

STEM Teacher Beliefs and Inquiry-Based Teaching Practices

INFLUENCING FACTORS, DEVELOPMENT, AND PRACTICAL IMPLEMENTATIONS

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Für Julius Horst Langhans

*For the world is changing:
I feel it in the water,
I feel it in the Earth,
and I smell it in the air.*

Treebeard, *The Lord of The Rings: The Return of The King* by **J. R. R. Tolkien**

Summary

Inquiry-based science and mathematics education as an innovative, student-centered teaching approach is, in contrast to more traditional, knowledge-focused teaching approaches, considered to better support all students in developing scientific and mathematical literacy with the goal of science and mathematics education for all. For this reason, there has long been a call for inquiry-based teaching as a preferred approach to teach the content of science and mathematics. To implement inquiry-based teaching as a reform initiative, teachers need to consolidate appropriate professional knowledge and apply it in classroom practice. As amplifiers and filters for teachers' translation of professional knowledge into classroom practice, teachers' beliefs play a particularly important role. In particular, teachers' learning-related beliefs and self-efficacy beliefs have been shown to be especially influential for teaching practice. Crucial to the influence of beliefs, however, are contextual factors in the form of supporting and hindering factors. The relative effects of different supporting and hindering factors offer insights into mechanisms to better support teachers in implementing innovative instructional practice.

Within the scope of this dissertation, the relationship between teachers' beliefs, inquiry-based teaching practice, and factors influencing them will be investigated. The goal is to help science and mathematics teachers to increase their implementation of inquiry-based teaching methods by strengthening their learning-related and self-efficacy beliefs. This work focused on three main areas: (i) the role of influencing factors on teachers' learning-related and self-efficacy beliefs, (ii) the relationship between change in teachers' beliefs and inquiry-based teaching practice and the role of interaction between the two constructs, and (iii) the importance of influencing factors in supporting or hindering change in teachers' beliefs and inquiry-based teaching practice in science and mathematics.

As part of the evaluation of an international professional development on inquiry-based teaching in science and mathematics education, N=467 teachers were surveyed about their beliefs, inquiry-based teaching practices, and internal and external influencing factors. Results indicate that teachers' self-efficacy beliefs are strongly influenced by internal supports and hindrances such as prior learning opportunities and the need for professional development, while teachers' learning-related beliefs vary more with respect to school and classroom factors and at the country level. School and class factors include, for example, perceived diversity of the class, perceived discipline problems, or collaboration with other colleagues. Furthermore, with N=320 teachers participating in both pre- and post-test before and after the professional development, changes in beliefs and inquiry-based teaching practices were examined. Learning-related beliefs had a positive effect on the development of teachers' inquiry-based teaching practice when teachers already had strongly held beliefs prior to the professional development. The

results of this study point to the importance of professional development measures that strengthen teachers' learning-related beliefs as a prerequisite for changes in instructional practice. A qualitative study with three selected teachers complemented the findings. Supporting and hindering factors for inquiry-based teaching in science and mathematics and their importance for changing teachers' beliefs and teaching practices were exploratively investigated.

By considering internal and external factors influencing change in teachers' beliefs and their inquiry-based teaching practices, this dissertation contributes to a systemic understanding of teachers' professional development. This systemic understanding provides insights into how teachers can be supported in integrating innovative instructional approaches such as inquiry-based teaching into their science and mathematics classrooms. With an increased implementation of inquiry-based teaching, students can develop subject content knowledge in the sense of a basic mathematical and scientific education with authentic, hands-on, investigative tasks, and also gain valuable insights into the scientific inquiry methods of science and mathematics.

Zusammenfassung

Forschend-entdeckender naturwissenschaftlich-mathematischer Unterricht bietet als prototypisch innovativer, schülerzentrierter Unterrichtsansatz, im Gegensatz zu traditionelleren, wissensorientierten Unterrichtsmethoden, in den naturwissenschaftlichen und mathematischen Fächern die Möglichkeit, alle Schüler*innen bei der Entwicklung naturwissenschaftlicher Kompetenzen mit dem Ziel einer naturwissenschaftlichen und mathematischen Bildung für alle zu unterstützen. Seit längerem wird aus diesem Grund der Einsatz von forschend-entdeckendem Unterricht als präferierte Vermittlung der Fachinhalte der Naturwissenschaften und Mathematik gefordert. Für die Umsetzung forschend-entdeckenden Unterrichts als Reforminitiative müssen Lehrkräfte entsprechendes professionelles Wissen festigen und dieses auch in der Unterrichtspraxis umsetzen. Als Verstärker und Filter für die Umsetzung professionellen Wissens von Lehrkräften in die Unterrichtspraxis spielen die Überzeugungen von Lehrkräften eine besonders wichtige Rolle. Insbesondere lehr-lernbezogene Überzeugungen und die Selbstwirksamkeitsüberzeugungen von Lehrkräften haben sich als besonders einflussreich für die Unterrichtspraxis gezeigt. Entscheidend für den Einfluss der Überzeugungen sind allerdings Kontextfaktoren in Form von unterstützenden und behindernden Faktoren. Die relativen Auswirkungen verschiedener unterstützender und behindernder Faktoren bieten Einblicke in Mechanismen zur besseren Unterstützung von Lehrkräften bei der Umsetzung innovativer Unterrichtspraxis.

Im Rahmen dieser Dissertation wird die Beziehung zwischen Überzeugungen der Lehrkräfte, der forschend-entdeckenden Unterrichtspraxis sowie den Einflussfaktoren auf diese untersucht. Das Ziel ist es, Lehrkräfte der Naturwissenschaften und Mathematik dabei zu unterstützen ihre Unterrichtspraxis so zu verändern, dass sie verstärkt forschend-entdeckenden Unterricht als Methode einsetzen. Dabei konzentrierte sich diese Arbeit auf drei Hauptbereiche: (i) die Rolle von Einflussfaktoren für die lehr-lernbezogenen Überzeugungen und die Selbstwirksamkeitsüberzeugungen von Lehrkräften der Naturwissenschaften und Mathematik, (ii) die Beziehung zwischen der Veränderung der Überzeugungen von Lehrkräften und der forschend-entdeckenden Unterrichtspraxis sowie die Rolle der Interaktion zwischen den beiden Konstrukten und (iii) die Bedeutung von Einflussfaktoren bei der Unterstützung oder Behinderung der Veränderung von Überzeugungen von Lehrkräften und der forschend-entdeckenden Unterrichtspraxis in den Naturwissenschaften und Mathematik.

Im Rahmen der Evaluation einer internationalen Fortbildung zu forschend-entdeckendem Lernen im naturwissenschaftlich-mathematischen Unterricht wurden N=467 Lehrkräfte zu ihren Überzeugungen, ihrer forschend-entdeckenden Unterrichtspraxis sowie zu internen und externen Einflussfaktoren befragt. Die Ergebnisse zeigen, dass die Selbstwirksamkeitsüberzeugungen der Lehrkräfte bereits

stark von internen Unterstützungen und Hindernissen wie bisherigen Lerngelegenheiten und dem Bedarf an Fortbildungen beeinflusst werden, während die lehr-lernbezogenen Überzeugungen der Lehrkräfte in Bezug auf Schul- und Klassenfaktoren sowie auf Länderebene stärker variieren. Zu Schul- und Klassenfaktoren zählen beispielsweise die wahrgenommene Heterogenität der Klasse, wahrgenommene Disziplinprobleme oder die Kollaboration im Kollegium. Mit N=320 Lehrkräften, die sowohl an Pre- und Post-Test teilnahmen, konnten darüber hinaus die Veränderungen in den Überzeugungen und die Veränderung im Einsatz von forschend-entdeckender Unterricht untersucht werden. Die lehr-lernbezogenen Überzeugungen wirkten sich positiv auf die Entwicklung der forschend-entdeckenden Unterrichtspraxis von Lehrkräften aus, wenn die Lehrkräfte vor der angebotenen Fortbildung bereits stark ausgeprägte Überzeugungen vorwiesen. Die Ergebnisse dieser Studie weisen auf die Bedeutung von Weiterbildungsmaßnahmen hin, die die lehr-lernbezogenen Überzeugungen der Lehrkräfte als Voraussetzung für Veränderungen in der Unterrichtspraxis stärken. Eine qualitative Studie mit drei Lehrkräften ergänzt die gewonnenen Erkenntnisse. Explorativ wurden für forschend-entdeckendes Lernen im naturwissenschaftlich-mathematischen unterstützende und hinderliche Faktoren und ihre Bedeutung für die Veränderung der Überzeugungen der Lehrkräfte und ihrer Unterrichtspraxis untersucht.

Durch die Berücksichtigung interner und externer Einflussfaktoren für die Veränderung der Überzeugungen von Lehrkräften und ihrer forschend-entdeckenden Unterrichtspraxis trägt diese Dissertation zu einem systemischen Verständnis der beruflichen Entwicklung von Lehrkräften der mathematisch-naturwissenschaftlichen Fächer bei. Dieses systemische Verständnis liefert Erkenntnisse darüber, wie Lehrkräfte dabei unterstützt werden können, innovative Unterrichtsansätze wie den forschend-entdeckenden Unterricht in ihren naturwissenschaftlichen und mathematischen Unterricht zu integrieren. Mit einem verstärkten Einsatz von forschend-entdeckendem Unterricht können Schüler*innen im Sinne einer mathematisch-naturwissenschaftlichen Grundbildung mit authentischen, praktisch-investigativen Aufgabenstellungen fachliche Inhalte erarbeiten und erhalten darüber hinaus wertvolle Einblicke in die Arbeitsweisen der Naturwissenschaften und Mathematik.

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1 Introduction

Just as J. R. R. Tolkien stated in his 1955 novel *The Return of the King*: “*The world is changing*” (1955, p. 981). Over the last years, rural to urban migration as well as immigration led to changing demographics and thus changes in classroom compositions. Changes in classroom compositions as well as a general transition towards constructivist teaching approaches accentuated student diversity by highlighting differences in backgrounds, previous skills and knowledge, and particularly the dimensions of cultural and linguistic as well as socio-economic diversity (OECD, 2012, OECD, 2019a). Especially the socio-economic status is closely linked to varying levels of student academic achievement (Carlisle & Murray, 2015; Çiftçi & Melis Cin, 2017; Ramburuth & Härtel, 2010). Academic achievement, in science and mathematics, is related to achieving scientific and mathematical literacy, as scientific and mathematical literacy are broadly considered a general understanding of science and mathematics (Millar, 2007). Ensuring student academic achievement and thus scientific and mathematical literacy for all has been declared as one of the main goals of science and mathematics education (National Research Council, 2012; Osborne & Dillon, 2008).

Ultimately, by accentuating differences in students’ socio-economic status and thus academic achievement, changing classroom compositions highlight the academic diversity in classes. However, addressing this academic diversity is one core challenge teachers are facing in their day-to-day teaching (Kee, 2012; Schwartz, 2008). Teachers need to adapt their teaching to support low-achieving students at the same time as they need to offer learning environments that provide cognitive stimulation for high-achieving students. All this is to make sure that disparities in performance related to socio-economic status do not develop and especially do not widen throughout students’ lives (OECD, 2018). Academic diversity and thus disparities in performance need to be addressed explicitly to offer science and mathematics education that benefits all students (Chinn, 2016; Rocard, 2007; U.S. Department of Education, 2013).

A vision for science and mathematics education that benefits all students has been emphasized by several international institutions. This vision entails fostering interest in and attitudes towards science and mathematics for all students as well as scientific and mathematical learning itself (Rocard, 2007). The objective of good science and mathematics education is to prepare all students for lifelong learning and to develop a

deeper appreciation for mathematics and the sciences in the world around us. It has become clear that science and mathematics education should be more than a means to prepare students for a science or mathematics degree. Science and mathematics education should offer “*a broad overview of the major ideas that science offers, how it produces reliable knowledge and the limits to certainty*” (Osborne & Dillon, 2008, p. 7). The objective of science and mathematics education thus can be summarized as scientific literacy for all (Holbrook & Rannikmae, 2009; Sadler & Zeidler, 2009).

Inquiry-based teaching (IBT) can fulfill this objective by offering a means to develop scientific literacy (KMK, 2015, KMK, 2020). The scientific process and therefore scientific inquiry play a particularly important role in the European vision for inclusive science and mathematics education. Thus, the European Commission funded several large-scale projects in science education that promoted the use of inquiry-based science education for engaging young people in science (see e.g., projects like PRIMAS 2010-2013, mascil 2013-2017, PARRISE 2014-2017, or MaSDiV 2017-2020). The idea of scientific inquiry as the core of science teaching and learning is also brought up by the National Research Council in the New Generation Science Standards (NGSS). Students are encouraged to “*develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world*” (National Research Council, 2000, p. 23). Thus, “*students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry*” (National Research Council, 2012, p. 218).

Inquiry-based science and mathematics education incorporates many aspects of our vision of good science and mathematics education for all students. IBT is a teaching pedagogy in which students are deeply engaged in scientific activities to discover scientific knowledge with varying degree of support given by the teacher (Artigue & Blomhøj, 2013; Bruder & Prescott, 2013; Furtak, 2006). The support might vary in form of feedback or scaffolding, depending on students’ previous knowledge or problem-solving approaches, making inquiry-based teaching an effective approach to address diversity in achievement. The implementation of inquiry-based teaching requires a shift in the instructional approach from the teacher as the center of instruction to a more student-centered approach, as teachers facilitate student thinking and communication in learning groups (Abd-El-Khalick et al., 2004; Anderson, 2002). However, teachers still need to guide students through the use of investigations (Forbes et al., 2020; National Research Council, 2000). Those investigations also involve hands-on activities to explore

the phenomenon directly and produce possible solutions (Savery, 2006). The phenomenon of investigation should focus on real-life questions and authentic contexts to motivate a need-to-know in the students (Maass & Artigue, 2013; Nordine et al., 2019). Thus, inquiry-based teaching can be characterized involving investigations, using hands-on activities, addressing authentic contexts in a student-centered way.

Regardless of the potential of IBT for addressing academic diversity (see e.g., Alfieri et al., 2011; Brown, 2017; Minner et al., 2010; Wilson et al., 2010), teachers struggle with implementing inquiry-based teaching practices in day-to-day teaching (Maass et al., 2017). Historically, teachers are more used to a more traditional teaching approach with the teacher as the transmitter of knowledge. The transmission-based teaching approach implies that teachers provide the questions, dictate observed variables, demonstrate methods, check results, and leave students to only employ well-known procedural techniques. The shift from more teacher-centered approaches to an inquiry-based teaching approach is not as straightforward and means overcoming several impediments that possibly influence the lack of implementation of IBT.

Missing professional knowledge could be one of the factors, either on the lesson content, or the teaching method and its benefits and implications (Capps et al., 2016; Zion et al., 2007). Teachers especially need knowledge about instructional strategies centering IBT, and knowledge of students' understanding regarding IBT tasks (Magnusson et al., 1999; Neumann et al., 2019; Shulman, 1987). In their 2016 study about teachers' knowledge of inquiry-based science teaching, Capps et al. (2016) described teachers' knowledge and their enactment of IBT and found that most of the 149 teachers did not have well-structured inquiry knowledge, despite reporting frequent implementation. The authors argue, that the teachers probably overestimate their IBT enactment. The lack of professional knowledge about IBT becomes apparent in the interviews, as teachers described "*inquiry using potential alternative conceptions such as hands-on learning*" (Capps et al., 2016, p. 954). Addressing students' understanding and implementing instructional strategies that involve all students in IBT is particularly eminent for addressing academic diversity (Kurtén & Henriksson, 2021; Turner, 2014). To address diversity in achievement, teachers thus need to know how to translate their professional knowledge into inquiry-based teaching practices.

In spite of all efforts to promote the use of inquiry-based science education by offering professional development courses for teachers that enhance their professional

knowledge, teachers apparently do not put the knowledge into practice. The lack of implementation may also well be explained by unrefined or conflicting teacher beliefs (Talbot & Campbell, 2014; Zheng, 2013). If teachers do not believe in the benefits of inquiry-based teaching, they will not be likely to implement the teaching approach, even if they have the professional knowledge to do so. Especially transmissive learning-related beliefs might conflict with the idea of teaching science in an inquiry-based and thus student-centered approach (Dobber et al., 2017; Luft, 2001). Additionally, underdeveloped self-efficacy beliefs might hinder teachers in implementing new and innovative teaching approaches such as inquiry-based teaching (Knoblauch & Woolfolk Hoy, 2008; Teig et al., 2019). If teachers do not trust themselves to handle the process of inquiry-based teaching in the classroom or if they struggle with e.g., classroom management or unanticipated student solutions, they are unlikely to try out new approaches and teaching methods.

Another significant aspect of lacking implementation of IBT is the role of external hindrances: factors that limit teachers in their teaching approaches. Factors such as time limits in the classroom or disruptive classroom situations (i.e., classroom management), missing collaboration among teaching staff e.g., to create professional learning communities and build on best practice examples (i.e., system restrictions), or the lack of adequate teaching materials (i.e., resources) are strongly influential on teachers' day to day teaching practices (Navy et al., 2019). The shift to the more student-centered approach of inquiry-based teaching therefore involves overcoming impediments in the form of system restrictions, resources, and classroom management (Maass & Engeln, 2018).

As a result, supporting teachers in a more regular implementation of IBT involves formal support to sufficiently prepare teachers on IBT. Sufficient preparation comprises the development of professional knowledge on the potential of IBT to address academic diversity (Brunner et al., 2006; Clarke & Hollingsworth, 2002; Dunn & Shriner, 1999), the development of supportive learning-related and self-efficacy beliefs (Anderson, 2002; Holzberger et al., 2013) as well as equipping teachers with resources to overcome external hindrances (Navy et al., 2019; Teig et al., 2019). All these factors should be addressed and teachers can be supported in their struggles to implement inquiry-based teaching to address achievement-related diversity.

Despite the general effort to foster inquiry-based teaching in mathematics and science classrooms and the massive funding to ensure the support for teachers in doing so, research on effective large-scale professional development for inquiry-based teaching has only just picked up (see e.g., Hofer & Lembens, 2019; Kurtén & Henriksson, 2021; Swan et al., 2013). In their review of the research on inquiry professional development, Capps et al. (2012) identify categories of desired outcomes of said PD programs. The authors argue the need for more research on successful professional growth regarding inquiry-based teaching. Ultimately, the authors fail to recognize limiting factors in the process of professional development and the implementation of reform-based teaching approaches.

The objective of this dissertation was to investigate a teacher professional development on inquiry-based teaching as a teaching approach to address diversity in the science and mathematics classroom. Understanding the link between teacher beliefs, teacher self-efficacy beliefs and external factors will help future endeavors to enhance professional development initiatives on inquiry-based teaching. In order to support teachers in a changing world, this thesis aims to offer insights into the mechanisms of teacher change to better foster the implementation of innovative teaching approaches such as inquiry-based teaching. This thesis therefore intends to determine factors that support teachers in their development and to which extent teachers experience hindrances and support in their professional development.

2 Theoretical Background and Current State of Research

A vision for science and mathematics education for all predominantly includes “*that science education is essential for human development [...] and for having active and informed citizens*” (UNESCO, 2000, p. 9). The focus of science and mathematics education therefore shifted from knowledge transmission to scientific literacy for all (National Research Council, 2012; Osborne & Dillon, 2008). Scientific literacy for all entails equity in science and mathematics education. A recent PISA report emphasized the ongoing need for measures to dismantle socio-economic inequalities (OECD, 2018). Reform efforts to establish equity in science and mathematics education and therefore scientific literacy for all are still ongoing.

Research on successful student learning has made apparent that teachers are incredibly important for successful reform initiatives and thus for successful learning (Bromme, 2001; Epstein, 2002; Kennedy et al., 2008). In his synthesis of over 800 meta-analyses from 2009, Hattie (2009) concludes that 30% of student achievement variance can be explained through the teachers’ influence. This summary highlights the continuing need for extensive research into the teacher profession to ensure adequate student learning.

2.1 SCIENTIFIC LITERACY FOR ALL

Historically, the term scientific literacy has been used to broadly describe a general understanding of science and thus can be understood as a desired outcome of science education. However, there is still uncertainty about the meaning of scientific literacy (DeBoer, 2000; Millar, 2006). Although differences of opinion still exist, there appears to be some agreement that scientific literacy refers to “*the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen*” (OECD, 2019b, p. 35).

The National Science Education Standards (NSES) emphasizes that scientific literacy for all is a matter of equity and excellence. The idea of equity and excellence suggests that all students can achieve understanding of science if they are given the opportunity. For scientific literacy this understanding of science includes specific types of abilities. An overview of the NSES conception of scientific literacy can be found in Table 1.

Table 1

Conception of scientific literacy according to the National Science Education Standards
(National Research Council, 1999, p. 22).

Scientific literacy means that a person can...

... Understand, experiment, and reason as well as interpret scientific facts and their meaning.

... Ask, find, or determine answers to questions derived from curiosity about everyday experiences.

... Describe, explain, and predict natural phenomena.

... Read articles with understanding of science in the popular press and engage in social conversation about the validity of the conclusions.

... Identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed.

... Evaluate the quality of scientific information on the basis of its source and the methods used to generate it.

... Pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.

The idea of scientific literacy goes beyond the possession of conceptual understanding of scientific ideas and phenomena or scientific problem solving but comprises socio-scientific decision making and enables citizens to effectively participate in our world (Gillies, 2020; Holbrook & Rannikmae, 2009; Roberts & Bybee, 2014). Scientific literacy thus emphasizes the idea to develop science (and mathematics) education further than to focus on the “learning of science” (Hazelkorn et al., 2015). This focus on science content without considering societal implications can be opposed by a learning “of and about science” (Osborne & Dillon, 2008) that explicitly comprises understanding of nature, applications, and implications of science.

Promoting scientific literacy and especially encouraging all students to develop scientific literacy has several benefits. Millar (1996) presents five arguments on promoting the public understanding of science (see also Fortus et al., 2022).

The economic argument for scientific literacy for all is that “there is a connection between the level of public understanding of science and the nation’s economic wealth” (Millar, 1996, p. 9). Scientific literacy for all therefore entails fostering student interest and motivation in science and mathematics. The utility argument emphasizes the practicality of an understanding of science and technology for a navigation through society. For Fortus et al. (2022) this means not only promoting conceptual knowledge but also promoting mastery orientation towards science and positive attitudes towards a lifelong learning of science. The democratic argument involves the characteristics of scientific literacy centered on evidence-based decision making and communication competences. These characteristics are a foundation for active citizenship and are vital in democratic societies (see also Maass et al., 2022 for more on active citizenship in Mathematics and Science Teaching). The social argument as well as the cultural argument evolve around the idea of science and mathematics as a major achievement of culture and the need to prevent the further alienation of the public from science and technology for all the already mentioned reasons.

Scientific literacy deliberately includes active engagement with scientific content as well as decision-making and communication competencies. These characteristics of science and mathematics education for scientific literacy can also be found in the concept of inquiry-based teaching (Krajcik & Sutherland, 2010; Lederman et al., 2013). Inquiry-based teaching, based on the concept of scientific inquiry, evolved at least partially with the intention of promoting scientific literacy.

2.2 SCIENTIFIC INQUIRY

Inquiry is the general process of seeking information or understanding by asking questions to which the answer is unknown (Welch et al., 1981). The process of inquiry itself is thus characterized by the attempt to gain new insight by an iterative process of asking questions, collecting evidence to test possible explanations in a scientific manner and drawing conclusions in order to find an answer to the questions (Harlen, 2012).

The Standing Conference of the Ministers of Education and Cultural Affairs of the German states (Kultusministerkonferenz or KMK) has defined and published standards for different school graduation forms in Germany. These standards for mathematics and science education emphasize the importance of scientific literacy for understanding and evaluating technical, natural, social, and cultural phenomena and processes with the help of mathematics and science (KMK, 2015). Especially the science standards point out the important role of scientific inquiry for investigating scientific phenomena to develop scientific literacy (KMK, 2005, KMK, 2020). The US National Science Education Standards define scientific inquiry as *“the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work”* (National Research Council, 1999, p. 23). This understanding of scientific inquiry regards the scientific process itself and is therefore independent of educational processes (Anderson, 2002). Furthermore, *“inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world”* (National Research Council, 1999, p. 23). This addition to the definition of scientific inquiry focusses more on the implementation of classroom inquiry as a means for learning about scientific inquiry. **Table 2** offers insights into the features of classroom inquiry. This part of the definition aims attention at individual skills such as problem solving, use of evidence, logical and analytical reasoning, clarification of values and decision-making (Welch et al., 1981).

Table 2

Essential Features of Classroom Inquiry (National Research Council, 2000, p. 25).

Learners are engaged by scientifically oriented questions.

Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.

Learners formulate explanations from evidence to address scientifically oriented questions.

