation for this might be the fact that constructivist approaches are still lacking in schools. The findings of our study underline the fact that constructivist didactics should be more strongly emphasized in teaching methodology courses at universities in the sciences (Commission of the Federation and the Länder for Educational Planning and Research Promotion, 1997). Another explanation could be a bias in the way the students remembered their previous lessons. As teacher-centered views are often referred to as 'traditional' or 'old' perspectives, they might be more inclined to remember these 'old' lessons as being more teacher-centered than they actually were.

Although the majority of the participants seem to have experienced teacher-centered teaching in their biology lessons, their beliefs about teaching and learning were mainly student-centered (Q1, Q2). This is in line with recent findings on the beliefs about teaching and learning of prospective biology teachers (Brauer et al., 2014; Brauer et al., 2015; Markic et al. 2006; Markic & Eilks, 2007; Schumacher et al., 2018). This might be explained by the fact that students in the sample have already gained some exposure to current teaching and learning theories. Even though this was their first course in biology education, they might have encountered constructivist theories in other courses. Indeed, preservice teachers in Germany are generally required to take courses not only in educational sciences, but also teaching methodology courses in the two subjects they wish to teach.

In our third research question we were interested whether there is a correlation between the experienced biology lessons and the imagined lessons concerning the beliefs about teaching and learning of prospective biology teachers. The correlation turned out to be not significant. This finding is not in line with the results of previous studies (Da-Silva et al., 2007; Kagan, 1992b; Woolfolk Hoy et al., 2006; Pajares, 1992; Thomas et al., 2001). However, there appears to be a lack of empirical evidence for this assumed relationship because most of these studies were qualitative in nature and had quite small sample sizes. Another explanation could be that the response behavior was distorted by the specific subdivision of the two parts into experienced lessons and imagined lessons. This may have led the test persons to recognize the purpose of the survey and to draw their imagined lessons intentionally differently from what they experienced.

Conclusion

Overall, the advantage of the DASTT-C survey method is that the teaching environment and the participants' beliefs can be surveyed very directly (Ainsworth et al., 2011; Al-Balushi et al., 2020) and no specific verbal skills are required to answer (Finson et al., 1995). These advantages of drawings as nonverbal ways to assess beliefs have been

demonstrated in other contexts as well (Oztabak, 2020). Likewise, comparing images with verbalized statements in questionnaires enable internal beliefs to be linked to external situations. In our study, this applies to the possibly unconscious influence of the experienced lessons (Van der Veen, 2012).

Although teaching and learning beliefs are considered to be relatively persistent (Pajares, 1992; Woolfolk Hoy et al., 2006), a trend towards more student-centered, constructivist teaching and learning beliefs could be identified in the context of this study. The results of this study show a positive trend in biology teacher training at German universities. The prospective teachers seemed to be willing to adopt a more student-centered approach in the future even though most of them reported having had teacher-centered biology lessons during their school time. Therefore, a positive conclusion can be drawn. The prospective biology teachers of this study are very likely to enter their teaching career as "future change agents" regarding student-centered approaches (Heinz & Flemming, 2019).

Limitations

Some limitations to our study need to be addressed. Beliefs about teaching and learning are a complex and wide-ranging construct that is influenced by various factors (Jones & Leagon, 2014; Thomas et al., 2001). The method of drawing may not be multifaceted enough to do this complex construct justice (Rheinisch et al., 2017). One instrument to compare in this context is the Draw-A-Scientist-Test, which assesses beliefs about perceptions of scientists (Chambers, 1983). Rheinisch et al. (2017) evaluated this rather similar instrument and noted that its use can be problematic, especially with older participants. Some participants in the study might have felt that drawings are not capable of adequately capturing their views on teaching biology (Finson et al., 1995; Finson & Pedersen, 2011). In their opinion the seriousness of the subject was not met by the method, so they may have refused to participate wholeheartedly or at all. Hence, their drawings could not be used. Another possible limitation could be the linking of graphic abilities to the drawing (Losh et al., 2008). In our study, only 16 drawings could not be used in our analysis.