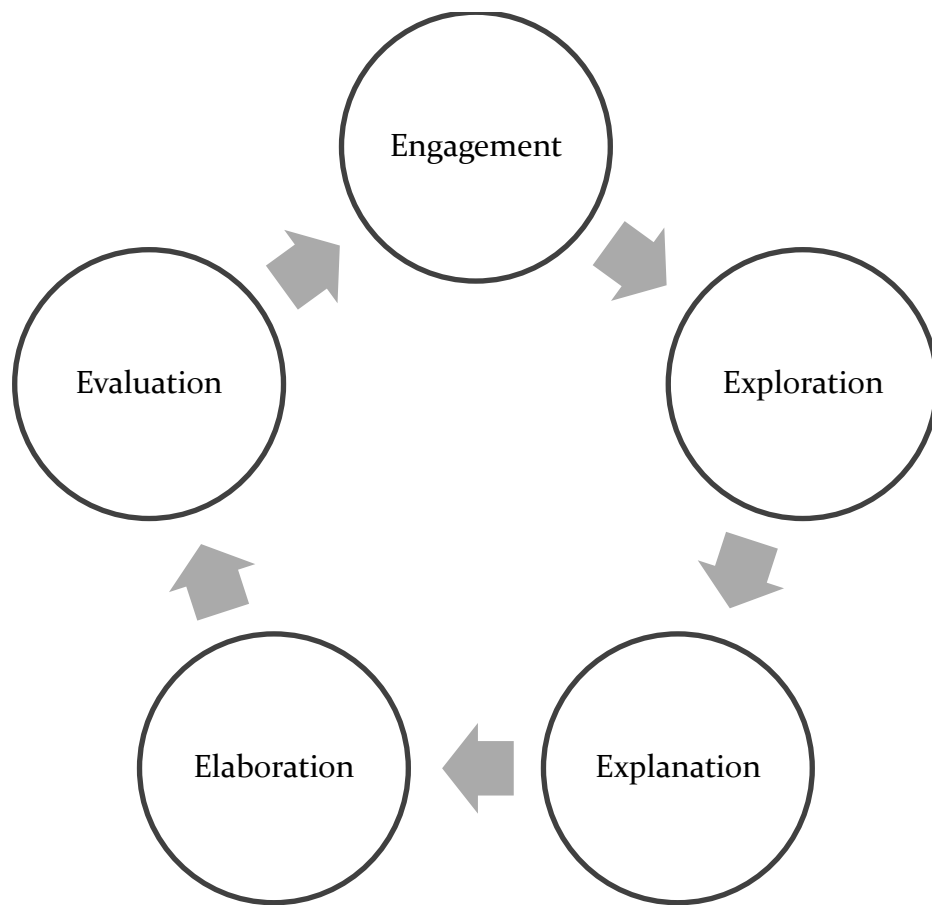
Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.

Learners communicate and justify their proposed explanations.

Historically, scientific inquiry stems from the shift in epistemology from seeing knowledge as given to knowledge based on reflective thinking and experimentation (Dewey, 1916, 1938). Implementing scientific inquiry in science and mathematics teaching actively draws on Dewey's ideas of discovery and learning as part of the constructivist view of learning. Scientific inquiry as a process in science and mathematics learning leads students through five phases, summarized in the 5E Instructional Model by Bybee et al. (2006). The model is summarized in Figure 1. Implementing the instructional model contributes to inquiry-based science and mathematics teaching.

Figure 1

The BSCS 5E Inquiry-Based Instructional Model (Bybee et al., 2006; Bybee, 2009).



2.2.1 Inquiry-Based Teaching

Inquiry-based teaching (IBT) can be understood as the implementation of teaching methods and strategies to foster scientific inquiry in the science and mathematics classroom. Students are invited to work in ways similar to how mathematicians and scientists work (Artigue & Blomhøj, 2013; Rönnebeck et al., 2015). The inquiry-based teaching approach involves students in an active learning process to develop understandings of scientific content, as *“students will engage in the [science] practices and not merely learn about them secondhand”* (National Research Council, 2012, p. 30).

Implementing inquiry-based teaching in science and mathematics education however still requires teachers to guide students through the process of scientific inquiry. The essential features of inquiry shown in Table 2 summarize that inquiry-based teaching is driven by student investigations such as problem-solving, modelling activities, or experiments (Forbes et al., 2020; National Research Council, 2000). There is consent that those investigations should center around actual hands-on activities to foster student engagement to explore the phenomenon directly (Savery, 2006). Student engagement involves open-ended, challenging activities that are embedded in authentic contexts and focus on real-life questions (Maass & Artigue, 2013; Nordine et al., 2019). With a flexible amount of guidance by the teacher as a facilitator of knowledge, inquiry-based teaching can be seen as a means to implement optimal student learning. As a result, inquiry-based teaching is aimed at meeting students’ needs. Thus, inquiry-based teaching can be characterized involving investigations, using hands-on activities, addressing authentic contexts in a student-centered way.

Taking the 5E instructional model as a prototypical inquiry-based teaching process would involve students in the five phases of scientific inquiry:

1. The teacher engages the students with a question or activity, embedded in an authentic context. In doing so, the teacher draws on the students’ prior knowledge, promotes curiosity, and thus meets students’ needs.
2. In the exploration phase, students carry out hands-on activities to make sense of a concept. The students ask questions, conduct research, test the hypothesis by gathering data, analyze and interpret the data, draw a conclusion, and communicate the results. This phase usually includes the main inquiry-based experience to foster the students’ understanding (Duran & Duran, 2004).

3. Students then explain their understanding of the concept. The teacher's role is to correct students' misconceptions by providing formal definitions, notes, and labels.
4. Students elaborate their newly developed understanding by transferring it and by reinforcing new skills. Additional activities might be offered and might offer opportunities for more interdisciplinary work. This phase also offers the option for debates and discussions.
5. Finally, students review and reflect on their learning in the phase of evaluation and might receive feedback in terms of the educational outcomes. This in turn could lead to a new engagement phase, as students might have come to new scientifically oriented questions.

The five phases offer several opportunities for teacher guidance in different nuances. Furtak et al. (2012) describe methods of science teaching as a continuum, with traditional, direct instruction as one end of the continuum, and open-ended scientific inquiry as the other end. In the latter, students find and investigate problems and questions themselves, deciding on the methods and materials without relying on the teacher. This approach is considered to be the most student-centered approach by providing the freedom to solve problems in a variety of different ways (Bruder & Prescott, 2013). This minimal guidance approach however has been criticized, as it might overwhelm students by radically increasing their mental load (see e.g., Kirschner et al., 2006). More prominently, guided inquiry approaches are being implemented. In guided inquiry, the teacher provides the problem or question and the essential materials. In doing so, students can focus on appropriate problem-solving strategies. Guided inquiry would fall somewhere between the extremes on the continuum of methods of science teaching. Lastly, Bruder and Prescott (2013) describe structured inquiry as another form of teacher guidance in the inquiry process. However, they recognize that there is little difference between the structured inquiry approaches and traditional, teacher centered direct instruction approaches, as the teacher not only offers the problem or question to be solved but also specify methods and materials to use. The identification of approaches such as the alleged guided inquiry as inquiry-based teaching is one of the reasons that teachers struggle to interpret and implement inquiry-based teaching as an education reform (see e.g., Capps et al., 2016).

2.2.2 Inquiry-Based Teaching for Diversity

The essential features of classroom inquiry (see Table 2) are greatly comparable to the general understanding of scientific literacy (see Table 1). It can therefore be assumed that inquiry-based teaching is a means to fulfill the need for scientific literacy for all. Inquiry-based teaching is particularly effective and beneficial to all students and can be used to address academic diversity (see e.g., Amaral et al., 2002; Kahle et al., 2000; Newmann et al., 1995). In their randomized control study, Wilson et al. (2010) showed for example that regular science instruction resulted in a significant achievement-gap by race, whereas implementing IBT did not. IBT explicitly builds on students' prior knowledge, engages students actively in learning content as well as organizing learning and offers opportunities for constructing deep understanding (Bransford, 2000). Wilson et al. therefore argue that IBT is more suitable to meet the need for science for all (Brown, 2017; Wilson et al., 2010).

IBT offers the opportunity for students to follow diverse approaches and solutions according to students' previous knowledge, their interests and needs (Minner et al., 2010). These diverse approaches and solutions can be individually supported through systematic assistance, feedback and scaffolding for low-achieving students while high-achieving students work autonomously (Alfieri et al., 2011; Brown, 2017). Much of the presented literature on inquiry-based teaching emphasizes the positive impact of inquiry-based teaching on student outcomes, such as greater scientific literacy, critical thinking, and positive attitudes towards science (Chandler et al., 2017; Crawford, 2014; Cuevas et al., 2005). Overall, IBT has the potential to foster student achievement and address academic diversity.

2.3 TEACHER PROFESSIONAL COMPETENCE

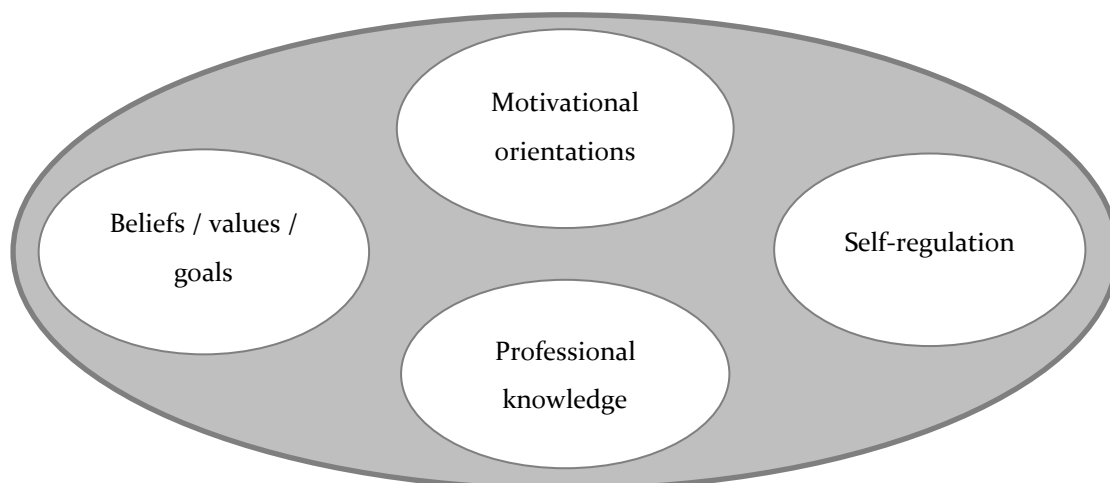
For high quality inquiry-based teaching, teachers need professional competence (Blömeke et al., 2022; Kunter, Klusmann et al., 2013). The term competence is understood as “[...] the skills, knowledge, attitudes, and motivational variables that form the basis for mastery of specific situations” (Kunter, Klusmann et al., 2013, p. 807). Teacher professional competence therefore are skills, knowledge, attitudes, and motivational variables teachers need to master the teaching profession.

2.3.1 Models of Teacher Professional Competence

The COACTIV study (Kunter, Baumert et al., 2013) suggested a generic model of teacher professional competence and is presented in Figure 2. The model describes the different aspects of professional competence with professional knowledge at the core of professional competence. In summary, professional competence can be understood as a multidimensional concept.

Figure 2

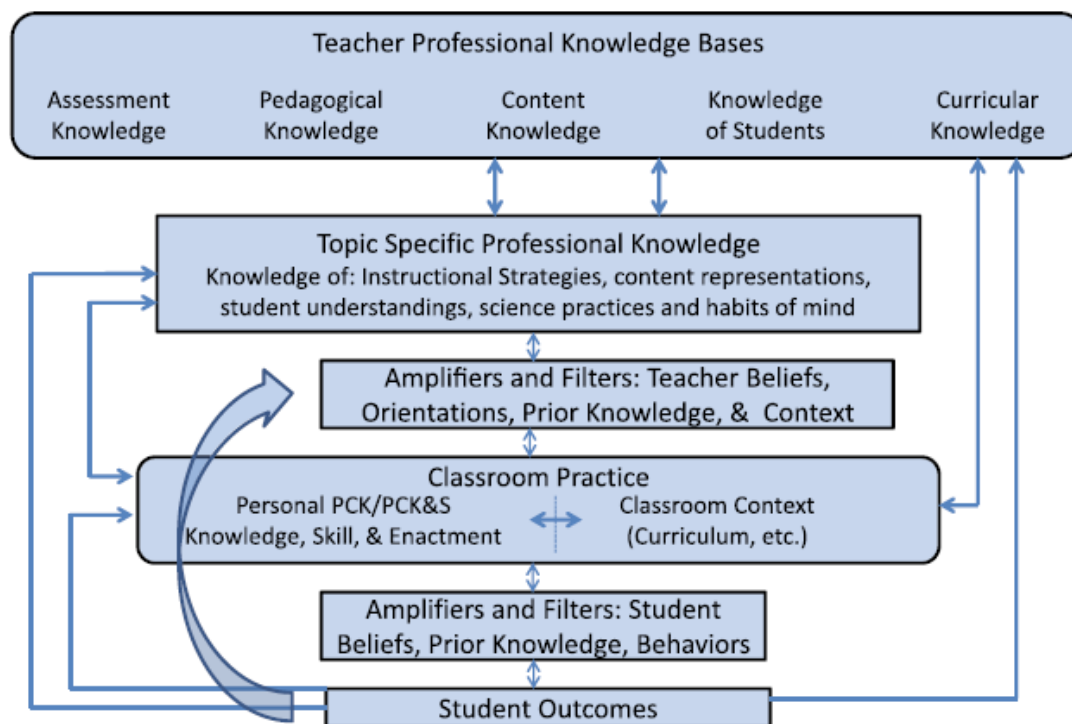
Aspects of professional competence according to the COACTIV model of professional competence (Baumert & Kunter, 2013, p. 29)



International efforts to unify teacher professional competence led to the 2021 summit on pedagogical content knowledge, resulting in a consensus model of teacher professional knowledge and skills as seen in Figure 3 (Gess-Newsome, 2015). The model focusses on the transition of professional knowledge into teaching practice and comprises not only several aspects of professional knowledge but also classroom practice and student outcomes.

Figure 3

A model of teacher professional knowledge and skills including PCK referred to as the 2012 Consensus Model (CM) (Gess-Newsome, 2015, p. 31).



In an attempt to specify the construct of pedagogical content knowledge, Carlson et al. (2019) introduced the Refined Consensus Model (RCM) of PCK, representing the different domains as concentric circles with a strong focus on knowledge exchanges between the circles. The RCM is illustrated in Figure 4.

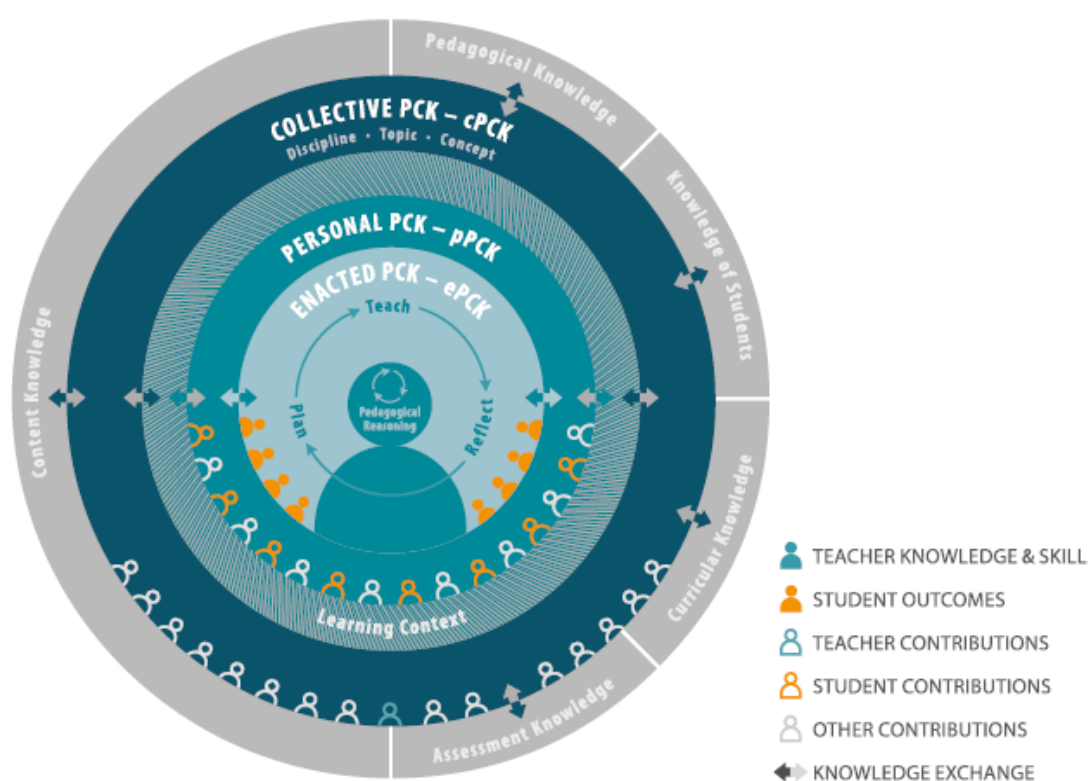
2.3.2 Professional (Inquiry) Knowledge

More recent research has gone into detail on professional knowledge, specifically analyzing the role of pedagogical content knowledge (PCK) (Gess-Newsome, 2015; Sorge et al., 2017). Initially one of seven knowledge bases needed by teachers (Shulman, 1987), PCK is widely recognized as an important part of professional competence that teachers need to effectively plan, teach, and reflect on instruction, i.e., successfully implement teaching practices (e.g., Krepf et al., 2018; Rollnick, 2017; Schiering et al., 2022). PCK is comprised of five core components (Magnusson et al., 1999; Park & Oliver, 2008): (i) students' understanding of science, (ii) instructional strategies, (iii) curriculum, (iv) students' assessment, and (v) orientations toward science teaching. The model of

teacher professional knowledge and skills including PCK (Gess-Newsome, 2015) includes the teacher professional knowledge bases and addresses PCK as a personal knowledge base that influences teaching practice. In doing so, the 2012 consensus model only broadly situated PCK within teacher professional knowledge and the bigger picture of classroom practice and student outcomes but without specifying PCK itself. The refined consensus model (Carlson et al., 2019) offers a more explicit visualization.

Figure 4

Representation of the Refined Consensus Model (RCM) of PCK (Carlson et al., 2019, p. 83).



Besides the obvious difference of visualization between the two models, there are a few more differences to highlight in terms of transition of professional knowledge into teaching practice. On the one hand, the 2012 Consensus Model aims at representing the role of teacher professional knowledge for classroom practice and student outcomes and in doing so offers place for constructs other than knowledge. Amplifiers and filters such as teacher beliefs and the context on the teacher level but also student beliefs and prior knowledge on the student level are explicitly depicted. The RCM on the other hand constitutes the learning context as a stepping stone between the knowledge exchange

between collective PCK (cPCK) held by multiple educators in the field and personal PCK (pPCK) held by an individual teacher. Teacher beliefs as well as the influence of prior knowledge and experiences are incorporated in the construct of pPCK as a “*cumulative and dynamic pedagogical content knowledge and skills of an individual teacher that reflects the teacher’s own teaching and learning experiences*” (Carlson et al., 2019, p. 85).

For successful inquiry-based teaching, teachers especially need knowledge about instructional strategies centering IBT, and knowledge of students’ understanding regarding IBT tasks (Magnusson et al., 1999; Neumann et al., 2019; Shulman, 1987). Addressing students’ understanding and implementing instructional strategies that involve all students in IBT is particularly eminent for addressing academic diversity (Brown, 2017; Wilson et al., 2010). In spite of extensive teacher education and ongoing calls for teacher reform towards IBT, teachers often express conceptualizations of inquiry-based teaching that are understood as a less informed understanding (Capps et al., 2016; Kang et al., 2008; Ozel & Luft, 2013). This less informed understanding comprises of more traditional views of the inquiry process, like collecting data and drawing conclusions. Capps et al. (2016) described these elements of inquiry as salient dimensions. The authors argue, that the knowledge about inquiry-based teaching needs to include less-salient dimensions such as communicating, modeling, argumentation, explaining evidence, and interpreting data as well. This informed, or more structured, knowledge about inquiry-based teaching is needed for teachers to develop high quality implementation of inquiry-based teaching in the classroom. Inquiry-based teaching is a demanding approach with lots of benefits for students’ scientific literacy. Which means, teachers need strong professional competence to implement IBT in their science and mathematics classrooms.

Looking beyond professional knowledge, professional competence also includes motivational-affective characteristics. There is ample evidence that aspects beyond knowledge may be important in determining teaching practices. These motivational-affective characteristics determine whether and how teachers act in teaching situations (Keller et al., 2017; Kunter, Klusmann et al., 2013). These characteristics include teachers’ ability for professional self-regulation, work-related motivation, and teacher beliefs.

Teachers’ professional beliefs have been acknowledged as determining which pedagogical ideas will ultimately be put into teaching practice (Gess-Newsome, 2015). Roehrig and Kruse (2005), for example, in their study with 27 chemistry teachers, found

that teachers who do not believe in the potential of a reform-based curriculum show only minor changes in their teaching practices after the introduction of new curricular materials. Similarly, Maass (2011) observed that teachers with teacher-centered beliefs fail to implement innovative teaching approaches in a way that would foster more effective student learning (see also Maass et al., 2017). This research suggests that in order for teachers to adopt an innovative teaching approach and thus implement their professional knowledge, their beliefs need to be in alignment with those practices. That is, supporting teachers in adopting innovative teaching approaches needs to consider teachers' beliefs specifically.

2.3.3 Teacher Beliefs

Beliefs can be defined as "*psychologically-held understandings, premises or propositions about the world that are felt to be true*" (Richardson, 1996, p. 106). Rokeach (1989) gives a more simplistic definition of beliefs. He described beliefs as any proposition that may begin with the phrase: "*I believe that...*" (Rokeach, 1989, ix). Both definitions show that beliefs are subjective truths to the respective individual. Teachers' professional beliefs are therefore their subjective truths about teaching and learning or, more generally, educational processes. Teachers' professional beliefs regarding educational processes can be distinguished into the three major categories: epistemological beliefs, learning-related beliefs and self-efficacy beliefs (Blömeke et al., 2015; Depaepe & König, 2018; Fives & Buehl, 2012).

Epistemological beliefs comprise beliefs about the nature of knowledge and knowing (Hofer & Pintrich, 2016; Luft & Roehrig, 2007). Epistemological beliefs range from naïve beliefs that knowledge is certain, absolute, and handed down by an authority, to more sophisticated beliefs that knowledge is tentative, evolving, and derived from reason and evidence (Schommer-Aikins et al., 2005). Research did not find a definitive impact of specific epistemological beliefs of on teachers' teaching practice. Lederman (1999) investigated the relationship between teachers' understanding of Nature of Science and classroom practice, but could not confirm that teachers' preference for a specific instructional approach depended on their epistemological beliefs. Kang and Wallace (2005), similarly, noted that naïve beliefs were strongly correlated with a more direct instructional approach, whereas teachers with sophisticated beliefs showed either direct or inquiry instruction. Fives and Buehl (2012), in their review of research on teachers' beliefs, suggested that the impact of epistemological beliefs on teachers' teaching

practice is mediated by their learning related beliefs. A teacher believing that knowledge is handed down by an authority is more likely to believe that students learn better through teacher-centered methods and therefore tends to more direct instruction (e.g., Mansour, 2013). Teachers with sophisticated epistemological beliefs, on the contrary, choose their teaching methods according to their teaching goals and the students in their class, adopting the instructional approach most suitable in the respective context (e.g., Hashweh, 1996). As it seems, beyond epistemological beliefs, learning-related beliefs are more predictive of teachers teaching practice (e.g., Anderson, 2015; Chen et al., 2015).

Learning-Related Beliefs

Learning-related beliefs are subjective, implicit and explicit notions and assumptions of teachers about learning-related phenomena and processes (e.g., how students learn best) (Pajares, 1992). According to Richardson (1996), teachers' personal experiences, experiences with schooling and instruction, as well as teachers' experience with formal knowledge all shape teachers' learning-related beliefs. While early on in their career, teachers' learning-related beliefs might be more malleable, the learning-related beliefs are either discarded or become more consolidated as teachers' experiences either confirm or contradict already existing learning-related beliefs. Over the course of a teacher's career, some learning-related beliefs become more central within the structure of the teachers' belief system (Rokeach, 1989).

Teachers' learning-related beliefs come at different levels of specificity from more general beliefs (e.g., constructivist beliefs, Kunter, Klusmann et al., 2013) to very specific beliefs (e.g., ignoring scientific ideas that students generate themselves can limit their learning, Beswick, 2005). Talbot and Campbell (2014) report, for example, a case study in which the teacher expressed beliefs about the principle effectiveness of innovative practices but also expressed beliefs about the benefits of teacher-centered instruction in situations with time-constraints. The authors conclude that it depends on the specific situation which learning-related beliefs are activated and which teaching practices are chosen accordingly (see also Mansour, 2013; Skott et al., 2018). Similarly, Zheng (2013) described the existence of different type of beliefs within teachers. In their case study approach, they investigated this system of beliefs and concluded that the interaction of the existing beliefs determines the relationship between the teacher's beliefs and teaching practice.

As guides for teaching practice, learning-related beliefs have empirically been shown to strongly determine concrete teaching practices (Mansour, 2013; Talbot & Campbell, 2014; Wilkins, 2008). Roehrig and Kruse (2005) examined the role of reform-based curricular materials in influencing the classroom practices of 12 high school chemistry teachers and found that experienced teachers with transitional or student-centered teaching beliefs demonstrated the most growth in reform-based teaching practices. This indicates that the student-centered teaching beliefs might have been stabilized over the teachers' years of teaching experience, setting a foundation for innovative teaching practices. Similarly, Wilkins (2008) found that teachers' belief in the effectiveness of inquiry-based instructional practices had a positive relationship with teachers' use of inquiry-based methods. The author also reported a mediating function of teachers' beliefs for professional knowledge, highlighting the importance of teachers' learning-related beliefs for instructional practice. Ultimately, teachers' learning-related beliefs act as filters for interpretation of situations, frameworks for decision making, and guides for teaching practice (Fives & Buehl, 2012). Concrete teaching practices such as the successful implementation of inquiry-based teaching are therefore greatly influenced by adequate teacher beliefs on the potential of inquiry-based teaching to address academic diversity (Luft et al., 2003).

In addition to a teachers' learning related beliefs, the eventual choice of a teaching practice depends also on how competent a teacher feels in the use of this practice; that is, their self-efficacy beliefs (Fives & Buehl, 2012).

Self-Efficacy Beliefs

Teachers' self-efficacy beliefs are commonly understood as teachers' beliefs about their capabilities to teach effectively despite challenges that may arise from specific teaching situation (Tschannen-Moran & Woolfolk Hoy, 2001). Self-efficacy beliefs in general are believed to determine whether a behavior will be initiated and how much persistence will be deployed (Bandura, 1977). In the academic context, teachers' self-efficacy beliefs therefore are thought to have powerful effects, as they have been related to a variety of student outcomes, most importantly student achievement and motivation (Ross, 1992; Tschannen-Moran et al., 1998).

Bandura (1997) postulated four sources for teachers' self-efficacy beliefs, namely enactive experiences, vicarious experiences, social persuasion, and physiological and emotional arousal. *Enactive experiences* are prior experiences with the tasks in question. Especially successes validate the beliefs about the capabilities and therefore provide the most reliable resource of information (Bong & Skaalvik, 2003; Charalambous et al., 2008). *Vicarious experiences* refer to experiences of people with similar skills and in similar positions. *Verbal persuasion* that comes in the form of evaluative feedback is particularly resourceful when the feedback giver is received as knowledgeable and credible and when the information is viewed realistic. *Physiological and emotional arousal* and specifically positive feelings are sources for self-efficacy beliefs since it builds up anticipation of future success.

Teachers' self-efficacy beliefs are oriented towards the future, directed at a specific goal, specific to a domain and situation in this domain (Bong & Skaalvik, 2003). The future orientation signifies that the self-efficacy beliefs refer to courses of action that could only be carried out in the future. Most importantly, domain and situation specificity, i.e., context relevance is strongly emphasized for the concept of self-efficacy beliefs (Bandura, 2006; Skaalvik & Skaalvik, 2007). Teachers' self-efficacy beliefs therefore are not global personality variables but require situation specific assessment. Teachers' self-efficacy beliefs include, for example, the extent to which teachers believe that they can promote students' learning (future- and goal-orientation) using an innovative teaching approach (domain-specificity), even if the conditions are difficult (situation-specificity).

Drawing on a domain- and situation-specific measurement of teachers' self-efficacy beliefs, Teig et al. (2019) find teachers with higher self-efficacy beliefs to report a more frequent implementation of inquiry-based teaching strategies. Seeing as teachers' self-

efficacy beliefs are important predictors for high quality instructional practices (Depaepe & König, 2018; Holzberger et al., 2013), it is believed that teachers with strong self-efficacy beliefs are more open to new ideas and more willing to implement innovative teaching practices (Charalambous et al., 2008). More generally, research indicates that teachers' domain- and situation-specific self-efficacy beliefs are among the most important predictors for the implementation of specific instructional practices (Künsting et al., 2016; Tschannen-Moran et al., 1998).

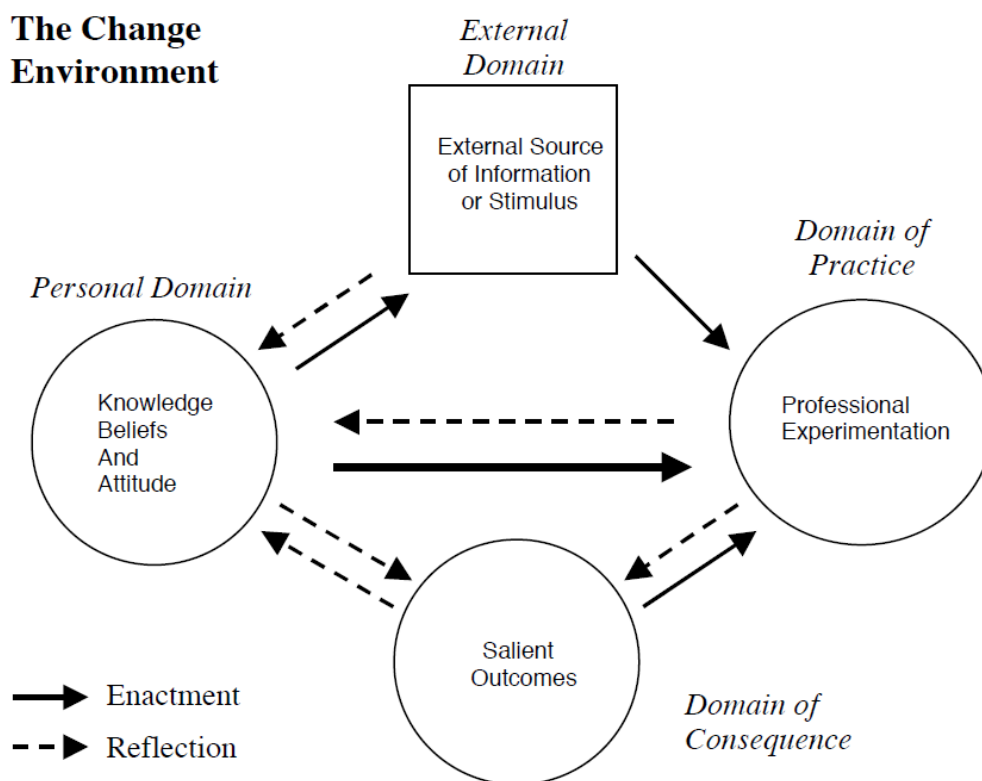
In summary, specific learning-related and self-efficacy beliefs determine the extent to which teachers in fact adopt innovative teaching approaches. However, teachers' self-efficacy beliefs are not only predictors of instructional practice but also outcomes of educational processes as these processes are viewed as enactive experiences (Holzberger et al., 2013; Hoy & Spero, 2005). As a consequence, it is important to understand the factors influencing the development of specific teachers' learning-related and self-efficacy beliefs.

2.4 DEVELOPMENT OF TEACHER BELIEFS AND TEACHING PRACTICES

To support teachers' development of specific teachers' learning-related and self-efficacy beliefs, in-service teachers need opportunities for professional development (Darling-Hammond et al., 2017). Teacher professional development primarily aims to change teachers' classroom practices and thus to maintain and strengthen teachers' professional competences. Change in professional competences is facilitated by processes to help teachers grow professionally and accordingly can be described as professional growth. The model of teacher professional growth (Clarke & Hollingsworth, 2002), as seen in Figure 5, identifies four different domains in which development can happen: personal domain (knowledge, beliefs and attitude), external domain (external source or information or stimulus), domain of practice (professional experimentation), and domain of consequence (salient outcomes). These domains influence each other through either reflection or enactment as mediating processes (Clarke & Hollingsworth, 2002). The model highlights that change in one domain is related to change in another domain. The development of both learning-related beliefs and teaching practice through learning experiences such as reflective practice or professional development therefore seems to be "*dialectical, rather than unilateral*" (Poulson et al., 2001, p. 273).

Figure 5

The interconnected model of professional growth by Clarke and Hollingsworth (2002, p. 951).



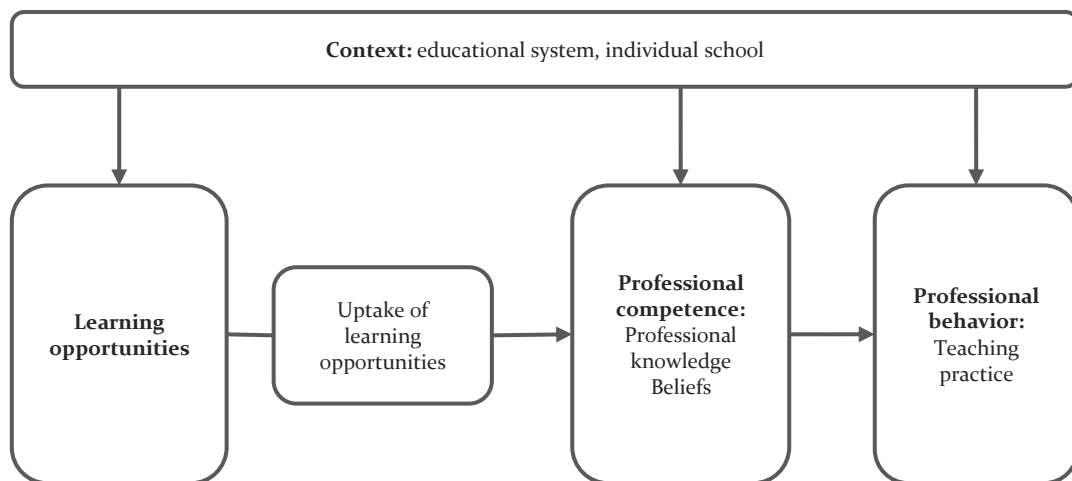
Although the model of teacher professional growth emphasizes the relation of change between domains, it does not provide information on how the changes are interrelated. More extensive development models with a focus on the development mechanism are constructed in a sequential form (Sansom, 2019). Two sequential development models emerge as dominant (Guskey, 2002; Kunter, Kleickmann et al., 2013). On the one hand, according to the model of factors determining and consequences of teachers' professional competence (see Figure 6), a learning opportunity leads to a development of beliefs (Kunter, Kleickmann et al., 2013). In learning opportunities, teachers are encouraged to explicitly reflect their beliefs. They then go through a process of negotiation between their altered learning-related beliefs and encountered barriers. A subsequent change in teaching practice results from the teachers' desire to overcome the barriers and transform the teaching practice to align with teachers' learning-related beliefs (Baron, 2015; Gamlem, 2015). However, to support concrete teaching practices through teaching reforms, they need to be coherent with teachers' already existing learning-related beliefs (Darling-Hammond et al., 2005; Haney et al., 1996). Literature

on professional development has shown that professional development courses are particularly successful and lead to a development of teaching practice when teachers' initial learning-related beliefs are taken into account (Lipowsky & Rzejak, 2015; Luft et al., 2003; Maass & Engeln, 2018). Therefore, it can be expected that teachers' initial learning-related beliefs impact the transition in teaching practice after attending a professional development program. The development sequences from change in learning-related beliefs to change in inquiry-based teaching practice has been confirmed in much research, including for example Berger et al. (2005), Erdamar and Alpan (2013), and Nghia (2017).

Figure 6

Model of the determinants and consequences of teachers' professional competence

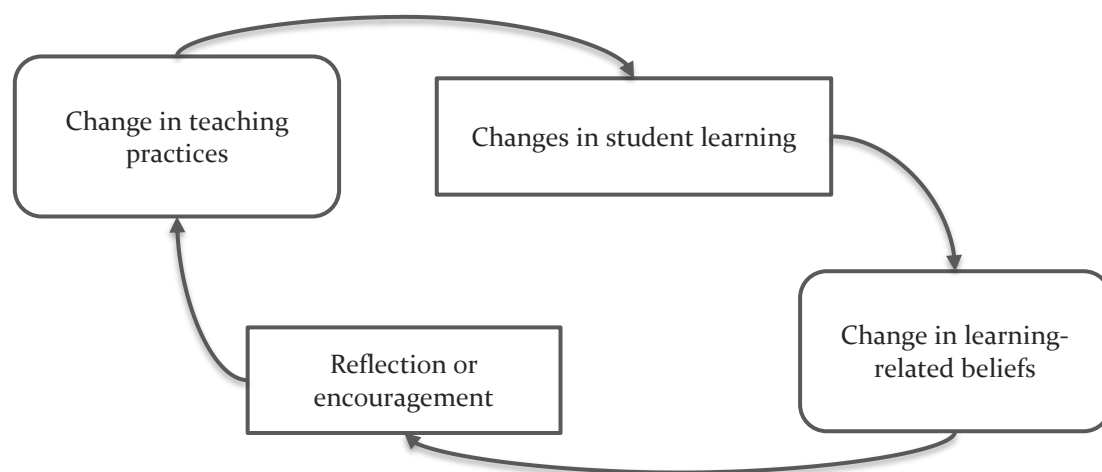
(adapted from Kunter, Kleickmann et al., 2013, p. 67).



On the other hand, Guskey (2002) suggests that successful professional development offers chances of trying out the favored teaching practice. Only when these try-outs lead to a noticeable change in student learning will a significant development in teachers' learning-related beliefs takes place (Guskey, 2002). This perspective on belief development is supported and explicitly promoted by recent studies, as reflection of try-out phases seems to help teachers maintain the changes by adapting and broadening their learning-related beliefs (Capps & Crawford, 2013; Girvan et al., 2016; Soysal & Radmard, 2017). However, both attempts to elaborate on the development mechanism have been criticized for assuming strictly sequential development processes (Sansom, 2019). Both paths can be summarized in a dialectical model of change for learning-related beliefs as seen in Figure 7.

Figure 7

Dialectical model of change for learning-related beliefs based on theoretical arguments by Guskey (2002) and Kunter, Kleickmann et al. (2013).



For a successful professional development teachers thus either need to develop adequate learning-related beliefs or need to reflect on already existing learning-related beliefs to reinforce suitable teaching practices (Levitt, 2002; Mansour, 2013).

The common factor of the described models of professional development is the logical conclusion that limitations in either domain influence other domains. According to Charalambous (2015), limitations in either professional knowledge or teacher beliefs impact teachers' implementation of IBT to address academic diversity. His multiple-case approach over the course of a one-year teaching education program with three prospective teachers revealed that the teachers needed both professional knowledge and strong beliefs to offer instructions to support conceptual understanding for students. While Charalambous (2015) highlighted the importance of internal factors, e.g., professional knowledge and beliefs, external contextual factors are expected to be equally important for the implementation of IBT. Gess-Newsome (2015) identified the classroom context as vital for the implementation of pedagogical content knowledge as teacher decision-making is impacted by e.g., types of curriculum materials, supplies, or supports available. Determinants like the classroom or school context should be especially decisive for the implementation of IBT due to their supportive or hindering nature in teachers' everyday experiences (Buehl & Beck, 2015). In their study on the TIMSS 2015 data with 804 teachers, Teig et al. (2019) were able to show that perceived time constraints limit the implementation of inquiry-based cognitive activation

strategies whereas strong self-efficacy beliefs somewhat attenuates the effect. Their research shows the importance of both external determinants as well as internal factors but does not reveal the process of how teachers build upon supporting factors like extensive knowledge or strong professional beliefs to overcome hindrances. In order to fully support teachers with the implementation of IBT practices, we need to understand the challenges they face and how they overcome these obstacles by drawing on supporting factors.

2.5 FACTORS INFLUENCING TEACHER BELIEFS AND TEACHING PRACTICES

Teachers' learning-related beliefs develop as teachers aim to establish congruence between their prior beliefs and their actual teaching and learning experience (Darling-Hammond et al., 2002; Zheng, 2013). Chant (2002) noted that teachers' reflection on their ability to implement their beliefs shaped the further development of their beliefs. Failure to implement their personal practical theories (i.e., beliefs) about teaching led, for example, to the abandoning of the respective beliefs and the formation of new ones more in line with teachers' experiences. Successful implementation, on the contrary, led to reinforcement of the respective beliefs. Both failure and success (and the interpretation thereof) depended on the individual teacher as well as the classrooms and the school environment. This finding is corroborated by a wealth of other research.

Factors of individual teachers that impact the interpretation of the implementation of learning-related beliefs are teachers' prior experiences as well as presented social norms (Chen et al., 2015). Key experiences for teachers are professional development opportunities that can trigger changes in learning-related beliefs if they prove to be of value in their subsequent enactment (Alghanmi & Shukri, 2016; Barkatsas & Malone, 2005). An indicator for socially shaped norms and other beliefs are teachers' gender, which has been associated with teachers' learning-related beliefs. Rubie-Davies et al. (2012) reported that male teachers put more value on performance orientated teaching practices while female teachers' instructions were more mastery oriented. Female teachers thus put more value on assisting their learners in developing new skills, improving, and acquiring additional knowledge, a value that is in line with scientific literacy for all. At the level of the classroom, student behavior and time restraints have been identified as influences on teachers' learning-related beliefs (Barkatsas & Malone, 2005; Talbot & Campbell, 2014). Additionally, class size has been associated with disruptive student behavior in the form of discipline problems (Finn et al., 2003). Perceived or anticipated discipline problems are therefore considered to influence teachers' learning-related beliefs (Buehl & Beck, 2015; Kang, 2008). Teachers' perception of barriers in the classroom context such as discipline problems are regarded as the factors that prevent teachers from enacting their learning-related beliefs. Beyond the classroom, school culture has been found to affect the development of teachers' learning-related beliefs. Crawford (2007) reported, for example, that the openness or

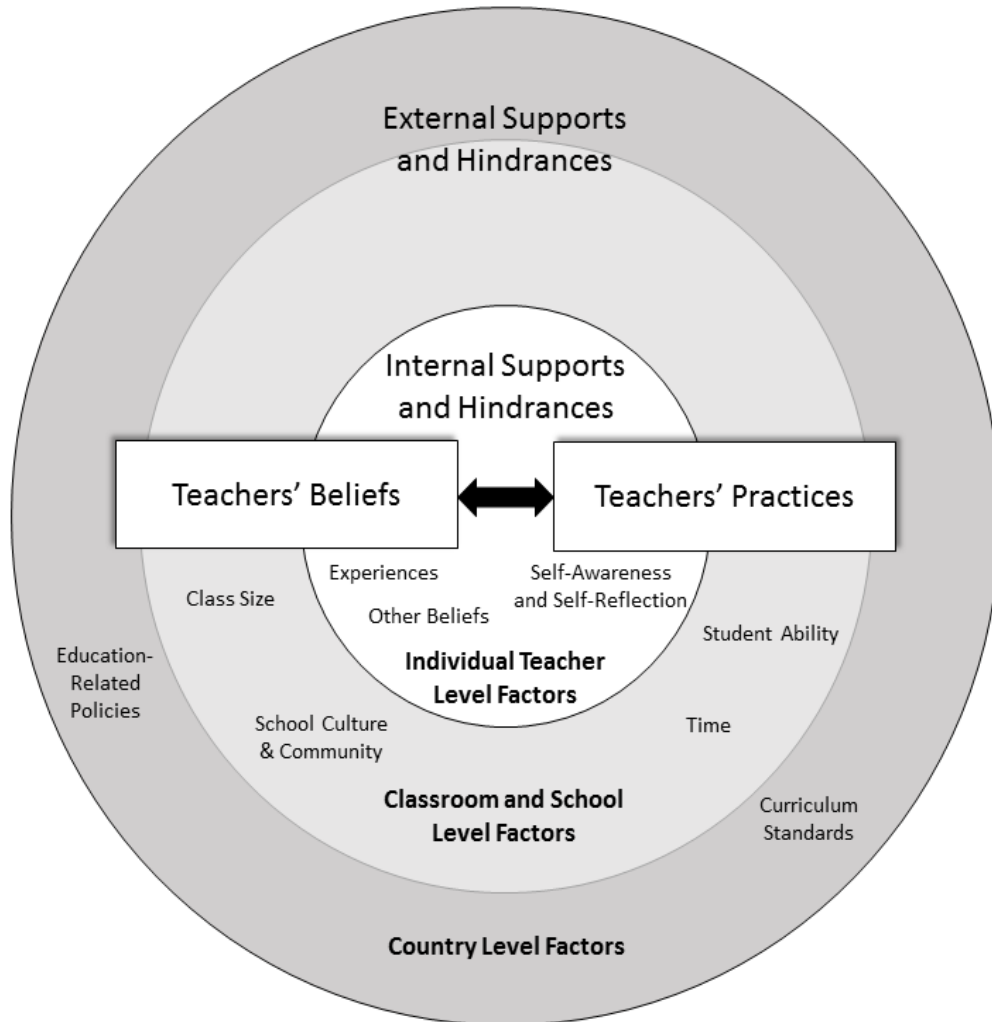
reluctance of a mentor teacher towards new approaches is decisive for novice teachers' learning-related beliefs highlighting the role of collegial interactions in school. More generally, a collaborative working environment was found to be a source for positive learning-related beliefs about innovative teaching approaches (Haney & McArthur, 2002; Skott, 2009). Finally, research highlights the relevance of societal and cultural characteristics for the development of teachers' learning-related beliefs (e.g., Bryan, 2012). Science education is subject to a bigger social and cultural context (Sánchez Tapia, 2020). Hence, teachers' experiences and teachers' reflection thereof and thus their learning-related beliefs are affected by cultural and social factors. Socially and culturally shared norms and values about the importance of individual goals and interests in comparison to the prioritization of communal goals have, for example, proven to influence teachers' learning-related beliefs (Blömeke et al., 2014; Leung, 2006). Therefore, teachers' learning-related beliefs may be assumed to depend on the orientation of the respective society or culture as a whole (Hermans et al., 2008; Ng & Rao, 2008).

Like teachers' learning related-beliefs, their self-efficacy beliefs develop in particular through personal experiences and the reflection of such (Bandura, 1997). Bandura (1997) identified mastery experience, vicarious experience, verbal persuasion, and physiological reactions as sources of self-efficacy beliefs. These sources are created through self-awareness and self-reflection of the interaction between individual and context. In their study of 44000 teachers' self-efficacy beliefs, Fackler and Malmberg (2016) found that 88.7% of variance in teacher self-efficacy stemmed from individual level factors such as educational level, work experience, and gender. Experiences in the classroom that have been found to restrict teachers' self-efficacy beliefs are time constraints or, more generally, classroom characteristics that limit teachers' feeling of control of the situation in the classroom (Skaalvik & Skaalvik, 2010; Teig et al., 2019). At the school level, support from both colleagues and the administration have been identified as factors fueling teachers self-efficacy beliefs through vicarious experiences and verbal persuasion (Charalambous et al., 2008; Knoblauch & Woolfolk Hoy, 2008). That said, the study by Fackler and Malmberg (2016) revealed that the country explained more variance in teachers' self-efficacy beliefs than classroom or school level factors together. This suggests that societal and cultural characteristics may play a central role in the formation of teachers' self-efficacy beliefs as well.

In summary, research on teachers' beliefs has identified a broad range of factors affecting the teachers' learning-related and self-efficacy beliefs. Buehl and Beck (2015) proposed a model that groups these factors into internal and external supports and hindrances (see Figure 8). The authors locate at the center of the model the interactive relationship of teachers' beliefs and practices. That is, teachers' beliefs determining their practice and teachers' practice (and the reflection thereof) determining teachers' beliefs (Chant, 2002). This process is directly affected by internal supports and hindrances (i.e., factors at the level of the individual teacher positively or negatively affecting practice and beliefs), and indirectly influenced by external supports and hindrances (i.e., factors beyond the level of the individual teachers). Based on our review of the literature, we suggest delineating the external supports and hindrances into classroom and school level as well as country level factors – effectively grouping factors into three levels: the individual teacher level, the classroom and school level, and the country level. Interestingly, although prior research has a broad range of factors at each level, little research has investigated the relative effect of the factors at each level (cf. Fackler & Malmberg, 2016). Fackler and Malmberg (2016), however, have demonstrated that it is crucial to consider factors at all levels to understand teachers' self-efficacy.

Figure 8

Relationship between teachers' professional beliefs and teachers' practices in a system of internal and external supports and hindrances (adapted from Buehl & Beck, 2015, p. 74.)



3 Research Aims

Inquiry-based teaching is considered to fulfill several aspects of a high-quality science and mathematics education that offers scientific literacy for all students. However, to date, quality inquiry-based teaching it is still lacking from most science and mathematics classrooms (Maass & Artigue, 2013). It is widely recognized that teacher professional competence is the most valuable predictor of student achievement (Cochran-Smith & Zeichner, 2005; Darling-Hammond & Youngs, 2002). Professional competence has professional knowledge as its foundation but teachers also need corresponding learning-related beliefs and self-efficacy beliefs in order to integrate inquiry-based teaching into the classroom and implement it successfully.

Teachers' beliefs act as amplifiers and filters and therefore play an important role in the transition of professional knowledge into teaching practices (Gess-Newsome, 2015). Teachers' learning-related beliefs strongly influence teachers' interpretation of situations, and play an important role to guide specific teaching practices (Fives & Buehl, 2012). Beyond an informed understanding of inquiry-based teaching and thus strong professional knowledge, teachers need strong learning-related beliefs on the benefits of inquiry-based teaching. Strong learning-related beliefs however do not necessarily directly translate into the according teaching practices if teachers lack self-efficacy beliefs on the respective teaching practice (Fives & Buehl, 2012). Thus, teachers' self-efficacy beliefs, as strong predictors for the implementation of specific instructional practices, need to be considered for educational reforms. Professional development programs that aim to foster educational reforms and invigorate innovative teaching practices like inquiry-based teaching should not only address professional knowledge but also include measures to strengthen teachers' learning-related as well as self-efficacy beliefs (Clarke & Hollingsworth, 2002; Hubers et al., 2020).

Integrating inquiry-based teaching practices into everyday teaching, however, repeatedly confronts teachers with factors in their everyday life that they may not be able to influence (see chapter 2.5: Factors Influencing Teacher Beliefs and Teaching Practices, and especially the model by Buehl & Beck, 2015 in Figure 8). Teachers plan their lessons within the context of their respective school and teaching settings and consequently encounter internal and external influencing factors. Thus, internal as well as external factors play a critical role for teachers' learning-related beliefs, the self-

efficacy beliefs and accordingly on the translation into teaching practices (Buehl & Beck, 2015). Successful professional development should take these factors into account, thereby supporting teachers in their inquiry-based teaching practice.