Another problem with the DASTT-C checklist is that the notions of teaching and learning and the experienced learning environment are only classified on the basis of one dimension, namely the continuum between student-centered and teacher-centered classes. It would be interesting to add other standardized methods that describe the experienced and imagined future learning environments more precisely through an additional number of items. The recording of mental models and beliefs can often lead to the participants responding in a socially desirable way (Döring & Bortz, 2016). As the survey was conducted in a course on the education of biology, the participants may have felt compelled to act according to social norms (Döring & Bortz, 2016). It is, therefore, possible that the students might have thought that imagining more student-centered instruction would be more socially desirable, or at least constitute the right answer in the eyes of the researchers (Reinecke, 1986).

In several studies, the means to evaluate the type of learning environment has been problematic. This was also the case in other studies in which the DASTT-C was used (Markic & Eilks, 2008; Minogue, 2010). If the participants created very precise illustrations, a larger number of details usually resulted in a higher score. As a result, some drawings were allocated to the teacher-centered group even though this sometimes contradicted the written explanations they provided. It was also difficult to classify actions outside the classroom (Minogue, 2010).

The drawings that could not be clearly assigned to one of the two types (student- or teacher-centered) were problematic. Consequently, 18.8 and 20.4 percent of the participants' responses were classified as undecided. The existence of seemingly incompatible beliefs about teaching and learning was also a factor found in previous studies (Brauer et al., 2014; Magnusson et al., 1999; Pajares, 1992).

Recommendations

For the further development of science didactics, extensive and precise knowledge of the beliefs of prospective teachers is of great importance (Brown et al., 2013). In university education, it is necessary to develop seminar formats that encourage future teachers to reflect on their teaching and learning beliefs in order to promote their professionalization process and to improve the quality of teacher training. Several aspects can be concluded from our study. One way to help prospective teachers become aware of their own beliefs could be seminars that help them to reflect on their beliefs about teaching and learning (Jao, 2016; Utley et al., 2020). In these seminars, students should be provided with opportunities to reflect on their beliefs, for example, using methods based on the structure laying technique (Flick, 2018). Another way might be to use instruments such as the DASTT-C to enable students to explore their own mental models (Thomas et al., 2001). If this survey method is used in teaching education, it can help students to be aware of their own beliefs about teaching and learning (Pajares, 1992). Therefore, the results could be discussed with the students in order to help them to become more aware of their beliefs about teaching and learning and the extent to which these may be influenced by lessons they have experienced before (Savasci & Berlin, 2012; Thomas et al., 2001). In order to do this without a time-consuming survey, the study by Thomas et al. (2001) provides a checklist for students to use in seminars to interpret their own drawings.

In our study, the correlation between experienced biology lessons and imagined future biology lessons turned out to be not significant. However, various studies indicate that there is such a correlation (Da-Silva et al., 2007; Kagan, 1992b;

Woolfolk Hoy et al., 2006; Pajares, 1992; Thomas et al., 2001). This needs to be investigated in future studies. Moreover, the time for completing the drawings might be extended. In our study, 16 drawings could not be evaluated because some of them were not detailed enough. As mentioned earlier, further studies could benefit from triangulating the images and the written statements. In this study, this was not possible due to the short written statements. It would also be possible to conduct interviews with some of the participants about drawings, allowing a more differentiated assessment of the beliefs.

Acknowledgements

We acknowledge support for the publication costs by the Open Access Publication Fund of Bielefeld University.

References

Ainsworth, S., Prain, V., & Tytler, R. (2011). Science education. Drawing to learn in science. *Science*, *333*(6046), 1096-1097.