Several attempts have been made to identify the role of teacher beliefs for instructional practice (Mansour, 2013; Polly et al., 2013), just as existing research recognizes the critical role of supporting and hindering factors for teacher beliefs (Talbot & Campbell, 2014) and thus teaching practices (Maass & Engeln, 2018; Teig et al., 2019). The relative impact of different supporting and hindering factors could offer insights into mechanisms to better support teachers in strengthening the implementation of innovative teaching practices such as inquiry-based teaching. However, a systematic understanding of how influencing factors contributes to the development of teacher beliefs and teaching practice is still lacking. This dissertation thesis addresses this very issue by investigating the change in inquiry-based teaching practice in relation to change in teacher beliefs. By taking into account both internal and external influencing factors, this systemic understanding of professional change will provide insights into how teachers can be supported to integrate innovative teaching approaches such as inquiry-based teaching into their science and mathematics teaching.

The purpose of this investigation is to explore the relationship between teachers' learning-related and self-efficacy beliefs with respect to influencing factors to ultimately change teachers' inquiry-based teaching practices. This relationship is investigated in the context of inquiry-based science and mathematics teaching for supporting all students in developing scientific literacy as a prototypical innovative teaching practice with the goal of science and mathematics education for all. Thus, the aim of this work is to answer the following question:

1. What influencing factors play a role for teachers' learning-related beliefs and self-efficacy beliefs?

Understanding the role of influencing factors on teachers' learning-related and self-efficacy beliefs is only one step in closing the discrepancy between political efforts to implement inquiry-based teaching and its absence in day-to-day teaching. The indicated lack of refined learning-related beliefs (Levitt, 2002; Mansour, 2013) needs to be addressed by offering opportunities for development in teachers' learning-related beliefs to establish inquiry-based teaching practices. Clarke and Hollingsworth (2002) identify four domains of change and provide evidence that change in one domain is related to

change in another domain. However, they do not specify the mechanisms of change. Other models provide insights into the development sequences regarding teachers' learning-related beliefs and teaching practices (Guskey, 2002; Kunter, Kleickmann et al., 2013). But while they offer explanations on possible change sequences, they are strictly sequential and moreover fail to incorporate teachers' prerequisites. Teachers' initial learning-related beliefs for example affect teachers' participation in a professional development program (Lavrenteva & Orland-Barak, 2018).

This research offers the opportunity to address the vehemently expressed criticism on the strictly sequential development models by Guskey (2002) and Kunter, Kleickmann et al. (2013) and to better understand the mechanisms of development in teachers' learning-related beliefs and inquiry-based teaching practices. It does so by investigating the relationship of the development of teachers' learning-related beliefs and the development of inquiry-based teaching, taking into account teachers' initial learning-related beliefs. The aim is to answer the following research questions:

2. How are beliefs and instructional practices changed?
3. What is the role of the interaction of beliefs and teaching practice in their change?

Effectively changing teachers' beliefs and the inquiry-based teaching practice requires appropriate professional development measures on inquiry-based teaching. Effective professional development measures primarily offer professional knowledge and in doing so should take previous experiences and knowledge of the teachers into account (Lipowsky & Rzejak, 2015). Considering the important role of teachers' beliefs as amplifiers and filters, professional development measures should foster teachers' reflection on their beliefs as well as on their teaching experiences (Tirosh & Graeber, 2003). Ultimately, professional development measures should account for the respective teaching context, as it has shown to influence teachers' implementation of professional knowledge and beliefs into teaching practice (Buehl & Beck, 2015; Gess-Newsome, 2015; Teig et al., 2019). It seems only reasonable to assume that while influencing factors, i.e., the context, play an important role for everyday teaching, they also influence teachers' efforts to foster change in their teaching practices (Lipowsky & Rzejak, 2015).

Integrating learning-related and self-efficacy beliefs as well as internal and external factors into a professional development measure on an innovative teaching practice such as IBT can be challenging. The challenge in this is to design a professional

development measures not only for teachers to acquire knowledge and understanding of the innovative teaching approach but to offer opportunities to strengthen learning-related and self-efficacy beliefs within the respective context the teachers encounter in their everyday teaching. Changing instructional practice needs to take into account all the supports and hindrances teachers experience in their day to day teaching. Only then can they draw on supports to overcome hindrances and successfully include inquiry-based teaching into their repertoire for a high-quality science and mathematics education for all. In order to fully support teachers with the implementation of IBT practices, we need to understand the challenges they face and how they overcome these obstacles by drawing on supporting factors. The final research question of this thesis therefore is:

4. How do teachers deal with influencing factors in this change? What factors influence change positively or negatively?

4 Research Context

To answer the proposed research questions, this thesis drew on data from the international MaSDiV project. Within this project, ministry-university tandems from six European countries worked closely together to develop and implement a professional development course. The main goal of the project was to support mathematics and science teachers in addressing diversity and promoting fundamental values. The MaSDiV Professional Development course, which was developed during the project, includes innovative teaching approaches and links inquiry-based learning with the influence of culture and fundamental values. MaSDiV therefore provides an evidence-based approach to tackle current challenges in STEM education. Further information can be found on the website: <https://masdiv-project.eu/>.

The professional development course was structured into three modules with a minimal total length of 14 hours (for details on the professional development see Sorge, 2020). The three modules were interconnected through the concept of inquiry-based teaching. In the first module, inquiry-based teaching was introduced as a means for addressing achievement-related diversity. The second module explored the role of realistic and relevant contexts in inquiry-based teaching and the third module embedded inquiry-based teaching in multicultural settings. The activities for each module were organized as collaborative and active learning activities with suggestions for try-out and research activities between the modules. Teachers were encouraged to adapt and implement the activities in their classrooms and the PD offered phases of feedback and reflection of the implementation.

Participation in the professional development course was voluntary in all countries. Teachers voluntarily participating in a professional development on supporting students with diverse backgrounds might have already reflected on their initial learning-related beliefs (Bryan, 2012; Schraw & Olafson, 2015). This process allows for a more reliable assessment of teachers' learning-related beliefs since teachers do not have to express their beliefs on the spot but rather can use their previous reflection about the benefits of inquiry-based teaching for students with diverse abilities. The participants were surveyed at the beginning and at the end of the course.

Research question 1 will be answered in study 1 (Chapter 5.1) which is about factors influencing teacher self-efficacy and learning-related beliefs. The study follows the model by Buehl and Beck (2015) on the relationship between teachers' professional beliefs and teachers' practices in a system of internal and external support and hindrances. The internal and external supports and hindrances thereby are divided into individual, school and classroom as well as country level factors (see Chapter 6). Drawing on current research on influencing factors, the main objective of study 1 is to identify key supports and hindrances for teachers' learning-related and self-efficacy beliefs about the potential of inquiry-based teaching for supporting all students in developing scientific literacy. The study design utilized data from the pre-test of the MaSDiV professional development course from all six European countries.

Study 2 (Chapter 5.2) will answer research questions 2 and 3 and thus address the issue of change in teachers' learning-related beliefs and the change in inquiry-based teaching practice. To address this issue, we drew on data from the pre and post-tests from the MaSDiV professional development. Drawing on the model of professional growth by Clarke and Hollingsworth (2002) and the following discussion about the importance of teachers' prerequisites in either learning-related beliefs or teaching practice (see Chapter 6), the study aims to investigate the relationship of the development of teachers' learning-related beliefs about the potential of inquiry-based teaching for addressing achievement-related diversity and the development of teachers' inquiry-based teaching practice. Previous research indicates that teachers with strong initial learning-related beliefs might show a stronger development in their inquiry-based teaching practices.

Study 3 (Chapter 5.3) uses a qualitative case study approach to investigate teachers' implementation of inquiry-based teaching to address academic diversity in more depth to answer research question 4. This in-depth investigation carefully considers the role of teachers' professional knowledge on inquiry-based teaching and teachers' beliefs on the potential of inquiry-based teaching for addressing academic diversity. This study was conducted as a part of the MaSDiV PD course in the 2018/19 school year. By choosing the PD as a research context, the baseline for knowledge about diversity should be the PD content. Building on insights from study 1, the qualitative approach additionally offered the opportunity to consider teachers' perception of hindering and supporting factors.

5 Empirical investigations

5.1 STUDY 1: FACTORS INFLUENCING TEACHER SELF-EFFICACY AND LEARNING-RELATED BELIEFS

5.1.1 Introduction

The overarching goal of science education is to provide all students with the literacy in science needed to actively partake in society (European Commission, 2020; National Research Council, 2012). Inquiry-Based Teaching (IBT) has been promoted as a student-centered approach to support all students in developing such literacy (Rocard, 2007). However, despite its potential, IBT has not made its way into the majority of classrooms (Maass et al., 2017). The adoption of innovative teaching approaches is well known to depend on teachers' learning related and self-efficacy beliefs (Fives & Buehl, 2012; Polly et al., 2013). Hence, the observed discrepancy between the promise of IBT and the actual adoption rate may be indicative for teachers not believing in the potential of IBT for learning or their self-efficacy to implement it. To reduce this discrepancy teachers need to deepen their learning-related beliefs and self-efficacy beliefs on the potential of IBT. Supporting teachers in this effort requires knowledge of the factors that affect teachers' beliefs and, in particular, their relative impact on teachers' learning-related and self-efficacy beliefs.

Much research has focused on identifying factors affecting teachers' beliefs (for an overview see Bryan, 2012). This research has found that teachers' learning-related as well as self-efficacy beliefs are not just influenced by teachers' perception of themselves but also by their classrooms, their work environment and their cultural background (Talbot & Campbell, 2014; Zheng, 2013). Buehl and Beck (2015) distinguish between internal and external factors accordingly. Internal factors comprise for example previous learning and teaching experiences (Rubie-Davies et al., 2012) or teachers' self-reflection (Akçay, 2007). External factors include classroom (e.g., time constraints, Wang, 2011), school (e.g., collegial support, Skott, 2009) as well as cultural factors (e.g., underlying societal ideologies, Ng & Rao, 2008). Traditionally, research aiming to identify factors that affect teachers' learning-related or self-efficacy beliefs has focused on identifying either internal or classroom and school factors, and neglected cultural factors (cf. Fackler & Malmberg, 2016).

This study aims to investigate the relative impact of internal as well as external factors on teachers' learning-related and self-efficacy beliefs – including classroom, school and, in particular, cultural factors.

5.1.2 Research question

The research was guided by the following research question:

To which extent are individual, school and classroom as well as country level factors key supports and hindrances with respect to teachers' learning-related and self-efficacy beliefs about the potential of IBT for supporting all students in developing scientific literacy?

5.1.3 Methods

This study was designed to investigate the (relative) influence of individual (i.e., teacher), classroom and school, as well as country level factors on teacher's learning-related and self-efficacy beliefs. While qualitative research on teachers' professional beliefs has been crucial for identifying influencing factors, we chose a quantitative research paradigm to identify those factors that are key supports and hindrances for teacher professional beliefs.

Instruments

In addition to demographic information such as age, gender, subject, and previous formal learning experiences for IBT and academic diversity, a range of internal and external factors were surveyed. These factors are in line with the presented research and in particular with the belief-practice relationship model proposed by Buehl and Beck (2015). An overview of the constructs is presented in Table 3.

Table 3

Overview of internal and external supports and hindrances as operationalized in this study.

Factor Level	Factor (Buehl & Beck, 2015)	Operationalization
Internal	Experiences	Previous learning experiences
	Self-awareness & self-reflection	Need for professional development
	Other beliefs	Gender
External – classroom & school	Class size	Perceived discipline problems
	Student ability	Perceived diversity
	Time	Perceived time pressure
	School culture & community	Collaboration
External - country		Orientation of society (IDV)

Based on our literature review, we focused on previous experiences, self-reflection and other beliefs (e.g., Alghanmi & Shukri, 2016; Fackler & Malmberg, 2016) as internal factors. While teachers' prior learning experiences were assessed directly, teachers' self-awareness was operationalized as the need for professional development, as teachers recognized a gap of expertise. Gender was taken as an as an indicator for socially shaped other beliefs, since socialization processes pose shared beliefs on the construct of gender. External classroom and school factors surveyed were perceived discipline problems to account for the class size and student ability through perceived diversity. Additional factors assessed were perceived time pressure and the collegial school environment. The culturally shared norms and values represent the domain of country level influences. The items used were taken from existing and tested instruments such as e.g., the Perceived School Context Scale by Skaalvik and Skaalvik (2010, p. 1068) and the Need for professional development (PD) for teaching for diversity (OECD, 2014, p. 273).

Teachers' learning-related beliefs about the potential of IBT were assessed utilizing five items on a four-point Likert-scale (sample item: "Having students design their own experiments / investigations creates learning opportunities for all students."). The scale was newly developed based on the definition of learning-related beliefs by Pajares (1992) representing subjective truths to the teachers. Since learning-related beliefs are bound to specific teaching conditions, the items are chosen with a specific focus on the potential of IBT for addressing academic diversity. To confirm content validity, international project members from each participating country reviewed the appropriateness of the items for the targeted construct. The chosen items therefore represent a broad consensus amongst teacher educators from multiple countries in Europe for the assessment of teachers' learning-related beliefs.

Self-efficacy beliefs regarding the use of IBT for addressing academic diversity were also assessed with five items on a four-point Likert-scale (sample item: "I feel confident that I can use inquiry-based activities to engage all my students in learning."). Items require teachers to judge their confidence through the use of the expression "I feel confident that..." regarding the use of IBT for addressing academic diversity. Thus, the wording is in line with previously developed items about general self-efficacy beliefs about instruction (e.g., Bandura, 1997; Pajares, 1996). A similar procedure to the items on learning-related beliefs to ensure content validity was established for the assessment of teachers' self-efficacy beliefs items. Learning-related and self-efficacy beliefs scales used in the survey questionnaire can be found in the Appendix.

Participants

The sample included $N = 467$ mathematics and science teachers (63% female) from the six European countries Malta, Turkey, the Netherlands, Spain, Cyprus, and Germany. These teachers volunteered to participate in a professional development (PD) course about dealing with diversity and promoting fundamental values in mathematics and science in six different European countries. In 2018 and 2019, national and local policy departments for education advertised the PD course in the six countries. Interested teachers from all countries answered the call and applied for participation in the course. Thus, participation was voluntary in all countries and the teachers explicitly expressed the desire to enroll in the PD course. During the first session of the PD course, the teachers participated in a survey for approximately 30 minutes. This way we intended to assess teachers' entry characteristics without interference from the PD course.

The teachers had a mean age of 39 years ($SD = 11$ years). The distribution of teachers across the subjects is shown in Table 4. Overall, 51% of the participants were mathematics teachers and 46% taught science at school (3% did not provide an answer to this question).

Table 4

Sample distribution and Individualism Index.

	CY	TR	ES	MT	DE	NL
<i>N</i>	74	93	72	104	50	74
Mathematics	35.1%	54.8%	29.2%	58.7%	100%	23.0%
Science	62.2%	45.2%	59.7%	41.3%	0%	73.0%
IDV	35	37	51	59	67	80

To account for differences in culturally and socially shared norms and values as a country level factor, the sample was divided into two groups by their Hofstede-Index Individualism versus Collectivism IDV (Hofstede, 2001). More specifically, we chose the median of countries' IDV as a cut-off ($Mdn = 59$), to identify teachers from countries with more individualistic views, including Malta, the Netherlands and Germany, and those from countries with a more collectivistic value system consisting of Cyprus, Turkey and Spain.

Data Analysis

To address the research question, the data were analyzed in several steps using the statistical software R. Teachers' learning-related and self-efficacy beliefs were modelled as unobserved latent variables with questionnaire items representing indicators for the constructs. Teachers' learning-related and self-efficacy beliefs were assessed on a four-point Likert-scale and are therefore of ordered-categorical nature. For ordered-categorical data, mean- and variance-adjusted weighted least squares estimators (WLSMV) had shown superior to maximum-likelihood estimations (Sass et al., 2014). Consequently, WLSMV estimations were used for all model estimations. Confirmatory factor analysis (CFA) was applied to discover item-factor relationships for the learning-related as well as the self-efficacy beliefs (Brown, 2006). The CFA displayed small

loadings for one item of each scale. Reviewing the wording of the items in question revealed a different focus of the wording (i.e., attending especially to low-achieving students vs. attending to the needs of all students). After removing the item in each belief scale, the scales also show adequate reliabilities (Cronbach's $\alpha_{\text{Beliefs}} = .70$, $\alpha_{\text{SEB}} = .70$).

In order to compare the learning-related and self-efficacy beliefs between countries with a more individualistic oriented value system and more collectivistic oriented countries, measurement invariance between those country groups needed to be ensured (Vandenberg & Lance, 2016). Measurement invariance indicates that the latent constructs has been assessed equally in different groups. Measurement invariance is tested through stepwise increasing the restrictions in the form of equal parameters across the groups. Implementing a forward approach, there are the following steps of measurement invariance: Configural invariance exists with models containing no constraints, but the same model structure applies for all groups. Constraining the factor loadings, metric invariance is established. Additionally constraining the intercepts and thresholds across groups indicates scalar invariance which allows a comparison of means between the latent factors of the groups (Putnick & Bornstein, 2016). A statistical comparison between the nested models was accomplished by interpretation of $\Delta\chi^2$ (Sass, 2011).

The influence of internal and school and classroom as well as country level supports and hindrances on teachers' learning-related and self-efficacy beliefs was addressed by a stepwise multiple regression approach in a structural equation model (SEM) (Kline, 2011). Teachers' learning-related and self-efficacy beliefs were modelled as latent variables and influencing factors as manifest exogenous variables. Internal and external supports and hindrances were added stepwise. The benefit of this approach is the comparison between models. Each stepwise addition of factors should lead to changes in explained variance as well as the coefficients of regression of factors that are already controlled for. These changes can then be interpreted. To assess the quality of the models, established fit indices such as χ^2 , TLI, CFI, RMSEA, and SRMR were used (Hu & Bentler, 1999).

5.1.4 Results

The goal of this study was to investigate to which extent individual as well as classroom, school and country level supports and hindrances interact in their influence on teachers' learning-related and self-efficacy beliefs. To compare the differences between distinct culturally shared norms and values, teachers need to have a comparable understanding of the constructs based on the assessment with our instruments.

Measurement Invariance

The different invariance models are summarized in Table 5. Testing for measurement invariance between the more individualistic oriented country group and the one with a more collectivistic value system, none of the restrictions led to a significantly worse model fit.

Table 5

Model fit indices for different invariance models between the more collectivistic and the more individualistic oriented countries.

Model	χ^2	df	CFI	RMSEA	SRMR	$\Delta\chi^2$	p
Configural	51.119	38	0.981	0.040	0.054		
Metric	62.691	44	0.973	0.044	0.061	11.357	0.078
Scalar	70.196	50	0.970	0.043	0.064	11.734	0.068

More specifically, scalar invariance with loadings and intercepts restricted between the groups shows acceptable model fit indices ($\chi^2[50]=70.20$, $p=.031$; CFI=.970, RMSEA=.043, SRMR=.064) and a better model fit than the metric invariance model ($\Delta\chi^2=11.734$, $p=0.068$). This indication of scalar measurement invariance induces the assumption that teachers in the two country groups share a common understanding of the constructs. Based on that common understanding, *the mean score* for teachers' learning-related beliefs was moderately high with $M_{LRB}=3.34$ ($SD_{LRB}=0.44$). Teachers reported lower but still moderate scores for self-efficacy beliefs with $M_{SEB}=2.87$ ($SD_{SEB}=0.44$).

Predictors of Learning-Related and Self-Efficacy Beliefs

Predictors for differences in teachers' learning-related and self-efficacy beliefs were identified using a stepwise multiple regression (see Table 6). In a first step, internal factors were accounted for as predictors for the learning-related and self-efficacy beliefs. Despite the fact that female teachers report stronger learning-related beliefs ($\beta_{LRB} = -.19$, $p < .001$), gender has no significant influence on teachers' self-efficacy beliefs. Reported PD need for teaching for diversity has a different impact on self-efficacy beliefs ($\beta_{SEB} = -.28$, $p < .001$) than on learning-related beliefs ($\beta_{LRB} = .16$, $p < .01$). This difference indicates that while the recognition of a knowledge gap negatively impacts teachers' self-efficacy beliefs it has a positive influence of teachers' learning-related beliefs about the potential of IBT for supporting all students. Teachers' previous learning experiences has a significant influence on teachers' learning-related beliefs ($\beta_{LRB} = .16$, $p < .05$) as well as on teachers' self-efficacy beliefs ($\beta_{SEB} = .19$, $p < .01$). Learning-related and self-efficacy beliefs correlated significantly ($r(427) = .40$, $p < .001$). The first regression model accounts for a significant amount of variance for the self-efficacy beliefs ($R_{SEB}^2 = .14$) and a small amount of variance for the learning-related beliefs ($R_{LRB}^2 = .09$).

In a second step, classroom and school level factors were added (see model (2) in Table 6). The introduction of classroom and school level factors had almost no influence on the impact of gender on teachers' learning-related beliefs. However, previous learning experiences are no longer a significant predictor for teachers' learning-related beliefs.

Table 6

Regression models to predict differences in teachers' learning-related and self-efficacy beliefs.

		LRB	SEB	LRB	SEB	LRB	SEB
		(1)		(2)		(3)	
Internal	gender	-.19**	-.01	-.20***	-.03	-.21***	-.03
	previous learning experiences	.16*	.19**	.06	.12*	.06	.12*
	PD need	.16*	-.28***	.23***	-.22**	.20**	-.24***
external - classroom & school	perceived diversity			.25***	.09	.26***	.10
	collaboration			.15**	.12	.14*	.11
	perceived discipline problems			-.23***	-.02	-.24***	-.03
	perceived time pressure			-.08	-.26***	-.08	-.26***
external - country	orientation of society					-.13*	-.08
	R ²	.09	.14	.23	.23	.24	.23
	Correlation	.34***		.30***		.29***	

Notes. LRB – learning-related beliefs, SEB – self-efficacy beliefs, *** $p < .001$, ** $p < .01$, * $p < .05$; Gender: 0 - female, 1 - male, Orientation of society: 0 - more collectivistic, 1 - more individualistic. All variables standardized.

Different external factors on the classroom and school level, influence either teachers' learning-related or self-efficacy beliefs. Teachers reporting a higher perceived time pressure indicated weaker self-efficacy beliefs ($\beta_{SEB} = -.26$, $p < .001$) while less perceived discipline problems imply stronger learning-related beliefs ($\beta_{LRB} = -.23$, $p < .001$). Teachers differed in their learning-related beliefs if they reported higher collaboration with colleagues ($\beta_{LRB} = .15$, $p < .01$) and perceived the academic diversity in their class differently ($\beta_{LRB} = .25$, $p < .001$). The explained variance increases significantly by $\Delta R_{LRB}^2 = .14$ for

teachers' learning-related beliefs about the potential and by $\Delta R_{SEB}^2 = .09$ for teachers' self-efficacy beliefs regarding the use of IBT for addressing academic diversity.

Finally, the socially and culturally shared norms and values as an external measure on the country level influence teachers' learning-related beliefs ($\beta_{LRB} = -.13$, $p < .05$) significantly (see model (3) in Table 6). Teachers in more collectivistic countries report stronger beliefs about the potential of IBT for addressing academic diversity. The influence of the internal factors and the school and classroom factors remain nearly the same. Considering all external and internal supports and hindrances reduced the correlation between learning-related and self-efficacy slightly ($r(422) = .29$, $p < .01$). The full structural equation model had good model fit indices ($\chi^2[67] = 85.718$, $p = .061$; CFI = .980, RMSEA = .026, SRMR = .041). The model examining the influencing internal as well as external factors is able to explain a considerable amount of variance of the learning-related ($R_{LRB}^2 = .24$) and the self-efficacy beliefs ($R_{SEB}^2 = .23$).

5.1.5 Discussion

Teachers' learning-related and self-efficacy beliefs impact teaching practices (Baumert & Kunter, 2013; Blömeke et al., 2014). The development of teachers' beliefs in turn is subject to a broad range of internal and external supports and hindrances (Buehl & Beck, 2015). The purpose of the present study was to examine the relative influence of factors that can act as supports and hindrances on three levels. Our results suggest that teachers' learning-related beliefs are significantly influenced by classroom and school as well as country level supports and hindrances while self-efficacy beliefs majorly stem from the individual teacher level.

Amongst the individual teacher level factors, gender has been identified as a significant influence on teachers' learning-related beliefs in line with previous research (e.g., Rubie-Davies et al., 2012). Our results show that female teachers rate the potential of IBT as more conducive to learning. This effect corroborates the findings of Rubie-Davies et al. (2012) that female teachers emphasize assisting all their learners in developing new skills, improving, and acquiring additional knowledge. In their 2012 study, female teachers thus emphasized mastery goal orientation. This mastery goal orientation in turn could endorse learning-related beliefs on teaching practices that benefit the learning of all students equally.

As mentioned in the theoretical background, previous learning opportunities are expected to determine teachers' professional beliefs (Barkatsas & Malone, 2005; Fackler & Malmberg, 2016). Surprisingly, teachers' previous learning opportunities for teaching for diversity were not found to influence the learning-related beliefs significantly. Our results showed that the influence on teachers' self-efficacy beliefs was also only minor. A possible explanation for this might be that previous learning opportunities are not as relevant for teachers that teach under certain external conditions (i.e., no perceived diversity in class). Additionally, previous formal learning opportunities could also vary in quality, duration and temporal distance to the time of measurement and should therefore be considered with caution. Research should be careful with using previous learning opportunities as the sole indicator of teachers' self-efficacy beliefs. The reported current need for PD might be a more suitable indicator for teachers' recognition of a knowledge gap. A low need on professional development suggests a certain security with the topic that leads to significantly stronger self-efficacy beliefs regarding the use of IBT to address academic diversity. In addition to that, the positive influence of a reported need for professional development on teachers' learning-related beliefs indicates an awareness of the importance of the topic for the teachers. Thus, our results show that the effects of internal factors on teachers' learning-related and self-efficacy beliefs can also have conflicting outcomes.

Besides individual factors, classroom and school characteristics have an impact on teachers' beliefs. Teachers reporting stronger collaboration with colleagues and a higher perceived academic diversity also report stronger learning-related beliefs about the potential of the use of IBT for addressing academic diversity. These findings could be attributed to a comprehension of the importance of addressing academic diversity as teachers express greater perception of this diversity (Blömeke et al., 2015). Strong collaboration with colleagues functions as a support system influencing the context-specific learning-related beliefs (Knoblauch & Woolfolk Hoy, 2008; Lucero et al., 2013). In contrast, teachers with stronger perceived discipline problems report weaker specific learning-related beliefs. Our findings confirm that teachers prioritize their beliefs differently according to the perception of the instructional setting (Chant, 2002; Talbot & Campbell, 2014): stronger perceived discipline problems in the classroom indicates that academic diversity seems to play a less important role because the focus might be set on general classroom management measures (see e.g., Newman et al., 2004).

These factors do not show a significant impact on teachers' self-efficacy beliefs. A possible explanation for this might be that teachers' internal sources of self-efficacy beliefs such as successful learning and teaching experiences outweigh the influence of classroom and school level factors. Mastery experience has in fact been considered the strongest source for teachers' self-efficacy beliefs (Bandura, 1997; Charalambous et al., 2008). However, we found that perceived time pressure has a negative impact on the teachers' self-efficacy beliefs. This confirms previous findings (e.g., Skaalvik & Skaalvik, 2010). Improving teachers' time management skills could therefore support teachers in their efforts to address academic diversity through IBT. In conclusion, the findings of our study confirm the influence of school and classroom factors on teachers' learning-related beliefs while only perceived time pressure significantly influences teachers' self-efficacy beliefs.

Following the framework of internal and external supports and hindrances (Buehl & Beck, 2015), country level factors also play a role for teachers' professional beliefs. As Blömeke et al. (2014) reported, socially and culturally shared norms and values, as a special type of an individual person's belief system, influence teachers' learning-related beliefs. The current study further supports the idea of the interaction between more general, socially accepted beliefs with teachers' professional beliefs (Alghanmi & Shukri, 2016; Ng & Rao, 2008). Our analysis revealed significantly stronger learning-related beliefs for teachers' in more collectivistic countries than teachers in more individualistic countries. We derive that a communal goal such as the preference of IBT for addressing academic diversity would consequently be higher valued by teachers from a more collectivistic oriented society (Leung, 2006). Nonetheless, the orientation of society as a country level factor might be more distal for teachers. Compared to the results by Fackler and Malmberg (2016), the smaller increase in explained variance may be due to the perceived emphasis of school and classroom supports and hindrances teachers experience in everyday life. This perceived emphasis of factors that affect everyday teaching is probably highlighted through the wording of our items which was chosen particularly close to IBT practices and stands in direct contrast to the more general assessment of teachers' self-efficacy beliefs in the study by Fackler and Malmberg (2016).

Overall, this study has revealed that supports and hindrances show different effects on teachers' learning-related and self-efficacy beliefs, depending on the level. Individual teacher factors such as gender and need for professional development are related to

teachers' self-efficacy beliefs regarding the use of IBT for addressing academic diversity, and external factors like classroom and school supports and hindrances (e.g., perceived discipline problems and diversity) strongly influence teachers' learning-related beliefs about the potential of IBT for addressing academic diversity. While the model including the internal factors accounts for little variance for the learning-related beliefs ($R_{LRB}^2=.09$) and a significant amount of variance for the self-efficacy beliefs ($R_{SEB}^2=.14$), the model including classroom and school factors explained a significant amount more variance for teachers' learning-related ($R_{LRB}^2=.23$) and self-efficacy beliefs ($R_{SEB}^2=.23$). This indicates that teachers' self-efficacy beliefs are already strongly influenced by internal supports and hindrances while teachers' learning-related beliefs show more variation regarding classroom and school factors. Thus, the present study brings together isolated findings from previous research and combines those into a systematic investigation of the different domains of influencing factors on teachers' learning-related and self-efficacy beliefs.

5.2 STUDY 2: DEVELOPMENT OF LEARNING-RELATED BELIEFS AND TEACHING PRACTICES

5.2.1 Introduction

International large-scale assessment reported an increased diversity in students' mathematics and science achievement (European Commission, 2019; OECD, 2016). This diversity in student achievement poses a challenge for teachers to implement instructions beneficial for all students. Inquiry-based teaching as a student-centered approach can foster the involvement and support of all students by allowing students to individually explore scientific concepts through specific teacher guidance adapted to the individual previous knowledge of the students (Brown, 2017; Wilson et al., 2010). Inquiry-based teaching requires teachers to shift in their role as students are actively engaged in constructing understanding, rather than being passive recipients of scientific knowledge. This shift requires teachers to actively consider the amount of offered direction as well as the type of teacher regulation they provide. Thereby, undergoing this shift from a more teacher-centered teaching approach to providing inquiry-based teaching is challenging for teachers (Maass, 2018; Swan, 2007) as it requires teachers to actively consider their. To implement inquiry-based teaching successfully, it is essential that teachers have adequate learning-related beliefs about the potential of inquiry-based teaching for addressing achievement-related diversity (Kunter, Klusmann et al., 2013; Levitt, 2002; Mansour, 2013).

Recent research has suggested a reciprocal relationship between the development of teachers' learning-related beliefs and the development of teaching practice (Clarke & Hollingsworth, 2002; Poulson et al., 2001). Consequently, the development of inquiry-based teaching practices should be reciprocally related to the development of learning-related beliefs about the potential of IBT. On the one hand, a change in teachers' learning-related beliefs is assumed to translate into a change of inquiry-based teaching practice (Baumert & Kunter, 2013). On the other hand, significant changes in teachers' learning-related beliefs occur only after teachers gain evidence of the significant positive impact of inquiry-based teaching on student learning (Guskey, 2002). On the basis of these considerations it is still unclear whether there is a predominant effect of either development, and an empirical examination of possible reciprocal relations is still pending. Additionally, learning experiences that bring about change in teachers' learning-related beliefs and thus inquiry-based teaching practice were most effective

when taking into account teachers' needs and respond to already established learning-related beliefs (Lipowsky & Rzejak, 2015; Vermunt & Endedijk, 2011). Too little attention has been paid to the role of teachers' initial learning-related beliefs as prerequisites for the change of teachers' learning-related beliefs and inquiry-based teaching practice. Teachers' initial learning-related beliefs might strongly influence the perception of a learning experience that targets the development of inquiry-based teaching practice (Buehl & Beck, 2015; Lavrenteva & Orland-Barak, 2018).

This study therefore examines the relationship between the development of teachers' learning-related beliefs and inquiry-based teaching practice in consideration of teachers' prior established learning-related beliefs. This investigation helps to specify explicit measures of teacher professional development in order to support teachers in developing learning-related beliefs that transcend into teachers' inquiry-based teaching practice.

5.2.2 Research questions

The purpose of this paper is to investigate the relationship of the development of teachers' learning-related beliefs about the potential of inquiry-based teaching for addressing achievement-related diversity and the development of teachers' inquiry-based teaching practice. Through this investigation, we want to address the following research questions:

1. What role do teachers' initial learning-related beliefs play in the development of the inquiry-based teaching practice?
2. How do the development of teachers' learning-related beliefs and the development of inquiry-based teaching practices interact together?

Based on our theoretical arguments presented above, our hypothesis is that teachers with strong initial learning-related beliefs develop their inquiry-based teaching practice more through the provision of additional feedback and materials.

5.2.3 Methods

Instruments

Teachers' learning-related beliefs about the benefits of inquiry-based teaching for achievement-related diversity were assessed with a newly developed instrument consisting of 5 items (sample item: "Having students design their own experiments / investigations create learning opportunities for all students."). The scale was developed based on existing instruments of beliefs (e.g., Kleickmann et al., 2016). The items were formulated to address possible benefits from inquiry-based teaching for students with diverse abilities and teachers had to rate them to which degree they felt those statements to be true (see Chapter 5.1.3). A confirmatory factor analysis revealed adequate factor loadings, indicating satisfying item-factor relationships for the learning-related beliefs. Furthermore, measurement invariance for the participating countries was established, allowing for the comparison of differences in teachers' learning-related beliefs (see chapter 5.1).

Inquiry-based teaching practice addressing achievement-related diversity was assessed with a newly developed self-report instrument of 4 items (sample item: "In my teaching I allow every student to define their own problem-solving strategies and develop their own explanation."). The four items represent each one core features of inquiry-based teaching to ensure content validity: student-centered instructions, investigations, hands-on practical activities, and authentic contexts. The teaching practices asked the teachers for a frequency (ranging from *Never or hardly ever* to *Almost every lesson*). Both scales show adequate reliabilities ($\alpha_{LRB}=.75$, $\alpha_{TP}=.64$), as all items were chosen to represent the conceptual breadth within each construct (i.e., representing different aspects of inquiry-based teaching). Learning-related beliefs and inquiry-based teaching practice scales used in the survey questionnaire can be found in the Appendix.

Participants

Complete data sets were collected from $N = 320$ teachers for lower secondary STEM subject (66% female) from the six European countries Malta, Turkey, the Netherlands, Spain, Cyprus and Germany who volunteered to participate in the professional development course. The teachers had a mean age of 40 years ($SD = 11$ years). The average teaching experience is 11 years ($SD = 8$ years). The overview of the sample is shown in d 51% taught science at school.

Table 7. Overall, 49% of the participants were mathematics teachers and 51% taught science at school.

Table 7

Overview of the sample and subject distribution.

	CY	TR	ES	MT	DE	NL
N	44	50	53	81	35	57
Mathematics	40.0%	54.8%	34.6%	58.7%	100%	23.0%
Science	56.7%	45.2%	50.0%	41.3%	0%	73.0%

Data Analysis

The first step in our analysis was to test for normal distribution of teachers' learning-related beliefs and inquiry-based teaching practice, since the commonly used parametric testing methods only apply for normally distributed data. Testing for normal distribution can be done with a Shapiro-Wilk-Test (Shapiro & Wilk, 1965). The Shapiro-Wilk-Test indicated that the learning-related beliefs as well as the teaching practices of the pre-test do not follow a normal distribution: LRB $D(311)=.94$, $p<.001$, TP $D(311)=.97$, $p <.001$. Therefore, for further analysis, non-parametric testing was used. To assess whether and how teachers' learning-related beliefs and inquiry-based teaching practice changed over the course of a learning experience, first descriptive analyses such as computing mean values and comparing the pre- and post-test with the Wilcoxon signed-rank test were carried out. In a second step, we used regression analysis to investigate to which degree teachers' development in learning-related beliefs and teaching practice depended on their entry characteristics.

To investigate the relationship of the development of teachers' learning-related beliefs about the potential of inquiry-based teaching for addressing achievement-related diversity and the development of teachers' inquiry-based teaching practice, structural equation modelling (SEM) was used. SEM are a class of models to statistically test the relations between the variables in our hypothesized model structure (Beaujean, 2014; Kline, 2011). As teachers' learning-related beliefs and inquiry-based teaching practice do not follow a normal distribution, commonly used estimation methods for SEM like maximum-likelihood and generalized least squares are not appropriate. Mean- and

variance-adjusted weighted least squares estimators (WLSMV) had shown superior to maximum-likelihood estimations (Finney et al., 2013; Suh, 2015). Additionally, the use of WLSMV estimators is favorable for ordered-categorical data (Sass et al., 2014). Teachers' learning-related beliefs and inquiry-based teaching practice were assessed with a four-point Likert-scale and are therefore of ordered-categorical nature. Consequently, WLSMV estimations were used for all model estimations.

To investigate the influence of initial learning-related beliefs for teachers' inquiry-based teaching practices in order to answer our first research question, a multi-group cross-lagged design was implemented. We divided the sample according to the initial learning-related beliefs into a group with strong initial learning-related beliefs ($LRB_1 > 3$; $N = 205$) and a group with less strong initial learning-related beliefs ($LRB_1 \leq 3$; $N = 96$). Notice that teachers with a mean learn-related belief with three or more agreed or completely agreed that inquiry-based teaching is beneficial to support the learning of all students. The cross-lagged panel analysis used is an exploratory method to clarify the causal relations between uncontrolled variables (Frees, 2006; Tyagi & Singh, 2014). Due to the rather small sample size in each group, we relied on manifest modelling using mean values in order to investigate the influence of teachers' prerequisites.

To address our second research question on the relation of the development of learning-related beliefs and inquiry-based teaching practice, we applied latent change score modelling. Latent change score models are promoted for assessing and analyzing individual differences in change over time (Kievit et al., 2018; McArdle & Hamagami, 2002) as they offer a structural equation approach to longitudinal development data. With latent change score models, change can be modelled on the construct level while accounting for measurement errors in observed scores. To assess the quality of the latent change score model, established fit indices such as χ^2 , TLI, CFI, RMSEA, and SRMR were used (Hu & Bentler, 1999). All statistical analyses were performed using the software R.

5.2.4 Results

The aim of this study was to investigate the relationship between the developments of teachers' learning-related beliefs and teachers' inquiry-based teaching practice. Prior to answering our research questions, we therefore examined the development in teachers' learning-related beliefs and teaching practices in a first step. Table 8 shows the descriptive statistics according to the pre- and post-test as well as the Wilcoxon signed-rank test as a test of significance difference between pre- and post-test for teachers' learning-related beliefs and teaching practice.

Table 8

Descriptive statistics and test of significance for teachers' learning-related beliefs and inquiry-based teaching practice.

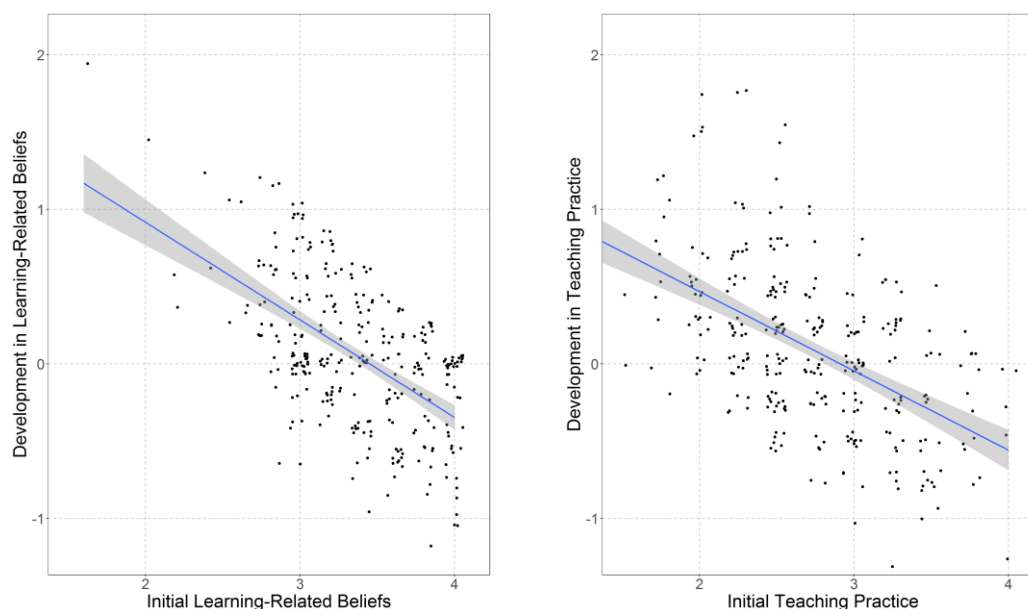
	Pre			Post			Test of Significance
	M_{Pre}	SD_{Pre}	Range	M_{Post}	SD_{Post}	Range	V(df), p
Learning-Related Beliefs	3.35	0.43	[1.6 - 4]	3.41	0.43	[2.2 - 4]	V(320)=10564, $p = 0.073$
Teaching Practice	2.73	0.54	[1.25 - 4]	2.81	0.52	[1.5 - 4]	V(320)=12012, $p < 0.01$

The paired Wilcoxon signed-rank test did not show significant differences for teachers' learning-related beliefs ($M_{Pre}=3.35$, $SD_{Pre}=0.43$, $M_{Post}=3.41$, $SD_{Post}=0.43$, $V(320)=10564$, $p = .073$). However, differences in means for teachers' inquiry-based teaching practice were significant ($M_{Pre}=2.73$, $SD_{Pre}=0.54$, $M_{Post}=2.81$, $SD_{Post}=0.52$, $V(320)=12012$, $p < .01$).

To see to which extent the development depended on teachers' initial learning-related beliefs and initial implementation of inquiry-based teaching practice (i.e., pre-test results) prior to entering the professional development program, we examined its relation with the respective development. The relation can be seen in Figure 9.

Figure 9

Teachers' Development of learning-related beliefs and teaching practice as a function of teachers' initial reported values.



From Figure 9 we can see that some teachers increase significantly, some stagnate and few decrease. However, this change is dependent on the initial values in both teachers' learning-related beliefs, as well as the inquiry-based teaching practice. Teachers' initial learning-related beliefs significantly predicted the development of learning-related beliefs, $b = -.63$, $t(306) = -11.91$, $p < .001$. Additionally, the regression coefficient of teachers' initial inquiry-based teaching practice predicting the development of teaching practice is significant, $b = -.51$, $t(303) = -10.71$, $p < .001$. It is apparent that the regression coefficients are negative. This indicates a stronger development of teachers' learning-related beliefs and teachers' inquiry-based teaching practice when the initial values are more subdued.

With respect to our first research question and following our hypothesis, we investigate the influence of teachers' initial learning-related beliefs by multi-group analysis in extreme groups. We divided the sample according to their initial learning-related beliefs into a group with strong initial learning-related beliefs ($LRB_1 > 3$; $N = 205$) and a group with less strong initial learning-related beliefs ($LRB_1 \leq 3$; $N = 96$). The cross-lagged regression model can be found in Figure 10.

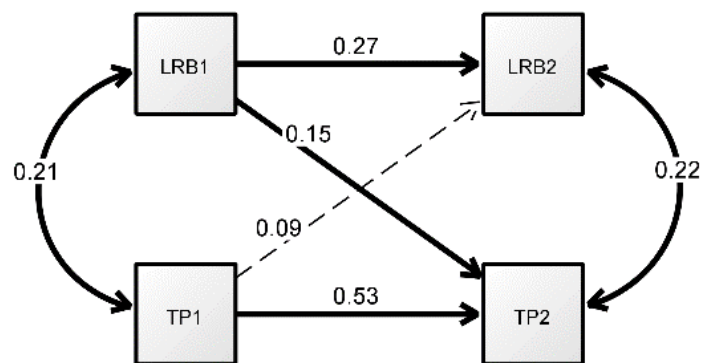
Figure 10

Multi-Group Manifest Cross-Lagged Model for the Development of Teachers' Learning-Related Beliefs (LRB) and Inquiry-Based Teaching Practices (TP).

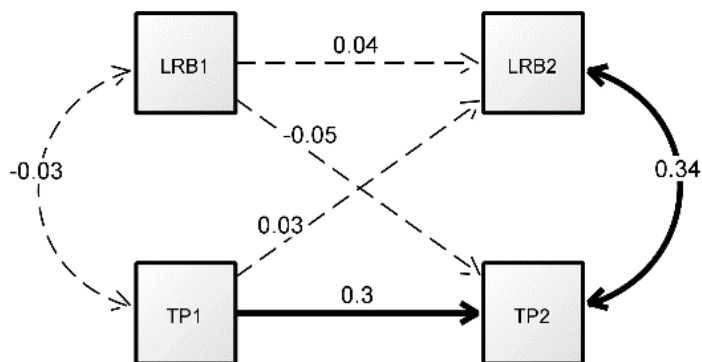
a) stronger initial Learning-Related Beliefs ($LRB_1 > 3$), $N = 206$

b) lower initial Learning-Related Beliefs ($LRB_1 \leq 3$), $N = 96$

a)



b)



Note: Solid lines indicate significance at the 99% level. Dashed lines indicate non-significance.

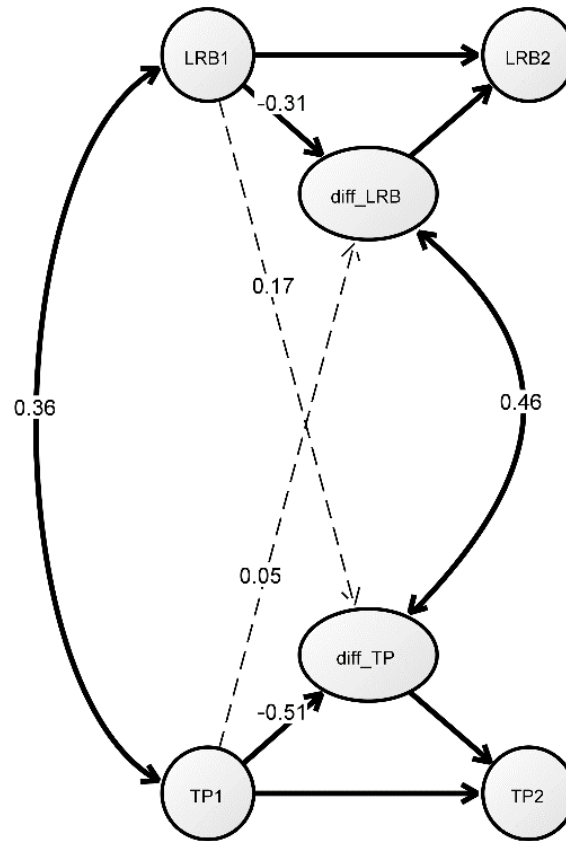
There are several differences in the manifest cross-lagged models according to teachers' initial learning-related beliefs. First, the correlation prior to the learning-experience differs strongly. Teachers with stronger initial learning-related beliefs on the potential of inquiry-based teaching for addressing achievement-related diversity report a more frequent implementation of inquiry-based teaching practice prior to the learning opportunity ($r(205) = .21, p < .01$). Teachers' learning-related beliefs are not correlated with teachers' inquiry-based teaching practice, when teachers reported weaker initial learning-related beliefs ($r(96) = -.03, p = .77$).

Second, teachers' learning-related beliefs and teachers' inquiry-based teaching practice were weakly to moderately correlated after the learning opportunity for both groups ($r_{LRB>.3}(205) = .22, p < .01$; $r_{LRB\leq.3}(96) = .34, p < .01$). Compared to teachers with strong initial learning-related beliefs, teachers with lower initial learning-related beliefs reported more coherent learning-related beliefs and inquiry-based teaching practice following the learning opportunity when controlling for the initial values. Lastly, the cross-lagged paths for teachers with lower initial learning-related beliefs were not significant. However, teachers with stronger initial learning-related beliefs report a more frequent implementation of inquiry-based teaching practice following the learning opportunity ($\beta = .15, p < .05$). This supports our hypothesis that teachers with stronger initial learning-related beliefs develop the inquiry-based teaching practice more.

In order to investigate how the development of teachers' learning-related beliefs relates to the development of teaching practices, latent change score analysis was applied. With the latent change score model we were able to analyze the change in the latent score of the teachers' learning-related beliefs (diff_LRB) and teaching practices (diff_TP). The model had good robust fit indices ($\chi^2[130] = 217.332, p < 0.001, CFI = .926, RMSEA = .047, SRMR = .060$) and is illustrated in Figure 11. Prior to the learning experience, teachers' learning-related beliefs and teachers' inquiry-based teaching practice correlated low with each other ($r(301) = .36, p < .001$). Teachers' initial learning-related beliefs significantly predicted the development of the learning-related beliefs ($\beta = -.31, p < .001$). Accordingly, teachers' initial inquiry-based teaching practice significantly predicted the development of reported teaching practice ($\beta = -.51, p < .001$).

Figure 11

Latent Change Score Model for Teachers' Learning-Related Beliefs (LRB) and Teaching Practices (TP).



Note: Solid lines indicate significance at the 99% level. Dashed lines indicate non-significance.

The correlation between the latent change score of the learning related beliefs and the latent change score of the inquiry-based teaching practice indicate a significant positive association between the development of the learning-related beliefs and the development of teaching practices ($r(301) = .46, p < .001$). However, the regression coefficient for the influence of teachers' reported implementation of inquiry-based teaching practice prior to the learning opportunity was not significant ($\beta_{\text{diff_LRB}} = .05, p = .60$). Furthermore, teachers' initial learning-related beliefs did not significantly influence the development of teachers' inquiry-based teaching practice ($\beta_{\text{diff_TP}} = .17, p = .15$).

5.2.5 Discussion

Addressing achievement-related diversity by actively engaging all students equally is important to foster interest and motivation for science and mathematics for all students (Adesoji & Raimi, 2004; Potvin & Hasni, 2014). Inquiry-based teaching is a student-centered approach and is therefore adequate for addressing achievement-related diversity (Kirschner et al., 2006; Wilson et al., 2010). However, successful implementation of inquiry-based teaching highly depends on adequately developed teachers' learning-related beliefs (Luft, 2001; Maass, 2011). Appropriate development of either learning-related beliefs or inquiry-based teaching practice needs to consider teachers' previous learning experiences, i.e., teachers' prerequisites. Following the theoretical argument on the importance of teachers' initial learning-related beliefs as starting points for further professional development (Lavrenteva & Orland-Barak, 2018; Luft et al., 2003), we hypothesized that participants with strong initial learning-related beliefs develop their inquiry-based teaching practice more. Our results confirm that for teachers with strong learning-related beliefs prior to entering the professional development program the learning-related beliefs had a positive impact on teaching practices whereas that was not the case for teachers' with less pronounced beliefs. Furthermore, our analysis also confirms a dialectical relationship between the development of teachers' learning-related beliefs and inquiry-based teaching practice. Both teachers' learning-related beliefs and inquiry-based teaching practices develop conjointly and reinforce each other.