Al-Balushi, S. M., Ambusaidi, A. K., Al-Balushi, A., Al-Hajri, F. H., & Al-Sinani, M. S. (2020). Student-centred and teacher-centred science classrooms as visualized by science teachers and their supervisors. *Teaching and Teacher Education, 89*, 1-10.

Alkış Küçükaydın, M., & Gökbulut, Y. (2020): Beliefs of teacher candidates toward science teaching. *Journal of Science Teacher Education*, *31*(2), 134-150.

Baumert, J., Kunter, M., Brunner, M., Krauss, S., Blum, W., & Neubrand, M. (2004). Mathematikunterricht aus Sicht der PISA - Schülerinnen und -Schüler und ihrer Lehrkräfte [Teaching maths from the PISA perspective: Leaners and their teachers]. In M. Prenzel, J. Baumert, W. Blum, R. Lehmann, D. Leutner, M. Neubrand, R. Pekrun, H.-G. Rolff, J. Rost, & U. Schiefele (Eds.), *Der Bildungsstand der Jugendlichen in Deutschland – Ergebnisse des zweiten internationalen Vergleichs* [The state of education of the youth in Germany – The results of the second international comparative study] (pp. 314-354). Waxmann.

Baumert, J., & Kunter, M. (2013). The COACTIV model of teachers' professional competence. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss, & M. Neubrand (Eds.), *Cognitive activation in the mathematics classroom and professional competence of teachers* (pp. 25-48). Springer.

Bielefeld University (2020). *Modulhandbuch Biologie/ Bachelor of science: Kernfach* [Module manual biology/ Bachelor of science: Core subject]. https://cutt.ly/uxa7cOL

Borko, H., & Putnam, R. T. (1996). Learning to teach. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 673-708). MacMillan.

Brauer, H., Balster, S., & Wilde, M. (2014). Lehr- und Lernvorstellungen künftig Lehrender zum Lernen von Schülerinnen und Schülern im Fach Biologie [Teacher and learner conceptions of teaching and learning in biology]. *Journal for the Didactics of Science/ Zeitschrift für Didaktik der Naturwissenschaften*, *20*(1), 191-200.

Brauer, H., Balster, S., & Wilde, M. (2015). Entwicklung eines Messinstruments zur Erhebung von Lernvorstellungen von angehenden Lehrenden [Developing an instrument to measure preservice teachers' notions of learning]. *Psychologie in Erziehung und Unterricht* [Psychology in education and teaching]*, 62*(3), 188-204.

Bromme, R. (1992). *Der Lehrer als Experte. Zur Psychologie des professionellen Wissens* [The teacher as an expert: On the psychology of professional knowledge]. Hans Huber.

Bromme, R. (1997). Kompetenzen, Funktionen und unterrichtliches Handeln des Lehrers [The competences, functions and behaviour of teachers]. In F. E. Weinter (Ed.), *Pedagogical Psychology/ Pädagogische Psychologie* (pp. 177-212). Hogrefe.

Brown, P., Friedrichsen, P., & Abell, S. (2013). The development of prospective secondary biology teachers PCK. *Journal of Science Teacher Education, 24*(1)*,* 133-155.

Buelens, H., Clement, M., & Clarebout, G. (2002). University assistants' conceptions of knowledge, learning and instruction. *Research in Education, 67*(1), 44-57.

Buldur, S. (2017). A longitudinal investigation of the preservice science teachers' beliefs about science teaching during a science teacher training programme. *International Journal of Science Education, 39*(1), 1-19.

Chambers, D. W. (1983). Stereotypic images of the scientist: The draw-a-scientist test. *Science Education, 67*(2), 255-265.

Clandinin, D. J., & Connelly, F. M. (1987). Teachers' personal knowledge: What counts as 'personal' in studies of the personal. *Journal of Curriculum Studies, 19*(6), 487-500.