It was also noteworthy that teachers' learning-related beliefs were already highly pronounced prior to the professional development course. Teachers participating in a professional development on supporting students with diverse backgrounds should have already reflected on their learning-related beliefs (Bryan, 2012; Schraw & Olafson, 2015). Since participation was voluntary, it was not surprising that participating teachers were already convinced that inquiry-based teaching is suitable for addressing achievement-related diversity (Engeln et al., 2013). It is therefore not surprising that the paired-Wilcoxon signed-rank test did not show significant differences for teachers' learning-related beliefs for the pre-post-comparison. Additionally, the Wilcoxon signed-rank test showed significant differences for teachers' inquiry-based teaching practice. This result illustrates that teachers report more frequent inquiry-based teaching practice

following the professional development indicating that the professional development course did impact the practice of the teachers.

Utilizing linear regression to analyze the relation of development to initial values shows that linear regression coefficients are negative ($b_{LRB} = -.63$; $b_{TP} = -.51$). The negative coefficients are not unexpected, considering that teachers' with strongly pronounced initial learning-related beliefs develop their learning-related beliefs less while teachers' with already fairly regular implementation of inquiry-based teaching develop their teaching practice less strongly. However, this is not just an instrument artefact. A possible explanation for this might be that teachers with less strongly pronounced learning-related beliefs and teachers with less frequent implementation of inquiry-based teaching have a strong potential for a development of learning-related beliefs or a change in inquiry-based teaching practice (Brownlee et al., 2016; Clough, 2006).

Surprisingly, some teachers' stagnate or even decrease in their learning-related beliefs or in their inquiry-based teaching practice. Overall, 20.9% reported lower learning-related beliefs and 17.5% reported less frequent inquiry-based teaching practice following the professional development course. A possible explanation for this results might be that the professional development helped teachers develop a more elaborate understanding of inquiry-based teaching practice as a means to address achievement-related diversity. These results are in line with the ideas of Kruger and Dunning (1999) who stated that beginners tend to be overconfident of their abilities whereas advanced learners have a more realistic perception of themselves. Our studies indicate that ideas formulated for self-confidence could also be applicable for other self-assessments such as beliefs and practices (Ehrlinger et al., 2008).

To investigate the role of teachers' initial learning-related beliefs and teachers' prior implementation of inquiry-based teaching on the development of learning-related beliefs and inquiry-based teaching practice we used cross-lag panel analysis and divided the sample into two groups according to the initial learning-related beliefs ($LRB > 3$; $LRB \leq 3$). In doing so we have taken into account that teachers either already developed stronger initial learning-related beliefs or need more learning opportunities to do so. For teachers with stronger developed initial learning-related beliefs these beliefs were moderately correlated to the inquiry-based teaching practice ($r(205) = .21$), indicating a moderately pronounced consistency between learning-related beliefs and inquiry-based teaching practice. For teachers with lower initial learning-related beliefs the correlation

between inquiry-based teaching practice and learning-related beliefs was not significant prior the learning opportunity but moderately pronounced following the learning opportunity ($r(96) = .34$). This result might be an indication that a specific learning opportunity targets learning-related beliefs purposefully. Teachers then establish a common understanding of inquiry-based teaching as a desired teaching practice (Gamlem, 2015; Luft et al., 2003).

Teachers with stronger initial learning-related beliefs however report a more frequent inquiry-based teaching practice following the learning opportunity ($\beta = .15$). This relationship may be explained by a differentiated effect of the professional development. For teachers with strong initial learning-related beliefs, the professional development course offers try-out periods, peer feedback and materials for a development of inquiry-based teaching practice. For teachers with less pronounced learning-related beliefs, the professional development course offers a learning opportunity to develop the learning-related beliefs as they are explicitly addressed and reflected during the course. The positive significant correlation between post-test beliefs and practices in the group with lower initial learning-related beliefs indicate that for those teachers' beliefs and practice were more in line after the course. Depending on the teachers' needs, the professional development course offers different developmental pathways.

For all teachers, this study found a significantly positive association ($r(301) = .46, p < .001$) between the development of teachers' learning related beliefs and the development of teachers' inquiry teaching practice. This finding is consistent with the teacher professional growth model of Clarke and Hollingsworth (2002) in which a change in one domain is translated into change in another domain through either reflection or enactment. It can thus be suggested that teacher professional development courses might be successful in changing teachers' inquiry-based teaching practice by addressing teachers' learning-related beliefs and that teachers' learning-related beliefs at the same time are altered by try-out phases of inquiry-based teaching practice. We therefore provide valuable evidence for the proposed dialectical relationship between the developments of teachers' beliefs and practices.

5.3 STUDY 3: CHALLENGES AND SUPPORTING FACTORS FOR CHANGING TEACHING PRACTICES

5.3.1 Introduction

The recent OECD report on equity in education alarmingly reported early developing disparities in performance that widen throughout students' lives (OECD, 2018, p. 30). These disparities in performance and the associated academic diversity need to be addressed explicitly to offer science and mathematics education that benefits all students (Rocard, 2007; U.S. Department of Education, 2013). Addressing academic diversity is demanding for teachers, especially since they already face restrictions and hindrances in their teaching context such as time constraints or specifications of the curriculum regarding the content (Dorier & Maass, 2014; Maass & Engeln, 2018). Inquiry-based teaching (IBT) offers a means to provide science and mathematics education for all, by offering student-centered instruction (Anderson, 2002; Swan, 2007), based on investigations (Forbes et al., 2020), authentic problems (Maass & Artigue, 2013; Nordine et al., 2019), and hands-on activities (Savery, 2006). However, the shift from traditional, teacher-centered methods to an innovative, student-centered approach is demanding for teachers and requires supporting teachers through respective professional development measures.

Professional development measures must be designed such that they support teachers in successfully implementing inquiry-based teaching; that is, professional development measures must provide teachers with an adequate understanding of IBT, i.e., professional knowledge. Informed understanding of IBT comprises not only professional knowledge about the process of scientific inquiry but also about instructional strategies centering IBT as well as about students' process of understanding during IBT tasks (Magnusson et al., 1999; Neumann et al., 2019). Besides professional knowledge, teachers need strengthened beliefs on the benefits of IBT, as putting professional knowledge of IBT into practice is heavily influenced by teachers' beliefs. Teachers' beliefs act as amplifiers and filters and thus play an important role for translating professional knowledge into teaching practice (Gess-Newsome, 2015; Roehrig & Kruse, 2005). Study 2: Development of learning-related beliefs and teaching practices highlighted the importance of teachers' initial learning-related beliefs for the development of teachers' inquiry-based teaching practice, supporting the claim that teachers' beliefs are important factors in teacher change. Despite the awareness for the role of teachers'

beliefs for the implementation of professional knowledge in practice, the interaction of professional knowledge of IBT and beliefs has received scant attention, as research either focused on the development of professional knowledge (see e.g., Carlson et al., 2019) or the congruence of teacher beliefs with teaching practices (Buehl & Beck, 2015; Mansour, 2013). Developing adequate professional knowledge in the sense of an informed understanding of IBT as well as fostering strong beliefs on the potential of IBT for addressing academic diversity should provide the basis of successful professional development measures on IBT.

To adequately foster implementation of IBT, professional development measures need to take into account the respective teaching context of teachers. Within their respective teaching context, teachers apply their newly developed understanding and negotiate between their prior beliefs and their actual teaching and learning experience (Chant, 2002; Zheng, 2013). Detailed examination of influencing factors on teacher beliefs in Study 1: Factors influencing teacher self-efficacy and learning-related beliefs confirmed the importance of considering teachers' respective teaching context. PD measures should therefore acknowledge the supports and hindrances teachers experience in their day to day teaching. In order to fully support teachers with the implementation of IBT practices, we need to understand the challenges they face and how they overcome these obstacles by drawing on supporting factors.

5.3.2 Research questions

In an effort to explore the role of teachers' understanding of IBT with respect to their beliefs for teachers' implementation of IBT to address academic diversity, this study offers a qualitative approach on the connection of teachers' understanding of IBT and their beliefs on the potential of IBT for addressing academic diversity and how teachers account for perceived hindering or supporting factors. We therefore addressed the questions:

1. What is the role of teachers' understanding of inquiry-based teaching for their expressed beliefs on IBT?
2. What hindrances do the teachers perceive with respect to their expressed beliefs and how is this linked to the teachers' understanding of IBT?

5.3.3 Methods

To answer the research questions by exploring teachers' professional knowledge on IBT, teachers' beliefs on the potential of IBT and hindrances, a qualitative approach was chosen. The use of qualitative case studies is a well-established technique in teacher belief research. Qualitative case studies are used as an exploration of a bounded system or case through in-depth data collection involving different sources of information (Creswell, 2013). Case studies thus offer the ability to capture complexities of real-life situations so that implicit and explicit notions of teacher beliefs and their connection to contextual factors can be studied in greater levels of depth (see e.g., Luft & Roehrig, 2007). Given the open ended and explorative nature of the research questions, a case study approach seemed the most sensible. Thus, a case study approach was adopted to capture teachers' knowledge, beliefs, as well as experienced supporting and hindering factors.

Data Collection

The collected data for the case study approach comprises lesson observations and semi-structured interviews from three teachers that all participated in the same professional development. At the end of the PD course, the teachers were asked to perform a lesson with a focus on IBT and asked to refer to the observed lesson to establish a narrative in the interviews. These lessons were therefore used as anchors to understand teachers' intentions and describe examples of their IBT practices. A particular focus for the interview was set on the potential teachers see in IBT for dealing with academic diversity (e.g., "What do you think – is IBT a good strategy to meet the needs of your students? Why/why not?"), the difficulties they encounter in its implementation (e.g., "What are key challenges for you regarding using IBT to address achievement-related diversity?") and the support they would have needed to overcome the difficulties (e.g., "What else would you like to have within the setting of such a professional development measure?"). The full interview guide can be found in the Appendix. Lesson observation complemented the interviews by providing a context for the interview as well as supplementary information about the student composition of the class, setting of the school, and other significant features of the lessons. The lesson observations thus helped to enrich the individual cases and to understand which contents from the professional development measure were particularly interesting for the teachers' lessons.

Participants

The research study focused on three secondary mathematics and science teachers that participated in the PD course and volunteered to participate in the case studies. The three teachers Tom, Lukas, and Paul (all pseudonyms) were purposefully chosen to represent a wide range of the participants from the PD course, as they had varying teaching experiences as well as different prerequisites on scientific inquiry and inquiry-based teaching. With a mean teaching experience of 7 years (SD=10 years) in the German professional development group (see Sorge, 2020), the sampled teaching experience of 10 years (Tom), 8 years (Lukas) and 5 years (Paul) represented a purposeful sampling of the PD participants. Additionally, even though the German professional development measure was explicitly advertised to mathematics teachers, the teachers all teach other STEM subjects, namely Earth Sciences and Physics and can thus implement the PD content in both of their subjects. This, in turn, enriches the PD experience with inquiry-based teaching and offers opportunities for deeper reflection. Background information on the participants are presented in Table 9.

Table 9

Background information of participant teachers.

	Tom	Lukas	Paul
Subjects	Mathematics, Geography/Earth Science	Mathematics, Physics	Mathematics, Physics
Teaching experience	10 years	8 years	5 years
Previous experiences with IBT	None	PD on teaching strategies that foster active engagement and cooperative learning but no PD on IBT.	Background in mathematics and first-hand experiences with scientific inquiry but no PD on IBT.

Data Analysis

Based on the conceptual framework of teachers' professional knowledge on IBT (Bybee et al., 2006; Capps et al., 2016), teacher beliefs (Luft & Roehrig, 2007) and perceived supports and hindrances (see Chapter 2.5) data analysis for the case studies was conducted (Boblin et al., 2013; Stake, 2005). Each case was analyzed with grounded theory (Corbin & Strauss, 2008). Lesson observations were accessed to get rich descriptions of the teachers' school and classroom context and to build individual lesson cases. During the interviews, teachers were probed to describe their beliefs on the potential of IBT for addressing academic diversity. To identify categories around the core phenomena of teachers' understanding of IBT and their professional beliefs, an orientational methodology was used (Patton, 2015). This orientational methodology includes inductive section coding during the reading of the transcriptions (Bogdan & Biklen, 2007). The coding was done by breaking down the text into small chunks based on an idea/concept in a statement. Categories for the teachers' understanding of IBT included the dimensions of inquiry as described in 2.2 with sub-categories by Capps et al. (2016). The sub-categorization was a result of the inductive section coding and proposes an amalgam of the 5E instructional model of scientific inquiry and the conceptual framing of teachers' knowledge of inquiry as presented by Capps et al. (2016). Teacher belief categories were based on the teacher beliefs inventory by Luft and Roehrig (2007) and perceived supports and hindrances were categorized based on Buehl and Beck (2015). Table 10 shows an excerpt from the coding manual used to categorize teacher statements. Together with the lesson observations, the teacher statements were used to first characterize the teachers in terms of their understanding and professional beliefs and then compare them to each other in a cross-case analysis (Yazan, 2015; Yin, 2009).

Table 10

Excerpt from the coding manual to identify concepts regarding the teachers' professional knowledge, the teachers' beliefs and the perceived supports and hindrances.

Frame	Category	Sub-Category	Example
Professional Knowledge	Exploration	Questioning	“Needs some opening of the philosophy on assignments [...], we need problems that can be solved. There must be barriers so that [the students] do not immediately know so or so it should be solved.”
		Investigating	“I have to offer the students that they [...] simply experiment, research and try out”
		Modelling	“[...] so to pose problems and to model them [...]”
	Evaluation	“They try to solve this problem with the knowledge they have, to try different solutions and then, in the reflection, to integrate the newly acquired knowledge into the cognitive structure, so to speak.”	
Beliefs	Teacher-centered: Focus on information, structure, sources	“Then I am there to order the whole thing, to systematize, to generalize, and then also to secure it mathematically.”	
	Student-centered: Focus on mediating student knowledge or interactions	“And what really offers itself [with IBT] is that student groups, medium to very strong, are actually completely self-sufficient, while low-achieving students can be supported either by their classmates or by myself.”	

Perceived Supports and Hindrances	External	Curriculum standards	“The main disadvantage is simply that textbooks are weak in this area, i.e., textbooks are much reduced to technical tasks and are less concerned with building up conceptual knowledge [...]. And there you have the challenge to provide these tasks yourself.”
		Classroom management	“If you are alone in a class with thirty children, you have set up group tables, you really want to work intensively with a group and behind you there is a lot of action, then it becomes difficult.”
		Materials	“Then you have the challenge of providing the materials yourself. Or modify what I have”
	Internal	Knowledge	“In addition, I find it not so easy to evaluate [...]. And the appreciation of the performance of each student, I think sometimes is not trivial. Because a trivial solution of a low-achieving student has a certain value, that to get recognized by the other students is sometimes not easy.”

5.3.4 Results

In a first step, case descriptions are offered to understand each teacher's background, their understanding of IBT, their expressed beliefs on the potential of IBT, as well as the perceived supports and hindrances when implementing IBT. To answer the research question, the cases were then compared.

The case of Tom

Tom is a teacher educator for the induction phase and has been a teacher for 10 years. He teaches mathematics as well as earth science. Tom was intrigued by the unpredictability in teaching situations and the necessity of exploring new ways to overcome unforeseen complex situations.

Because in principle the teaching profession simply appeals to me, because I like working with people, because I find this transfer of knowledge exciting, I also find the situation exciting that you can plan everything, and yet there is an uncertainty about it, every day is different, is new. (Tom)

The topic of the observed lesson was the waste production in our society and how it can be reduced by buying in zero-waste shops. Tom structured the lesson around the exercise "How much plastic production can be spared by buying in a zero-waste shop?" With this lesson, Tom implemented a modelling exercise that was introduced in the PD course. He considered the lesson to be mostly a success even though he did worry that they did not reach a mathematically correct result.

Tom didn't report any previous knowledge about IBT before the PD course. His understanding of IBT centered on openly phrased tasks that confront students with a problem. Tom emphasized the role of problem-solving and modelling activities and mentions the implementation of authentic contexts as beneficial, without going into much detail. His intention is to give students the opportunity to explore the content themselves:

But in my lessons, no matter if it is about a mathematical concept or a procedure or metacognitive strategies, I always say that I let the students do research, explore and gain their own experiences in new content. (Tom)

Tom's understanding of inquiry-based teaching revolves around the activities in the engagement and exploration phases of scientific inquiry. He emphasizes the dimensions

questioning and investigating but does not elaborate on less-salient dimensions like explaining evidence, interpreting data, communication, and argumentation.

[Inquiry-based teaching] needs a certain opening of the philosophy on assignments, like in the sciences, we need to be able to form hypotheses. After all, we need problems that can be solved. There have to be barriers, so that [the students] do not immediately know so or so it should be solved. [...] I also have to offer the students the opportunity to jump over their shadows and simply experiment, research and try things out. But the most important thing for me is the philosophy around assignments. You need a certain assignment-based philosophy so that inquiry-based teaching can take place at all, and we have to offer that. (Tom)

Tom mentioned experimenting and investigations several times but does not elaborate on what this entails. He therefore acknowledged the importance of hands-on activities but when asked about the potential of inquiry-based teaching, Tom asserts that his focus as a teacher is on information and structure.

*But in my lessons, of course, there is always [...] that I let the students research and explore new content, let them gather their own experiences. And then I am there to order the whole thing, to systematize, to generalize, and then to mathematically secure it.
(Tom)*

When asked about hindrances for implementing IBT regularly in their everyday teaching, Tom described the use of textbooks as a hidden curriculum as a key challenge.

*The main disadvantage is simply that textbooks are weak in this area, i.e., textbooks are much reduced to technical tasks and are less concerned with building up conceptual knowledge [...]. And there you have the challenge to provide these tasks yourself.
(Tom)*

Tom would love to have more materials to complement the textbook materials to foster the implementation of inquiry-based teaching. In his opinion, it is a challenge to provide materials for inquiry-based teaching or to modify already existing materials.

The case of Lukas

Lukas is also a teacher educator for the induction phase and has been teaching for 8 years. His subjects are mathematics and physics. Lukas implemented a task from the PD course on the design of a parking garage. The focus of the task is the modelling activity of designing a parking garage. Lukas started the lesson by showing his students a video on parking garages and how they are designed. During the following classroom conversation, students gathered ideas on how parking garages would be designed. With the method of Think – Pair – Share, he encouraged his students to design the layout of their own parking garage. After about 45 minutes into the lesson, Lukas was joined by a second mathematics teacher and they held the lesson in a co-teaching approach. The students, working in smaller groups at this point, were supported by Lukas as well as his colleague in this phase.

Lukas reported attending PD courses on teaching strategies that foster active engagement and cooperative learning but did not attend any PD courses on IBT strategies specifically. His understanding of IBT is a constructivist perspective. Lukas elaborated that new knowledge is constructed through active engagement as well as through the reflection of the process which, in his opinion, plays an important role for students to embed their newly found knowledge into already existing structures. In doing so, he explicitly involved the evaluation phase in his professional knowledge on inquiry-based teaching.

They try to solve this problem with the knowledge they have, to try different solutions and then, in the reflection, to integrate the newly acquired knowledge into the cognitive structure, so to speak. (Lukas)

Lukas pointed out that IBT should engage students through context-driven problem-solving or modelling activities and is most beneficial, if students develop their own questions:

The students should actually exploit [the mathematical content] themselves and that can only be done by investigation. (Lukas)

His professional knowledge of IBT therefore comprises the salient dimensions questioning and investigating as well as the less salient dimensions as modelling and explaining and interpreting evidence.

Lukas used a Think-Pair-Share approach in his lesson and mentioned several times that he values this approach as a means to mediate student interactions. And while he emphasized his student-centered beliefs on facilitating student learning, he also expressed the more teacher centered focus on structure and information:

For some students, it's also important that sometimes they just get told how to solve something, they just cannot figure out how to do it and then give them some help and if that does not work, just let's say, 'kids, listen, so and so can you solve it!' (Lukas)

Lukas therefore expressed conflicting beliefs, as he values the potential of inquiry-based teaching for constructing knowledge while recognizing that in some situations direct instruction might be needed.

When asked about perceived hindrances, Lukas mainly invoked two points. First, he mentioned time restraints as a hindrance for inquiry-based teaching. In the observed lesson, Lukas would have liked to offer the students more time to work on their solutions which he couldn't do.

They almost didn't want to stop, so I really said "Hey, now get that down on paper!" because time was just too short. (Lukas)

Secondly, Lukas recognized the importance for successful classroom management during inquiry-based teaching. Even with the second teacher in the room for the second half of the observed lesson, he mentioned the possible difficulties with group work in larger classes.

If you are alone in a class with thirty children, you have set up group tables, you really want to work intensively with a group and behind you there is a lot of action, then it becomes difficult. (Lukas)

Lukas expressed the desire for more ready-to-use materials to lessen the workload in lesson preparation. This would give him the opportunity to spend more time anticipating student solutions as well as possible classroom disturbances.

The case of Paul

Five years ago, Paul changed careers from being a researcher in mathematics to teaching. During the project duration but after he experienced the PD course he transitioned to a program specialist position at a university of education while still teaching part-time. He teaches mathematics and physics. Paul is particularly passionate about the beauty and relevance of mathematics and physics in everyday life and wants students to discover this relevance for themselves. Paul's lesson involved a task from the PD course. His students were to investigate how mathematics was used in a court process in the UK in 1999. Paul encouraged his students to pose questions beyond the pure mathematical content and involved his students in discussions of the cultural context as well as the mathematical argumentation of the case. In his opinion, the task gave the freedom to open exercises and instructions for all students to work on the task on their own level and in their own time. He as the teacher could then support the students who needed help while the more involved students worked independently.

Paul did not attend any other professional development courses on IBT. However, he has a background in mathematics and first-hand experiences with scientific inquiry. In his understanding, IBT almost always includes openly phrased tasks or problems that allow as many student solutions as possible. He emphasizes the implementation of modelling tasks and hands-on investigative sequences with the goal of students working together to solve the given problems.

I give the students a very openly phrased task, so that the students can involve themselves, at their level, to solve the task themselves.

The point is that they really acquire the knowledge themselves.

[...] I generally try to make sure that the students do not learn the knowledge [by heart], but that they build it up completely, that's why IBT has priority in my science lessons. (Paul)

Paul therefore mentions not only questioning and investigating, i.e., the salient dimensions of inquiry-based teaching but also explicitly includes modelling and communicating, i.e., less salient-dimensions. He described his goal in establishing and promoting respectful interactions within the class.

Especially since they also work together in IBT, to cooperate, there must be a mutual appreciation. (Paul)

Paul acknowledged the potential of inquiry-based teaching as an opportunity of active and independent student engagement. He focused on mediating student knowledge and interactions by pointing out possibilities to address academic diversity.

And what really offers itself [with IBT] is that student groups, medium to very strong, are actually completely self-sufficient, while low-achieving students can be supported either by their classmates or by myself. (Paul)

Paul's perceived hindrances lie mainly in assessment of the diverse student solutions. He acknowledged the value in the diverse student solutions but described the workload of putting together formative and summative assessment materials.

In addition, I find it not so easy to evaluate [...]. And the appreciation of the performance of each student, I think sometimes is not trivial. Because a trivial solution of a low-achieving student has a certain value, that to get recognized by the other students is sometimes not easy. (Paul)

Paul would value more ready-to-use materials in an effort to implement inquiry-based teaching assignments more often for assessment purposes. A summary of main findings on implementing IBT for addressing academic diversity can be found in Table 11.

Table 11

Summary of main findings on implementing IBT for addressing academic diversity.

	Tom	Lukas	Paul
Understanding of IBT	<p><i>More naïve:</i></p> <p>Investigative, openly-phrased tasks</p>	<p><i>More elaborate:</i></p> <p>Student-orientation through problem-oriented or modelling tasks and hands-on sequences</p>	<p><i>More elaborate:</i></p> <p>Student-orientation through openly phrased tasks, allowing as many student solutions as possible. Collaborative work on modelling tasks and in hands-on investigative sequences.</p>
Beliefs on the potential of IBT for addressing academic diversity	<p><i>Teacher-centered beliefs:</i></p> <p>Emphasized the role of the teacher as a facilitator of knowledge and regulator for the learning process.</p>	<p><i>Student-centered but conflicting beliefs:</i></p> <p>Individual support is ideal for student learning. However, sometimes students need direct instruction instead of IBT.</p>	<p><i>Student-centered beliefs:</i></p> <p>Students support each other instead of relying on the teacher. This fosters an active and independent student engagement.</p>
Hindrances for implementing IBT for addressing academic diversity	<p><i>External:</i></p> <p>Textbooks as the hidden curriculum and primary sources for materials limit IBT implementation.</p>	<p><i>External:</i></p> <p>Time restraints while planning and teaching as well as discipline problems due to large classes.</p>	<p><i>Internal:</i></p> <p>Assessment of diverse student solutions to establish and promote respectful interactions within the class.</p>

What is the role of teachers' understanding of inquiry-based teaching for their expressed beliefs on IBT?

All three teachers primarily drew on knowledge of IBT presented in the PD content. For once, the teachers highlighted the characteristics of IBT-oriented tasks as openly phrased and problem-oriented or including modelling activities. While Tom mainly described the investigative nature of the tasks, Lukas and Paul also mentioned the opportunities for student-orientation and sequences with hands-on activities. Tom's understanding of IBT is predominantly based on the use of scientific inquiry. Lukas and Paul on the other hand emphasized the role of investigations and the active construction and integration of knowledge. These expressed characterizations of the teachers' understanding of IBT will be used henceforth. Since Tom did not have any previous experiences with IBT, we assume that he got the chance to get to know IBT during the PD and did not develop a more elaborate understanding of IBT. He emphasized the importance of openly phrased tasks as a way to promote the involvement of students but rarely mentions hands-on sequences or the focus on students' needs as IBT characteristics. The themes identified in the interview responses are summarized as the main findings in Table 11. In general, the three teachers believed in the potential of IBT for addressing academic diversity, but accentuating different characteristics of IBT. Tom highlighted that the potential of IBT is in actively engaging students by building upon their prior knowledge.

That in the end every student has the chance to bring in his prior knowledge, we jointly put that together and I extract the important stuff. Everybody brings input on their own level. (Tom)

This prior knowledge can be connected through authentic contexts that the students relate to. Despite this focus on student engagement, Tom also strongly emphasized the teacher role as the person responsible for the regulation of the learning process. Lukas and Paul on the other hand recognized the potential of IBT for addressing academic diversity because of the active and independent role students take on during IBT.

Lukas emphasized the advantage of begin able to individually support students in IBT. He pointed out that, before the PD course, he usually used tip-cards for students to get help during tasks. This involved lots of anticipation beforehand and the flexibility of his feedback suffered. The individual advice and support he could give during IBT tasks

helped him understand his students' thought processes and lead them in the right directions.

So I can go to the group and say 'good approach, think about that and that and that' and then there are also really different solutions around. (Lukas)

His approach to mediating student knowledge and interactions was indicative of how much Lukas values the student-centered characteristic of IBT and shows that he appreciated individual guidance over less flexible variations for support. However, Lukas also expressed more critical beliefs on the potential of IBT, as he presumes that sometimes students need direct instruction instead of IBT. In his opinion, situational decisions have priority over a forced implementation of IBT in the classroom.

[...] sometimes you are simply surprised by things, so [...] things come up in class, students ask a question that you didn't expect beforehand. And then your tip cards are of no use to you. [...] You have to be able to react individually. (Lukas)

Overall, Tom showed a more naïve understanding of IBT, describing the more salient characteristics of IBT. Paul and Lukas highlighted the student-oriented attributes of IBT. Their understanding could be described as more elaborate. Paul and Lukas furthermore expressed more student-centered beliefs while Tom accentuated the role of the teacher as a facilitator of knowledge and regulator for the learning process. The teachers with a more elaborate understanding of IBT express beliefs regarding the importance of the student role during IBT. This indicates the importance of professional knowledge for adequate learning-related beliefs on the potential of IBT for addressing academic diversity. The teachers seem to need an elaborate understanding of IBT in order to develop and strengthen their beliefs on the potential of IBT for addressing academic diversity.

What hindrances do the teachers perceive with respect to their expressed beliefs and how is this linked to the teachers' understanding of IBT?

In the interviews, the teachers were asked about key challenges they encountered when implementing IBT for addressing academic diversity. Tom, Lukas, and Paul all reported different challenges or hindrances as predefined curriculum standards, time restraints, and classroom management issues, but when asked what support they would need to implement IBT more often, they all explained how more IBT materials from PD courses would help them.

So these tasks that you have given us, I see them as impulses and ideas for future lessons and if I had not been at the PD course, I would not have had access to the materials and I simply would not have held the lesson. (Lukas)

When asked about hindrances for implementing IBT regularly in their everyday teaching, Tom described the use of textbooks as a hidden curriculum as a key challenge.

*The main disadvantage is simply that textbooks are weak in this area, i.e., textbooks are much reduced to technical tasks and are less concerned with building up conceptual knowledge [...]. And there you have the challenge to provide these tasks yourself.
(Tom)*

For implementing IBT more often, he would therefore appreciate more tasks and materials to use in class. More materials would help Tom to better focus on his role of facilitator of knowledge in the process of scientific inquiry. Lukas also wished for more material, but for a different reason than Tom. He described the time-consuming planning process and classroom disturbances as the key challenges for him. For Lukas, classroom disturbances are one of the biggest challenges during IBT sequences and are particularly restrictive for the individual support he would give during IBT. Usually, Lukas would use tip cards to anticipate problems students might encounter to have more flexible time during the lesson to help individuals. He believed that developing IBT materials as well as planning for all eventualities, including classroom management situations, is very demanding. More ready-to-use materials would decrease his workload to focus on anticipating student solutions and possible problems in the classroom.

Lastly, Paul saw the key challenge in establishing fair assessment for IBT tasks as well as a supportive learning climate within the class. He expressed the wish for materials that also include references to feedback or even (summative) evaluation. This view reflects

Paul's student-centered beliefs, as he aims to foster an active and independent student engagement and is hence looking for more opportunities to implement inquiry-based teaching tasks into his teaching.

All three teachers expressed beliefs about the potential of IBT for addressing academic diversity but with varying degrees of emphasis on the student-centered nature of inquiry-based teaching. Interestingly, Tom and Lukas both reported more external perceived hindrances in the form of a hidden curriculum and classroom management problems. In his case, Tom expressed beliefs regarding the teacher role during IBT tasks. Lukas recognized the importance of the student role during IBT instructions but also expressed more critical beliefs about the potential of IBT as he points out that IBT might not be suitable for every student in every situation. The case of Lukas provides an excellent example of how teachers with an elaborate understanding of IBT might still voice conflicting beliefs regarding the use of IBT. Lukas also voiced more severe hindrances for IBT methods such as time constraints and classroom disturbances during group work. With strong beliefs about the potential of IBT, as in the case of Paul, difficulties are seen to be more internal, as Paul wanted to broaden his knowledge even further on assessment of IBT tasks. Paul expressed the dilemma of adequately acknowledging the work and progress of every student. Especially the social comparison in a class makes this hard to compensate, he pointed out. So while Paul struggled with fair assessment of IBT tasks, Lukas encountered obstacles like time constraints and possible discipline problems. Given the perceived hindrances, Lukas questioned the feasibility of IBT. This gives to show that even with an elaborate understanding of IBT, the teachers might hold more critical beliefs towards IBT depending on the hindrances they perceive. The three teachers all wish for more materials but give different reasons.

5.3.5 Discussion

Teacher beliefs are considered to act as amplifiers and filters for the transition of professional knowledge into practice and thus hold an important role for the development of innovative teaching practices such as inquiry-based teaching (Gess-Newsome, 2015; Polly et al., 2013; Roehrig & Kruse, 2005). The development of innovative teaching practices usually means undergoing a shift from more teacher-centered methods to a student-centered approach (Anderson, 2002; Mansour, 2013). This shift in teaching approaches needs systemic support through professional development measures (Darling-Hammond et al., 2017). This study therefore offered the opportunity to investigate how teachers' professional knowledge on IBT and teachers' beliefs on the potential of IBT for addressing academic-diversity interact and how teachers account for perceived hindrances.

On the question of the role of teachers' understanding of inquiry-based teaching for their expressed beliefs on IBT, this study found that the teachers with a more elaborate understanding of IBT express beliefs regarding the significance of the student role during IBT. This overall result is not particularly unanticipated as it confirms the association of professional knowledge with teachers' learning-related beliefs. While professional knowledge has been characterized as having a truth component that can be externally verified or confirmed (e.g., Richardson, 1996), teachers' beliefs are subjective claims that the teachers believe to be true (Basturkmen et al., 2004; Nespor, 1987; Pajares, 1992). Even though definitions of knowledge and beliefs differ, a clear separation of the two constructs does not seem possible (Murphy & Alexander, 2004; Woolfolk Hoy et al., 2006). That the constructs of professional knowledge and teachers' beliefs are not easily separable is also evident in their development. The development of teachers' professional knowledge mainly draws on formal learning opportunities in their pre-service teacher education (Kleickmann et al., 2013; Sorge et al., 2017) while informal learning opportunities such as reflective practice seem to be important to strengthen acquired professional knowledge in practice (Carlson et al., 2019; Schneider & Plasman, 2011). Teachers' beliefs develop in parallel and are strengthened by reflection on the situations to which they apply (Baron, 2015; Gamlem, 2015). A parallel development of knowledge and beliefs seems obvious, but apparently especially reflection and implementation phases are important for the development and consolidation of beliefs (see chapter 5.2 on the development of teachers' learning-related beliefs and e.g., Chant,

2002; Kunter, Kleickmann et al., 2013). It is therefore not surprising that Lukas and Paul both expressed an elaborate understanding of IBT and recognized the importance of the student-role during IBT instructions. Since they both reported no previous knowledge on IBT before the professional development, it can be assumed that they developed a more elaborate understanding of IBT during the PD, reflected on their understanding as well as on their beliefs and had the chance for implementation and try-outs during the PD that lead to manifested beliefs. Surprisingly, even though he attended the same professional development, Tom's beliefs on the potential of IBT for addressing academic diversity were teacher-centered but not transmissive. It can be questioned whether or not he fully understood the potential of IBT since he reported a more naïve understanding of IBT. So, even with the same learning opportunities and thus the same professional knowledge offered, teachers might not take the same learning output from a professional development. This is a strong hint for the importance of other factors like initial learning-related beliefs or previous experiences, ultimately shaping teachers' professional knowledge and their beliefs (Buehl & Beck, 2015; Gess-Newsome, 2015; Lavrenteva & Orland-Barak, 2018).

The presented study revealed that even with an elaborate understanding of IBT, the teachers might hold more critical beliefs towards IBT depending on the hindrances they perceive. Lukas encounters obstacles like time constraints and possible discipline problems. Given these perceived hindrances, Lukas questions the feasibility of IBT in all situations. Interestingly, the observed lesson Lukas held within the context of this study was partially in co-teaching with another teacher. Time constraints and possible discipline problems might be more manageable problems for Lukas in a co-teaching setting. This setting however might also highlight discipline problems for Lukas when he teaches mathematics and physics without his co-teacher. This case highlights the need for elaborate PD measures, as perceived hindrances need to be addressed in order for sustainable changes in classroom practices to happen for all teachers. PD providers need to account for hindrances in the teaching context and should individually support teachers in overcoming these obstacles. However, there is clearly the issue of social desirability (Graeff, 2005; Krumpal, 2013). Lukas expressed conflicting beliefs on the potential of IBT for addressing academic diversity. He might have expressed even more critical beliefs on the potential of IBT if someone unrelated to the project would have

interviewed him. The PD course had the objective of strengthening teachers' beliefs and he might have chosen to repeat the ideas discussed in the PD course.

On the question regarding what hindrances teachers perceive with respect to their expressed beliefs, our findings provide a complex picture. Paul and Lukas both expressed more positive beliefs towards IBT but still reported different hindrances in the implementation. The teachers all expressed the need for more IBT teaching materials. The perceived hindrances however reveal that the problem isn't really missing materials but the (teaching) context. Tom sees textbooks as a hidden curriculum and heavily relies on them for his teaching practices. Textbooks offer structures for content and often serve as reliable sources for lesson planning and are often used as a basis for lessons (Mullis et al., 2012; Schmidt et al., 1997; Sievert et al., 2021). This reliance indicates that he might not be sure if he's capable of designing IBT tasks himself. Lukas struggles with time management and disturbances within the classroom context. Time management and classroom disturbances have previously been reported as factors hindering teachers in implementing IBT (Maass & Engeln, 2018; Teig et al., 2019). Lukas might see IBT materials as a possibility to reduce his cognitive workload because he would not need time to design tasks himself but rather spend that time anticipating student solutions and possible disturbances. And Paul expresses the need for assessment guidelines because he might not feel capable of designing guidelines himself. This is either an indication of external hindrances not mentioned in the interview like time constraints (Chichekian et al., 2016; Hofer et al., 2018) for designing assessment guidelines, or might be an indication of internal hindrances such as self-efficacy beliefs (McKinnon & Lamberts, 2013; Sandholtz & Ringstaff, 2017) regarding student assessment. Our findings support the previously stated importance of internal and external factors for the relationship between teachers' learning-related beliefs and teachers' classroom practices (see chapter 5.1 for the influence on teachers' beliefs and e.g., Buehl & Beck, 2015). At first glance it seems like offering more materials might be an easy solution to help teachers implement IBT practices more frequently. Offering more materials would definitely offer some support for teachers as it would ease the burden of designing the tasks themselves. Offering more materials could assist teachers in focusing their cognitive load for lesson preparations on topics like performance assessment or anticipating student solutions or possible classroom management situations. However, this would not address the systemic internal and external hindrances they might face.

The presented research supports the claim for professional development measures to take the internal and external influencing factors into consideration.

Overall, the findings of this study provide further support for our understanding of the role of teachers' beliefs on the potential of IBT for addressing academic-diversity in relation to internal and external influencing factors for inquiry-based teaching practice. Our case study provides rich insights into specific perceived hindrances and therefore offers increment value for professional development providers for further development of professional development courses throughout the whole teaching career to provide time and support needed by teachers to foster inquiry-based teaching. As this case study only provides insights into the three presented cases, large scale studies would be needed to provide more generalizable results, especially considering the case studies were three German teachers locally based in Southern Germany. Large scale studies could offer insights into the systemic relationship of teachers' professional knowledge, teachers' learning-related beliefs and the perceived hindrances regarding the implementation of IBT. With this, professional development measures could provide in-depth support on factors that only recently have undergone massive structural changes in theoretical modelling.

6 Discussion

Teachers are key figures for success of the reform of classroom teaching and learning (see chapter 2 Theoretical Background and Current State of Research and Darling-Hammond & Bransford, 2005; Richardson & Placier, 2001). For the implementation of reform initiatives, teachers beliefs play a particularly important role (Darling-Hammond et al., 2005; Haney et al., 1996), as they act as amplifiers and filters for the translation of teacher professional knowledge into teaching practices (Fives & Buehl, 2012; Gess-Newsome, 2015). Existing research recognizes the critical role of supporting and hindering factors for teacher beliefs (Talbot & Campbell, 2014) and thus teaching practices (Maass & Engeln, 2018; Teig et al., 2019). The relative impact of different supporting and hindering factors could offer insights into mechanisms to better support teachers with implementing innovative teaching practices such as inquiry-based teaching. By taking into account internal and external influencing factors, this dissertation caters to a systemic understanding of professional change. This systemic understanding will provide insights into how teachers can be supported to integrate innovative teaching approaches such as inquiry-based teaching into their science and mathematics teaching. In an effort to deepen our understanding of teacher beliefs and their role in teacher professional change, this thesis focused on three main domains: (i) the role of influencing factors for teachers' learning-related and self-efficacy beliefs, (ii) the relationship of the change in teacher beliefs and teaching practice as well as the role of the interaction of the two constructs, and (iii) the prominence of influencing factors in supporting or hindering the change of teacher beliefs and teaching practice. While the results of the three research studies have been discussed separately in the respective chapters (see chapters 5.1.5, 5.2.5, and 5.3.5), the studies are briefly recapitulated and connections of the studies are discussed at this point.

A stepwise multiple regression was used in Study 1: Factors influencing teacher self-efficacy and learning-related beliefs to explore the relative influence of the internal, the classroom and school, as well as the country level factor in form of socially and culturally shared norms and values on teachers' learning-related and self-efficacy beliefs about the potential of IBT for supporting all students in developing scientific literacy. The supports and hindrances show different effects on teachers' learning-related and self-efficacy beliefs, depending on the level. The most obvious finding to emerge from this study is that teachers' self-efficacy beliefs are strongly influenced by internal supports and

hindrances while teachers' learning-related beliefs show more variation regarding classroom and school factors as well as the country level factors.

This dissertation thesis furthermore addresses criticism on already existing teacher professional change models and their sequential nature by investigating the change in inquiry-based teaching practice in relation to change in teacher beliefs. The role of initial learning-related beliefs is of particular interest for the change process as they seem to influence teachers' willingness to implement changes in teaching practice (Lavrenteva & Orland-Barak, 2018; Luft et al., 2003). Following the theoretical argument on the importance of teachers' initial learning-related beliefs as starting points for further professional development, the hypothesis was that participants with strong initial learning-related beliefs show stronger development in their inquiry-based teaching practice. The results of Study 2: Development of learning-related beliefs and teaching practices confirm that the learning-related beliefs had a positive impact on teaching practices for teachers with strong learning-related beliefs prior to entering the professional development program. That was not the case for teachers' with less pronounced beliefs. Furthermore, our analysis also confirms a dialectical relationship between the development of teachers' learning-related beliefs and inquiry-based teaching practice. Both teachers' learning-related beliefs and inquiry-based teaching practices develop conjointly and reinforce each other. The results of this study strongly hint at the importance for professional development measures that strengthen teachers' learning-related beliefs as a prerequisite of changes in teaching practice.

In an overarching attempt to foster sustainable professional change towards inquiry-based teaching, the final research aim of this thesis was to investigate supporting and hindering factors and their importance for the change of teacher beliefs and teaching practice. Changing teaching practices needs to take into account all the supports and hindrances teachers experience in their day to day teaching. Drawing on a case study approach, this thesis explored the challenges teachers face and how they overcome these obstacles by drawing on supporting factors. In a case study approach, Study 3: Challenges and Supporting Factors for Changing Teaching Practices investigated the role of teachers' understanding of inquiry-based teaching for their expressed beliefs on IBT and the role of the perceived hindrances for the teachers' beliefs towards IBT in relation to their understanding of IBT. In two of the three cases, elaborate understanding of IBT concurred with an emphasis of the student-role during IBT instructions. It seems

like the professional development course offered opportunities of reflection on the understanding of IBT as well as the expressed beliefs. However, in view of perceived hindrances, one case study revealed more critical beliefs regarding the feasibility of inquiry-based teaching instruction when confronted with classroom disturbances. This highlights the importance of the context and with this the significance of strengthening teachers' abilities to access the resources they already have (Navy et al., 2019) or to offer adequate support.

In light of the main aim to strengthen teachers' professional competences, all three presented studies explore teachers' learning-related beliefs in the context of inquiry-based teaching for all and elucidate the role of teachers' learning-related beliefs for the inquiry-based teaching practices. While study two mainly focused on the development of teachers' learning-related beliefs and the development of inquiry-based teaching practices, studies one and three shed light on the importance of context in the form of internal and external supports and hindrances and offer insights into the promising leverage effect of strengthening teacher beliefs in professional development courses. The supporting and hindering factors explored in study one were reflected in the case study approach in study three. The case study teachers reported time pressure and discipline problems as hindrances and collaboration as possible supports. Time pressure and collaboration are factors that were summarized as school and classroom level supports and hindrances and were shown to explain variance in teachers' learning-related beliefs in study one. Especially the factor of collaboration documented in study one played an important role in study three. Support from colleagues or mentors in the form of emotional or instructional support, co-planning or exchanging materials can be seen as social resources (Navy et al., 2019). The importance of this finding in study 1 as well as in study 3 could be an indicator for the need for professional learning communities as a means to support teachers in fostering inquiry-based teaching in their mathematics and science classrooms (Tam, 2015).

A professional learning community (PLC) is the idea of lifelong professional learning within the workplace community (Clarke & Hollingsworth, 2002; DuFour & Eaker, 1998; Grossman et al., 2001). This idea might offer additional value for the implementation of innovative and thus challenging teaching practices such as inquiry-based teaching. Teachers share their expertise within a community and develop a collective professionalism (Harris & Jones, 2010). This collective professionalism in turn helps

teachers explore new curriculum and new teaching practices as they collectively reflect on their beliefs and current teaching practice. PLCs can help overcome perceived hindrances like time pressure or discipline problems as teachers can collaborate on high quality teaching materials and discuss classroom management techniques within the respective school and classroom context. This collaboration and support from colleagues and leadership can rarely be offered by traditional professional development courses. Increased involvement, ownership and social and emotional support through PLCs in turn increases the commitment of teachers (Tam, 2015).

In study three, the case of Lukas offered opportunities to explore the impact of increased collegial support. Lukas reported the intention of co-teaching for some lessons, whenever they had the capacities. A co-teaching approach to inquiry-based teaching lessons might offer him a chance to overcome the perceived hindrances of classroom disturbances. Involving other teachers of the same school in a professional development measure on inquiry-based teaching might have offered the opportunity to collectively develop co-teaching lessons on inquiry-based teaching. This co-teaching would reduce the workload for each teacher for material development and anticipation of possible student solutions as well as the apprehension for necessary classroom management interventions. A professional learning community in this school would have supported Lukas in overcoming his perceived hindrances. However, traditionally, the idea of a PLC is to replace conventional professional development measures (Stoll et al., 2006). In my understanding, a PLC could rather complement a PD measure in such a way that the initiated teacher change could be deepened by the creation of a new structure and the building of a collaborative culture within the school. The (guided) professional development could initiate the reflection of and change in teacher beliefs and the professional learning community would offer the safe space for teachers to try out their acquired professional knowledge. This could create a synergy effect to enhance teacher change which would otherwise eventually cease over time.

Interestingly, individual influencing factors are not expressed as perceived supports or hindrances in study three, even though study one showed an influence on teachers' self-efficacy beliefs and study two confirmed the importance of initial learning-related beliefs for the change in teaching practice. As we did not specifically ask about internal factors, the teachers might not associate internal factors as supports and hindrances for their inquiry-based teaching practice. Study one nevertheless revealed the importance

of factors like gender, previous experiences, or expressed need for professional development measures on teachers' learning-related and self-efficacy beliefs. It seems like the teachers do not consciously connect these factors with their inquiry-based teaching practice. Drawing on their professional knowledge for their inquiry-based teaching practice, teachers still consciously accessed an internal factor (Navy et al., 2019), even though they did not explicitly mention their own professional knowledge as a supporting factor.

The most interesting connection however can be seen between study two and study three. Study two investigated the role of initial learning-related beliefs for the change in teaching practice and the relationship between the change in learning-related beliefs and the change in teaching practice during a professional development. Study three built on the results from study two and explored three teachers differing in their learning-related beliefs in relation to their understanding of IBT and their expressed supports and hindrances. Study two showed that for teachers with strong learning-related beliefs prior to entering the professional development program, the learning-related beliefs had a positive impact on teaching practices whereas that was not the case for teachers' with less pronounced beliefs. In study three, three teachers were examined after said professional development. It was therefore assumed that some sort of professional change was made during the professional development but the change itself was not the subject of investigation. In the case of Tom, who expressed more teacher-centered beliefs regarding the potential of IBT, the results from study would suggest that he mainly developed his inquiry-based teaching practice. Since study two indicated that teachers with stronger initial learning-related beliefs develop the inquiry-based teaching practice more, this would suggest that he would suggest that he did not develop to his full potential. A professional development course to adequately support him in implementing IBT more frequent would support him in developing a more elaborate understanding of IBT and strengthening his beliefs on the potential of IBT. Taken together with the results of the importance of initial learning-related beliefs for changes in teaching practice, the interpretation of Tom's case might indicate that changes in teaching practice might not be sustainable when facing hindering factors in his daily teaching without the support from a professional development measure.

Overall, this summarizes quite well the extent of the conducted research. Previous research attributes an important role to teachers' beliefs and the teaching and learning

context. These important roles were further emphasized in the presented studies. However, the important roles are not sufficiently depicted in the most recent models of professional knowledge. Especially the contemporary and highly significant PCK models do not do the role of teacher beliefs and teaching context for teaching practice justice. While the 2012 consensus model does account for teacher beliefs as amplifiers and filters, it only broadly situates PCK within teacher professional knowledge and the bigger picture of classroom practice and student outcomes without specifying PCK itself. The refined consensus model (RCM) focusses on the different facets of PCK and their meaning for teaching practice. It is particularly useful for research on the different PCK facets and while it accounts for the teaching and learning context, the role of teacher beliefs is moved to the background. Both models have their *raison d'être* as they specify different aspects of teacher professional competence. For professional development however, they offer little explanatory power, as huge parts of teachers' everyday reality are skimmed over. Especially for the RCM, the importance of teacher beliefs is hugely diminished as they are not even explicitly named in the model itself anymore (see Figure 4). Especially study two however showed how important teachers' initial learning-related beliefs are for the change of teaching practice. Study three additionally indicates the importance of learning-related beliefs as the interaction of perceived supports and hindrances in the teaching context with learning-related beliefs impacts teachers' willingness to implement innovative teaching practices such as inquiry-based teaching. On the whole, the presented studies provide a comprehensive assessment of the mechanisms related to teachers' learning-related beliefs about the potential of inquiry-based teaching for addressing achievement-related diversity. Study one investigated influencing factors on teachers' learning-related and self-efficacy beliefs, acknowledging the importance of teachers' beliefs for their learning experiences. Study two investigated the development of teachers' learning-related beliefs and confirmed their prominence for fostering innovative teaching reforms through teacher change. And study three supplemented the findings by exploring the relationship with inquiry-based teaching practice within the learning context and thus perceived supports and hindrances. These studies jointly add to the growing body of research that demonstrate the importance of teachers' beliefs for teacher change and the implementation of reform-initiatives such as inquiry-based teaching. However, there are some limitations to consider.

7 Limitations

Despite the contribution of this thesis to the research literature, some limitations are inevitably connected to the conducted studies. Elaboration of assessment issues, the design of the study as well as limitations with interpretation and generalizability of the research findings conclude constrains as well as opportunities for further research.

The major limitations for all three studies lie within the context of the data collection instruments. For the assessment of teachers' professional beliefs in studies one and two, we relied on self-reports. We therefore could only assess explicit beliefs teachers consciously expressed. As we believe that teachers' learning-related beliefs are implicit and explicit notions and assumptions, our assessment solely focusses on teachers' espoused self-reported beliefs. Future studies should also incorporate different assessment strategies such as beliefs in action with video analysis or observations (see e.g., Roehrig et al., 2009). Study 3 partially addressed this issue by using explorative interviews. Interview techniques are commonly understood as more sensitive in exposing teachers' learning-related beliefs as the teachers do not need to consciously reflect on their beliefs (Luft & Roehrig, 2007). However, study 3 has brought its own difficulties. The classification into naïve and elaborate / informed understanding for example is clearly an interpretation. We did not administer knowledge testing and the classification was merely based on the content of the PD course (Boérée et al., 2019). The classification of knowledge about the inquiry-based teaching dimensions could have been more elaborate if based on previously developed dimensions (see e.g., Capps et al., 2016). The chosen open and inductive analysis approach offered more flexible interpretation that suited the research questions better.