Commission of the Federation and the Länder for Educational Planning and Research Promotion (1997). *Gutachten zur Vorbereitung des Programms „Steigerung der Effizienz des mathematisch-naturwissenschaftlichen Unterrichts"* [Survey report on the preparation of the programme 'Improving the efficiency of teaching science and maths']. http://www.blk-bonn.de/papers/heft60.pdf

Dann, H.-D. (2000). Lehrerkognition und Handlungsentscheidungen [Teacher cognition and instructional decision-making]. In M. K. W. Schweer (Ed.), *Lehrer-Schüler-Interaktion. Pädagogische-psychologische Aspekte des Lehrens und Lernens in der Schule* [Teacher-learner interaction. Pedagogical-psychological aspects of teaching and learning at school] (pp. 79-108). Leske & Budrich.

Da-Silva, C., Mellado, V., Ruiz, C., & Porlán, R. (2007). Evolution of the conceptions of a secondary education biology teacher: Longitudinal analysis using cognitive maps. *Science Education, 91*(3), 461-491.

Dorfner, T., Förtsch, C., & Neuhaus, B. J. (2017). Die methodische und inhaltliche Ausrichtung quantitativer Videostudien zur Unterrichtsqualität im mathematisch-naturwissenschaftlichen Unterricht [The methodological and content-related orientation of quantitative video studies on teaching quality in mathematics and science education]. *Journal for the Didactics of Science/ Zeitschrift für Didaktik der Naturwissenschaften, 23*(1), 261-285.

Döring, N., & Bortz J. (2016). *Forschungsmethoden und Evaluation in den Sozial- und Humanwissenschaften* [Research methods and evaluation in the social and human sciences]. Springer.

Drechsel, B. (2001). *Subjektive Lernbegriffe und Interesse am Thema Lernen bei angehenden Lehrpersonen* [Subjective concepts of learning and preservice teachers' interests in the topic of learning]. Waxmann.

Dubberke, T., Kunter, M., McElvany, N., Brunner, M., & Baumert, J. (2008). Lerntheoretische Überzeugungen von Mathematiklehrkräften. Einflüsse auf die Unterrichtsgestaltung und den Lernerfolg von Schülerinnen und Schülern [Maths teachers beliefs on learning theory]. *Journal for Educational Psychology/ Zeitschrift für Pädagogische Psychologie, 22*(3-4), 193-206.

Fischer, H. E., Klemm, K., Leutner, D., Sumfleth, E., Tiemann, R., & Wirth, J. (2003). Naturwissenschaftsdidaktische Lehr-Lernforschung: Defizite und Desiderata [Science education research: Deficits and desiderata]. *Journal for the Didactics of Science/ Zeitschrift für Didaktik der Naturwissenschaften*, *9*(1), 179-209.

Fischler, H. (2000). Über den Einfluß von Unterrichtserfahrungen auf die Vorstellungen vom Lehren und Lernen bei Lehrerstudenten der Physik. Teil 2: Ergebnisse der Untersuchung [The influence of teaching experience on the beliefs about teaching and learning of physics teacher students. Part 2: Results of the study]. *Journal for the Didactics of Science/ Zeitschrift für Didaktik der Naturwissenschaften*, *6*, 79-98.

Finson, K., & Pederson J. (2011). What are visual data and what utility do they have in science education? *Journal of Visual Literacy, 30*(1), 66-85.

Finson, K. D., Beaver, J. B., & Cramond, B. L. (1995). Development and field test of a checklist for the Draw-A-Scientist Test. *School Science and Mathematics, 95*(4), 195-205.

Flick, U. (2018). *An introduction to qualitative research* (6th ed.). Sage.

Heinz, M., & Fleming, M. (2019). leading change in teacher education: balancing on the Wobbly Bridge of school-university partnership. *European Journal of Educational Research, 8*(4), 1295-1306.

Huibregtse, I., Korthagen, F., & Wubbels, T. (1994). Physics teachers' conceptions of learning, teaching and professional development. *International Journal of Science Education, 1*6(5), 539-561.

Jao, L. (2016). Shifting pre-service teachers' beliefs about mathematics teaching: The contextual situation of a mathematics methods course*. International Journal of Science and Mathematics Education, 15*(5), 895-914.

Jones, M. G., & Leagon, M. (2014). Science teacher attitudes and beliefs: Reforming practice. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 830-847). Routledge.

Kagan, D. M. (1992a). Implications of research on teacher belief. *Educational Psychologist 27*(1), 65-90.

Kagan, D. M. (1992b). Professional growth among preservice and beginning teachers. *Review of Educational Research, 62*(2), 129-169.

Kervan, S., Tezci, E., & Morina, S. (2021). Adaptation of the epistemological belief scale to Kosovo. *European Journal of Educational Research, 10*(1), 299-312.

Kleickmann, T. (2008). *Zusammenhänge fachspezifischer Vorstellungen von Grundschullehrkräften zum Lehren und Lernen mit Fortschritten von Schülerinnen und Schülern im konzeptuellen naturwissenschaftlichen Verständnis* [Connections between primary school teachers' subject-related conceptions regarding teaching and learning with the progress students make concerning their conceptual understanding in the sciences] [Doctoral dissertation, University of Münster]. German National Library. https://d-nb.info/992474906/34

Kleickmann, T., Vehmeyer, J., & Möller, K. (2010). Zusammenhänge zwischen Lehrervorstellungen und kognitivem Strukturieren im Unterricht am Beispiel von Scaffolding-Maßnahmen [Connections between teacher conceptions and cognitive structuring in the classroom using scaffolding as examples]. *Educational Science/ Unterrichtswissenschaft, 38*(3), 210-228.

Klinghammer, J., Rabe, T., & Krey, O. (2016). Unterrichtsbezogene Vorstellungen von Lehramtsstudierenden der Physik [Beliefs of student physics teachers about science teaching and learning]. *Journal for the Didactics of Science/ Zeitschrift für Didaktik der Naturwissenschaften, 22*, 181-195.

Koballa, T., Gräber, W., Coleman, D. C., & Kemp, A. C. (2000). Prospective gymnasium teachers' conceptions of chemistry learning and teaching. *International Journal of Science Education, 22*(2), 209-224.

Kohli, M. (1986). Antizipation, Bilanzierung, Irreversibilität. Dimensionen der Auseinandersetzung mit beruflichen Problemen im mittleren Erwachsenenalter [Anticipation, balancing, irreversibility. Dimensions of dealing with professional problems in the middle-age stage of life]. In K. Hurrelmann (Ed.), *Lebenslage, Lebensalter, Lebenszeit* [Life situation, life age, life time] (pp. 123-136). Beltz.

Krauss, S., Kunter, M., Brunner, M., Baumert, J., Blum, W., Neubrand, M., Jordan, A., & Löwen, K. (2004). COACTIV: Professionswissen von Lehrkräften, kognitiv aktivierender Mathematikunterricht und die Entwicklung von mathematischer Kompetenz [COACTIV: The professional knowledge of teachers, cognitively-activating teaching in maths and the development of mathematical competence]. In J. Doll & M. Prenzel (Eds.), *Bildungsqualität von Schule: Lehrerprofessionalisierung, Unterrichtsentwicklung und Schülerforderung als Strategien der Qualitätsverbesserung* [Educational quality of school: teacher professionalisation, teaching development and student challenge as strategies for quality improvement] (pp. 31-53). Waxmann.

Krauss, S., Neubrand, M., Blum, W., Baumert, J., Brunner, M., Kunter, M., & Jordan, A. (2008). Die Untersuchung des professionellen Wissens deutscher Mathematik-Lehrerinnen und -Lehrer im Rahmen der COACTIV-Studie [Researching professional knowledge of German maths teachers within the framework of the COACTIV Study]. *Journal for Mathematics Didactics/ Journal für Mathematikdidaktik, 29*(3/4), 223-258.