An additional uncontrolled factor are the possible response biases inherent in all three studies. The strongly pronounced learning-related beliefs prior to the professional development course in studies one and two indicate a positive sample selection. Being limited to a sample of science and mathematics teachers that participated voluntarily in the professional development, this study lacks broader insights into the mechanism of teacher learning-related belief development simply because the possibilities for development were limited due to the used assessment. Research on assessment methods for personal values in surveys suggests that more differentiation is provided by methods that offer participants the possibility to assess the construct by ranking the values before

rating them (McCarty & Shrum, 2000). This assessment method would prevent response bias constraints like ceiling or floor effects. Combining other assessment techniques with the investigation of teachers with less pronounced beliefs could be a possible pathway for future research. The interview nature of study three however was susceptible to acquiescence bias, a bias based on the respondents' perceptions of how they think the researcher wants them to respond (Graeff, 2005). The susceptibility to response biases in both the quantitative as well as the qualitative study can be seen as a research opportunity. Connecting interviews with survey instruments might offer validity arguments as well as in depth insights into teachers' learning-related beliefs about the potential of IBT for supporting all students in developing scientific literacy.

Furthermore, due to the cross-sectional design of study one, the results must be considered with caution and do not allow assumptions on causality. For example, teachers reporting a need for PD regarding the use of IBT to address academic diversity might have weaker self-efficacy beliefs whereas weak self-efficacy beliefs could also lead to teachers having a need for PD on that topic. The same interpretation might be considered for the found effect of perceived academic diversity on teachers' learning-related beliefs. Causality cannot be assumed for the results of our cross-sectional study. Our results provide the foundation for future longitudinal studies, focusing on the impact of influencing factors identified in this study on the development of teachers' beliefs.

The scope of this thesis was further limited by the research context. As such a limitation and likewise an opportunity for further research is the participation of teachers from only European countries. Especially the investigation of the cultural influence in study one might therefore be greatly underestimated as the countries share some of their cultural backgrounds. To develop a full picture of the influence of socially and culturally shared norms and values, additional studies are recommended. In spite of its limitations, the study certainly adds to our understanding of teachers' professional beliefs as a belief system and the influence of internal and external supports and hindrances. A second limitation for investigating the teacher change in studies two and three is the time frame of the professional development course. It is arguable, whether or not a professional development course with a presence time of 14 hours can be considered as long-term professional development. Some literature recommends extensive professional development for a sustained duration to provide adequate time to learn, practice,

implement, and reflect (Darling-Hammond et al., 2017; Yoon et al., 2007). Only then can substantial effects be measured and sustainable changes in classroom practices established. While the professional development course under investigation did offer additional time for try-outs and reflection, more long-term supported could even increase the effects of the course. Thirdly, study two did not account for the time frame variation in implementation of the professional development course. Even though all participating countries carried out professional development courses with at least 14 hours presence time, the courses were allowed to be arranged according to the national context. So, while, for example, Malta provided weekly meetings of one hour for 14 weeks, Spain organized a one-week summer course for teachers with an online follow-up reflection during the fall. Sample sizes would not allow for elaborate investigations of the development. We recommend case study approaches to evaluate the professional development with a focus on each country. Lastly, study two was not able to account for the complexity of everyday teaching with all internal as well as external context factors. Contextual factors such as time restraints or perceived discipline problems were found to influence teachers' learning-related beliefs and support or hinder inquiry-based teaching practices (Lucero et al., 2013). An exploratory investigation of the role of contextual factors in the relationship of the developments of teachers' learning-related beliefs and inquiry-based teaching practice was therefore aspired for study three.

In spite of its limitations, the thesis certainly adds to our understanding of the development of teachers' learning-related beliefs and development of inquiry-based teaching practice in face of daily perceived supports and hindrances.

8 Implications

There is abundant room for further work in several areas. First, suggestions for further research are discussed. Second, there are implications for professional development measures to be acknowledged. And third, suggestions for stakeholders in education and politics can be formulated.

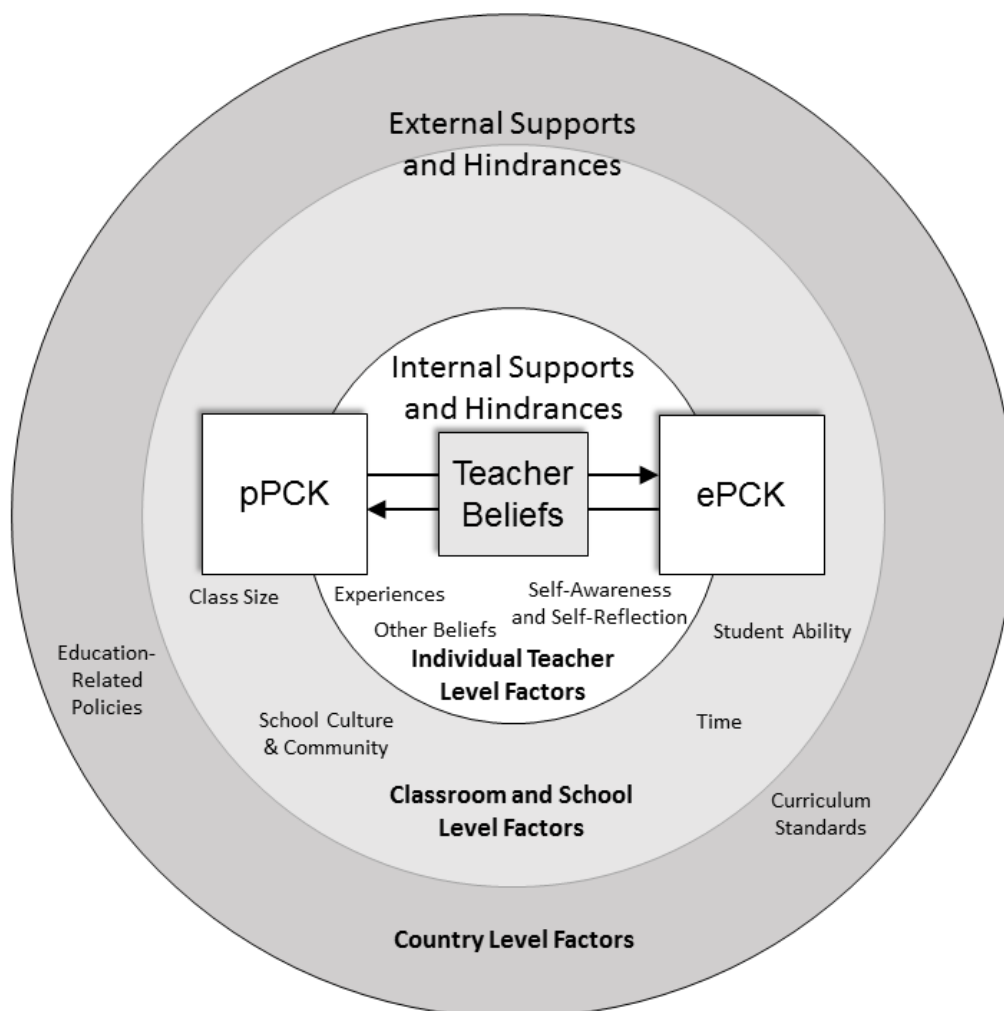
Overall, the presented findings raise intriguing questions regarding the feasibility of the PCK models for research on professional competence when including teacher beliefs. The presented studies have shown that teacher beliefs are of great importance for the anticipated success of teacher professional development measures. Especially the relationship between professional knowledge, teacher beliefs and teaching practice, as seen in studies two and three, indicate the urgency for including teachers' learning-related beliefs when investigating pPCK and ePCK. Possible implications for research include the need for an updated model for PCK that represents the importance of internal and external supports and hindrances in the form of context as well as teachers' beliefs as amplifiers and filters for putting PCK into practice. Teachers' beliefs are particularly important for the knowledge exchange between personal PCK and enacted PCK, as teachers set different highlights in the planning process and reflect their lessons according to their beliefs. This consideration of beliefs plays an exceptionally important role for teacher professional development measures. Professional development has the goal of advance teachers' teaching practices (Darling-Hammond et al., 2017; Fullan, 2007) by addressing their personal PCK and in turn strengthening their enacted PCK (Carlson et al., 2019; Magnusson et al., 1999). As teachers' beliefs frame and filter the knowledge exchange from cPCK to pPCK, teachers might not be able to strengthen their pPCK to their full potential. The same mechanism applies to the knowledge exchange from pPCK to ePCK, as teachers' beliefs frame and filter the translation of knowledge into practice. Strengthening pPCK and thus ePCK without addressing teachers' beliefs in this process might not be as effective to bring about lasting changes in classroom practice.

In an effort to integrate the PCK models (see Figure 3 and Figure 4) and the model by Buehl and Beck (2015) on the system of internal and external supports and hindrances (see Figure 8), the idea developed to offer a refined model that incorporates the PCK

aspects as well as teacher beliefs and the internal and external supports and hindrances. A first draft is presented in Figure 12.

Figure 12

Integrated model of PCK in a system of internal and external supports and hindrances.



Displaying the daily teaching routines in a model as this is an ambitious undertaking and the model in Figure 12 does not account for all facets of internal and external supports and hindrances or all aspects of PCK. Nonetheless, illustrating more detailed facets of PCK might be overwhelming. It is, however, important to expose the critical influences on teaching practices. Only then can these influences be acknowledged in research. The research in turn can be brought together to improve our knowledge of teacher education and continued professional development.

Some of the implications emerging from the presented studies relate specifically to continued professional development measures that foster the implementation of

innovative teaching practices. The aim of the MaSDiV professional development course for example was to strengthen teacher beliefs to promote inquiry-based teaching practices. The three modules were developed and publicized (Boerée et al., 2019) and particularly included the objective to foster reflection on and strengthening of teachers' learning-related and self-efficacy beliefs. However, standardizing activities that get teachers to reflect on their learning-related beliefs by explicitly challenging already existing beliefs are difficult to design as the reflection process might look different for every teacher.

Another reason why standardized reflection activities might not necessarily be beneficial is that teachers hold individual belief systems (Zheng, 2013). Our quantitative results indicate strong initial learning-related beliefs prior to the PD measure. The ceiling effect of our quantitative instruments however is not reflected in the qualitative approach and indicates a more diverse and individual system of teacher beliefs. This diverse system needs to be accounted for in the PD measure. Furthermore, supporting and hindering factors need to be taken into account. Addressing the individual belief systems as well as the supporting and hindering factors might be easier in smaller PD groups that explicitly reflect on their beliefs. This can be done in cycles of presenting new knowledge to expand the teachers' understanding of IBT towards a more elaborate knowledge of the IBT facets, followed by a reflection of already existing beliefs and try-out phases in school. The try-out phases in turn have to be reflected to support teachers in possible difficult situations and to enforce their learning-related beliefs (similar to the development model in Figure 7). This process is time consuming. Possible solutions could be professional learning communities within schools, mentoring tandems, or a buddy system for try-out phases with other teachers in the professional development measure. This would also take into account the access to human resources in form of collegial support (Navy et al., 2019).

Besides the already discussed implications for research and the implications for professional development providers, there are more general implications for stakeholders in politics and education. Understanding the professional change process offers insights into how to support large-scale professional development efforts regarding innovative teaching practices such as inquiry-based teaching. The characteristics of effective professional development measures have been extensively documented (Lipowsky & Rzejak, 2015; Roesken-Winter et al., 2015; Zehetmeier &

Krainer, 2011). But even though aspects like long-term, high-quality engagement with specific aspects of teaching are considered highly effective for a change in teaching practice, we still see strong fluctuation in PD duration, sometimes even within the same project. As can be seen in the presented research, even 14 hours of professional development do not necessarily result in significant changes in teachers' learning-related beliefs. Considering the perceived internal and external hindrances that were exposed in study three, professional development measures need to offer more opportunities to reflect on and discuss teachers' learning-related beliefs in light of the respective teaching context. This could be helpful especially for teachers with lower initial learning-related beliefs prior to the professional development.

The presented research highlights a need for a standardized professional development practice, to offer sufficient time for reflection and try-outs and to adequately build up support systems in terms of professional learning communities or teaching tandems. Reducing workload for teachers to attend long-lasting high-quality professional development measures should be a logical conclusion from previous research as well as the presented findings. Stakeholders in education and politics should jointly push towards a more sustainable professional development practice to ensure high quality teaching and successful reform efforts.

9 Summary and Conclusion

The quality of an education system cannot exceed the quality of its teachers. (Barber & Mourshed, 2007, p. 19)

The purpose of this investigation was to explore the relationship between teachers' learning-related and self-efficacy beliefs with respect to influencing factors to ultimately change teachers' inquiry-based teaching practices. This relationship is investigated in the context of inquiry-based science and mathematics teaching for supporting all students in developing scientific literacy as a prototypical innovative teaching practice with the goal of science and mathematics education for all.

In Study 1: Factors influencing teacher self-efficacy and learning-related beliefs, we set out to determine influencing factors on teachers' learning-related beliefs about the potential and self-efficacy beliefs regarding the use of IBT for addressing academic diversity. The relevance of the proposed division of influencing factors in the domains of internal and classroom and school factors as well as country level factors was supported by our results. On the one hand, internal supports in the form of previous learning experiences endorsed teachers' self-efficacy beliefs, while internal hindrances like a strong need for professional development limited teachers' self-efficacy beliefs. On the other hand, external supports and hindrances like perceived diversity and discipline problems had a strong impact on teachers' learning-related beliefs. The consideration of individual, institutional and cultural characteristics in measures designed to strengthen or change teachers' learning-related and self-efficacy beliefs can serve as a means to enhance teachers' professional behavior in the classroom. The findings of this study also have a number of practical implications. Firstly, the influence of gender and collectivistic orientation of society emphasizes the importance of mastery orientation and communal goals. Professional development with a focus on methods to address diversity need to create a shared awareness of the importance of teaching practices that benefit the learning of all students. Secondly, especially the perceived professional context (e.g., perceived diversity, perceived time pressure, and perceived discipline problems) influence teachers' learning-related and self-efficacy beliefs. This influence of external factors on the institutional level indicates the need for support systems for teachers. These could be established in form of professional learning communities to strengthen professional collaboration, especially since collaboration has been found to positively influence teachers' learning-related beliefs. Moreover, professional development

courses on e.g., classroom management topics might provide teachers with support and a solid foundation on which to choose teaching practices closely aligned with their professional beliefs. These implications should support teachers in designing and enacting lessons that are in line with recent reform efforts and strengthen the individual potential of all students.

Study 2: Development of learning-related beliefs and teaching practices was designed to examine the relationship of the development of teachers' learning-related beliefs about the potential of inquiry-based teaching for addressing achievement-related diversity and the development of teachers' inquiry-based teaching practice. We especially set out to investigate the role of teachers' initial learning-related beliefs for the development of teachers' inquiry-based teaching practice. The relevance of teachers' initial learning-related beliefs as a starting point for development is clearly supported by the current findings as teachers with stronger pronounced initial learning-related beliefs report a more frequent inquiry-based teaching practice following the learning opportunity. For teachers with less strong initial learning-related beliefs, the professional development led to a more coherent relationship between the beliefs and practices of those teachers. This dialectical relationship between the development of teachers' learning-related beliefs and the development of teachers' practices was also evident for all teachers. Addressing and strengthening teachers' learning-related beliefs through a professional development course also changes inquiry-based teaching practices and the other way around. In conclusion, our research provides important insights into the development of teacher professional competence for in-service teachers. It is therefore vital that professional development courses provides opportunities for both try-outs of teaching practice and reflection of those opportunities in order to support the development of both aspects and help teachers to change their practice in a sustainable way.

The main goal for Study 3: Challenges and Supporting Factors for Changing Teaching Practices was to assess how teachers benefit from supporting factors and overcome hindrances to implement IBT to address academic diversity. The most obvious finding to emerge from this study is that teachers' knowledge, beliefs and the perceived supports and hindrances interact and influence teachers' implementation of IBT. According to teachers' previous experiences and understanding of IBT, they see different potential in either a more student-centered implementation of IBT or an active teacher role in the implementation of IBT for addressing academic diversity. The key challenges the

teachers perceive align with the perceived potential, as the teachers describe either more external hindrances (e.g., time pressure and classroom disturbances) or more internal challenges (e.g., knowledge about assessment of IBT tasks). Our study confirms the reported struggle of teachers to shift from a more teacher-centered instruction to student-centered methods like IBT (Dobber et al., 2017; Maass et al., 2017). Despite the differences in perceived hindrances, the three teachers describe the need for more support through more ready-to-use IBT materials. Additionally, our case study complements the work of Charalambous (2015) by revealing the key role of perceived supports and hindrances as influences on teachers' beliefs about the potential of IBT for addressing academic diversity. However, not all internal and external supports and hindrances are equally influential on teachers' knowledge and beliefs. The insights gained from this study may be of assistance to understand the complex nature of teachers' beliefs and their impact on teaching practices.

Overall, the studies gave important insights into the significance of teacher beliefs. Study one highlighted the importance of teacher beliefs in the school and classroom context. This has direct implications for learning opportunities in a continued professional development. Study two expands our understanding on the relevance of teacher beliefs for the development of inquiry-based teaching practice as part of teacher change. And finally, study three shed light on the prominence of teacher beliefs in the conjunction with (inquiry-based) teaching practice. Furthermore, the investigations have especially highlighted the importance of internal and external hindrances for teachers' learning-related and self-efficacy beliefs and thus for inquiry-based teaching practices. Changing everyday teaching practices in the science and mathematics classroom towards more reform-based teaching practices is a challenging endeavor. Stakeholders in the educational sector with the goal of supporting teachers in successfully implementing innovative teaching practices with the goal of science and mathematics education for all are encouraged to draw conclusions from this work.

The main conclusion besides the importance of the system of internal and external supports and hindrances is the significance of teachers' beliefs not only for teaching practices but also for the professional change that might be required for a more pronounced implementation of innovative teaching practices. This thesis offers insights into the relationship between these factors and implications for further research as well as for professional development practice. Just as Barber and Mourshed (2007) put it, we

need to invest in our teachers by equipping them with knowledge and skills, and strong beliefs on the potential of the innovative teaching approaches to see these teaching practices in action and to ensure scientific literacy for all.

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11 Appendix

Internal and external influencing factors

Perceived autonomy

Item

In the subject that I teach I feel free to decide what content to focus on.

In my daily teaching I am free to choose, which contexts should be addressed during my instruction.

Perceived policy support regarding diversity

Item

In my country, policy prioritizes the need to address diversity in classes.

National curricula consider diversity in classes.

At my school, emphasis is placed on dealing with diversity.

Perceived collaboration in the school

Item

In my school, teachers usually exchange learning materials.

In my school, teachers have discussions about how to teach certain topics to certain students.

In my school, teachers work together to plan some lessons.

Perceived discipline problems

Item

I do not incorporate inquiry-based learning because it is often disrupted by students who lack discipline.

Some students with behavior problems make it difficult to carry out inquiry-based learning.

Perceived time pressure

Item

During class I do not have enough time to discuss social relevant contexts.

I have not enough time for preparing student-centered lessons.

Perceived achievement-related diversity

Item

In my classes, students differ greatly in their cognitive abilities.

Learning-related beliefs

To what extend do you agree with the following statements?

Item

Situating instruction in every day-life contexts can help engage all students in learning.

Encouraging students to explain their own ideas can support students with different ability levels in learning.

Inquiry-based activities are well suited to support all students in their learning.

Having students carry out practical / modelling activities can provide an opportunity to learn for students of all ability levels.

Having students design their own experiments / investigations creates learning opportunities for all students.

Self-efficacy beliefs

To what extent do you agree with the following statements?

I feel confident that ...

...I can design activities that allow students of diverse ability levels to test out their own ideas.

...I am able to help students of a wide range of abilities to see the relevance of the content to learn.

...I can facilitate classroom discussions in which even low-achieving students can engage.*

...I can use inquiry-based activities to engage all my students in learning.

...I can plan practical / modelling activities that support all students in their learning.

Notes. * Item got deleted due to wording.

Inquiry-based teaching practice

How often do the following activities take place in your lessons?

In my teaching ...

...I use a variety of contexts to engage students with diverse abilities.

...I engage as many students as possible in discussing their own ideas with each other.

...I provide different levels of support to students of different ability levels as they do practical activities.

...I allow every student to define their own problem-solving strategies and develop their own explanation.

Interview Guide

Guiding question	Prompt
What does 'inquiry-based teaching' (IBT) mean to you?	<ul style="list-style-type: none"> • What do you think are the main characteristics of teaching IBT? • What are the benefits from IBT from your perspective? • What kind of prior experience do you have using IBT? • What kind of professional development on IBT did you have? • How do you implement IBT in practice?
How did you try to address achievement-related diversity of your class?	<ul style="list-style-type: none"> • What strategies for addressing diversity did you implement? • How did you experience the implementation? • How did your students react to the strategies and methods you used?
How are you using IBT to address achievement-related diversity in your class?	<ul style="list-style-type: none"> • What activities/learning opportunities in this lesson were particularly helpful to address achievement-related diversity? • What are key challenges for you regarding using IBT to address achievement-related diversity? • How would you describe a lesson that you consider illustrative of using IBT to address achievement related diversity? • What do you think – is IBT a good strategy to meet the needs of your students? Why/why not?

<p>From your perspective what impact did the CPD course have on the lesson we saw?</p>	<ul style="list-style-type: none"> • How was your planning influenced by the CPD? • Which activities did you implement due to the CPD? Why?
<p>What aspects or activities of the CPD course were especially useful for you?</p>	<ul style="list-style-type: none"> • In which way did the course change your practice? • How did you implement activities of the CPD course into practice besides of the lesson today? • What are the benefits of the CPD course for your students? • What challenges do you encounter of putting CPD ideas into practice? • What will you keep on using? • Do you remember an aha-moment during the CPD course or related to the CPD course?
<p>How did the CPD help you to implement IBT to address diversity?</p>	<ul style="list-style-type: none"> • What did you try out? • What are you planning to try out?
<p>How would you change the CPD?</p>	<ul style="list-style-type: none"> • What else would you like to have within the setting of such a CPD? • Which activities could be cancelled? • How could the CPD course be improved?

12 Conference Contributions

Within the framework of this dissertation, the following conference contributions were made:

Langhans, A., Sorge, S., Engeln, K., & Neumann, K. (2019, August). *Same same but different? Understanding differences in teachers' diversity-related beliefs and self-efficacy*. 13th Conference of the European Science Education Research Association (ESERA), Bologna.

Langhans, A., Sorge, S., Engeln, K., & Neumann, K. (2019, September). *Entwicklung der lernbezogenen Überzeugungen, Selbstwirksamkeitserwartung und Unterrichtspraxis von Lehrkräften*. Jahrestagung der Gesellschaft für Didaktik der Chemie und Physik (GDGP) 2019: Naturwissenschaftliche Kompetenzen in der Gesellschaft von morgen, Wien.

Langhans, A., Sorge, S., Engeln, K., & Neumann, K. (2019, October). *Same same but different? Investigating STEM Teachers' Initial Beliefs Entering a Professional Development Programme Addressing Diversity*. Educating the Educators III: 3rd International Conference on Approaches to Scaling-up Professional Development in Maths and Science Education, Freiburg.

Langhans, A., Sorge, S., Engeln, K., & Neumann, K. (2019). Inquiry-based learning und Leistungsheterogenität - Überzeugungen und Selbstwirksamkeitserwartung von Lehrkräften. In C. Maurer (Ed.), *Naturwissenschaftliche Bildung als Grundlage für berufliche und gesellschaftliche Teilhabe : Jahrestagung der Gesellschaft für Didaktik der Chemie und Physik (GDGP) 2018* (pp. 771-774) Universität Regensburg:

Hesse, A., Sorge, S., & Neumann, K. (2020, September). *IBL und Leistungsheterogenität: Praxisstrategien auf dem Prüfstand*. Jahrestagung der Gesellschaft für Didaktik der Chemie und Physik (GDGP) 2020: Naturwissenschaftlicher Unterricht und Lehrerbildung im Umbruch?

Sorge, S., Hesse, A., & Neumann, K. (2021, April). *Overcoming Obstacles: Supporting Teachers to Implement Inquiry-Based Teaching*. 2021 Annual International Conference (NARST): Science Education, a Public Good for the Good of the Public? Research to Empower, Evoke, and Revolutionize.

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14 Affidavit/Eidesstattliche Erklärung

Hiermit erkläre ich, dass die vorliegende Dissertation – abgesehen von der Beratung durch meine Betreuer*innen – nach Inhalt und Form meine eigene Arbeit ist und keine anderen als die angegebenen Quellen und Hilfsmittel genutzt wurden. Die vorliegende Dissertation wurde weder ganz noch zum Teil einer anderen Stelle im Rahmen eines Prüfungsverfahrens vorgelegt, veröffentlicht oder zur Veröffentlichung eingereicht. Teile der Befunde der vorliegenden Dissertation wurden bereits in Form von Tagungsbandbeiträgen publiziert.

Die vorliegende Arbeit ist unter Einhaltung der Regeln guter wissenschaftlicher Praxis der Deutschen Forschungsgemeinschaft entstanden. Ich erkläre ferner, dass mir kein akademischer Grad entzogen wurde.

Kiel, den _____

Alice Hesse