Lienert, G. A., & Raatz, U. (1998). *Testaufbau und Testanalyse* [*Test setup and analysis*]. Beltz.

Losh, S. C., Wilke, R., & Pop, M. (2008). Some Methodological Issues with "Draw a Scientist Tests" among Young Children. *International Journal of Science Education, 30*(6), 773-792.

Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education, 11*(2), 38-63.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95-132). Kluwer.

Markic, S., & Eilks, I. (2007). Vorstellungen von Lehramtsstudierenden der Physik über Physikunterricht zu Beginn ihres Studiums und ihre Einordnung [Conceptions of preservice physics teachers regarding physics lessons at the beginning of their studies and the categorisation thereof]. *PhyDid A-Physik und Didaktik in Schule und Hochschule* [PhyDid A-Physics and Didactics in School and University]*, 2*(6), 31-42.

Markic, S., & Eilks, I. (2008). Unterrichtsbezogene Vorstellungen von Lehramtsstudierenden der Chemie am Beginn ihres Studiums und ihre Einordnung [Teaching-related conceptions of preservice chemistry teachers at the beginning of their studies and the categorisation thereof]. *Forum for Teaching and Didactics/ Forum für Unterricht und Didaktik, 15*(2), 69-74.

Markic, S., Valanides, N., & Eilks, I. (2006). Freshman science student teachers' beliefs on science teaching and learning– a mixed methods study. In I. Eilks & B. Ralle (Eds.), *Towards research-based science teacher education* (pp. 29-40). Shaker-Verlag.

Marsch, S., Hartwig, C., & Krüger, D. (2009). Lehren und Lernen im Biologieunterricht Ein Kategoriensystem zur Beurteilung konstruktivistisch orientierter Lernumgebungen [Teaching and learning in biology lessons. A classification system to assess constructivist-oriented learning environments]. *Journal for the Didactics of Science/ Zeitschrift für Didaktik der Naturwissenschaften*, *15*(1), 109-130.

Mayring, P. (2016). *Einführung in die qualitative Sozialforschung* [Introduction to qualitative social research]. Beltz.

Minogue, J. (2010) What is the teacher doing? What are the students doing? An application of the Draw-a-Science-Teacher-Test. *Journal of Science Teacher Education, 21*(7), 767-781.

Norman, D. A. (1983). Some observations on mental models. In D. Gentner, D. & A. L. Stevens (Eds.), *Mental models* (pp. 7-14). Erlbaum Associates.

Norton, L., Richardson, J. T. E., Hartley, J., Newstead, S., & Mayes, J. (2005). Teachers' beliefs and intentions concerning teaching in higher education. *Higher Education, 50*(4), 537-57.

Oztabak, M. U. (2020). Refugee children's drawings: Reflections of migration and war. *International Journal of Educational Methodology, 6*(2), 481-495.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332.

Prawat, R. S. (1992). Teachers' beliefs about teaching and learning: A constructivist perspective. *American Journal of Education, 100*(3), 354-395.

Reinecke, J. (1986). Sozial erwünschtes Antwortverhalten: gewiss kein fiktives Forschungsproblem! Anmerkungen zu Meiers Forschungsstrategie [Socially-desired response behaviour: Surely no fictitious research problem! Comments on Meier's research strategy]. *Diagnostica - Journal of Psychological Diagnostics and Differential Psychology / Diagnostica - Zeitschrift für Psychologische Diagnostik und Differentielle Psychologie*, *32*(3) 193-196.

Reinmann, G., & Mandl, H. (2006). Unterrichten und Lernumgebungen gestalten [Teaching and setting up learning environments]. In A. Krapp & B. Weidenmann (Eds.), *Pädagogische Psychologie* [Pedagogical Psychology] (pp. 615-658). Beltz.

Reusser, K., & Pauli, C. (2014). Berufsbezogene Überzeugungen von Lehrerinnen und Lehrern [Professionally-related beliefs of teachers]. In E. Terhart, H. Bennewitz, & M. Rothland (Eds.), *Handbuch der Forschung zum Lehrerberuf* [Handbook of research on the teaching profession] (pp. 642-661). Waxmann.

Rheinisch, B., Krell, M., Hergert, S., Gogolin, S., & Krüger, D. (2017). Methodical challenges concerning the Draw-A-Scientist Test: a critical view about the assessment and evaluation of learners' conceptions of scientists. *International Journal of Science Education, 39*(14), 1952-1975.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), *Handbook of research on teacher education* (2nd ed., pp. 102-119). Macmillan.

Richardson, V. (2003). Preservice teachers beliefs. In J. Raths, & A. C. McAninch. (Eds.), *Teacher beliefs and classroom performance: The impact of teacher education* (pp. 1-22). Information Age Publishing.

Savasci, F., & Berlin, D. F. (2012). Science teacher beliefs and classroom practice related to constructivism in different school settings. *Journal of Science Teacher Education, 23*(1), 65–86.

Schumacher, F., Großmann, N., Eckes, A., Hüfner, C., & Wilde, M. (2018). Lehr- und Lernvorstellungen angehender Biologielehrender im Kontext des Praxissemesters [The conceptions of preservice biology teachers concerning teaching and learning in the context of a practice-based preservice teaching semester]. *Journal for Didactics of Biology (ZDB) - Biology Teaching and Learning/ Zeitschrift für Didaktik der Biologie (ZDB) - Biologie Lehren und Lernen, 22*(1), 31-48.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-22.

Skinner, B. F. (1971). *Erziehung als Verhaltensformung. Grundlagen einer Technologie des Lehrens* [Education as behaviour shaping. Foundations of a technology of teaching]. E. Keimer-Verlag.

Southerland, S. A., & Gess-Newsome, J. (1999). Preservice teachers' views of inclusive science teaching as shaped by images of teaching, learning, and knowledge. *Science Education, 83*(2), 131-150.

Stofflett, R. T., & Stoddart, T. (1994). The ability to understand and use conceptual change pedagogy as a function of prior content learning experience. *Journal of Research in Science Teaching, 31*(1), 31-51.

Thomas, J. A., Pedersen, J. E., & Finson, K. (2001). Validating the draw-a-science-teacher-test checklist (DASTT-C): Exploring mental models and teacher beliefs. *Journal of Science Teacher Education, 12*(4), 295-310.

Thomas, J. A., & Pedersen, J. E. (2003). Reforming elementary science teacher preparation: What about extant teaching beliefs? *School Science and Mathematics, 103*(7), 319-330.

Treagust, D. F., Duit, R., & Fraser, B. J. (1996). Overview: Research on students' preinstructional conceptions – The driving force for improving teaching and learning in science and mathematics. In D. F. Treagust, R. Duit, & B. J. Fraser (Eds.): *Improving Teaching and Learning in Science and Mathematics* (pp. 1-16). Teacher College Press.

Utley, J, Reeder, S, Redmond-Sanogo, A. (2020). Envisioning my mathematics classroom: Validating the Draw-a-Mathematics-Teacher-Test rubric. *School Science and Mathematics, 120*(6), 345-355.

Van der Veen, J. (2012). Draw your physics homework? Art as a path to understanding in physics teaching. *American Educational Research Journal, 49*(2), 356-407.

Weber, S., & Mitchell, C. (1996). Drawing ourselves into teaching: Studying the images that shape and distort teacher education. *Teaching and Teacher Education, 12*(3), 303-313.

Wirtz, M., & Caspar, F. (2002). *Beurteilerübereinstimmung und Beurteilerreliabilität* [Interrater agreement and interrater reliability]. Hogrefe.

Woolfolk Hoy, A., Davis, H., & Pape, S. J. (2006). Teacher knowledge and beliefs. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology* (pp. 715-737). Lawrence Erlbaum.