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Putting inquiry-based learning into practice: How teachers changed their beliefs and attitudes through a professional development program

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Abstract:

Despite the tremendous efforts which have been made over the last few years, inquiry-based learning (IBL) has not become an established practice in science education yet. Even if teachers consider IBL an important and valuable approach, they still refrain from implementing it in their own science classes. Research findings suggest that the teachers' beliefs and attitudes have a crucial influence on their classroom practice. Only if they are compatible with the approach of IBL, the teachers will be willing to implement IBL in their own classes. This article demonstrates how the beliefs and attitudes of three Austrian chemistry teachers changed over the period of a 9-monthly professional development program (PDP). In order to ascertain their beliefs and attitudes regarding IBL previous to and after the PDP, we conducted a group discussion and three individual interviews. The statements from both dates were analyzed using a qualitative content analysis and indicate substantial changes concerning the teachers' beliefs about the efficacy, capability and practicability of IBL. After participating in the PDP, the teachers took a more positive attitude regarding both IBL in general and its implementation. Considering the findings from this study, we formulate implications for designing PDP at the end.

Keywords: beliefs and attitudes, inquiry-based learning, teacher professional development

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Introduction

When examining research articles on the subject of inquiry-based learning (IBL), the following picture emerges time and again: IBL is regarded as an indispensable element of science education and fostering its implementation is substance of various reform efforts. Despite that, there has been only a slight impact on science teachers' practice so far (e.g. Capps, Shemwell, & Young, 2016; Crawford, 2014; DiBiase & McDonald, 2015). Even though science teachers consider IBL as an important instructional approach, they implement it only infrequently or occasionally in their own classes. As reasons for this, they prevalently name external factors like lacking resources, unsuitable organizational conditions as well as the inconsistency with curricula, standards and final exams (Anderson, 2002; DiBiase & McDonald, 2015; Hofer, Abels, & Lembens, 2018). Research findings, however, suggest that especially internal factors like beliefs and attitudes affect whether teachers implement IBL or not (e.g. Jones & Carter, 2007). Hence, professional development programs (PDP) need to particularly address these internal factors in order to persuade teachers to apply IBL. This study investigates the impact of a collaboratively designed PDP on the participating teachers' beliefs and attitudes as well as on their willingness to implement IBL in their own chemistry classes.

Theoretical framework

According to Jones and Carter (2007), teachers' beliefs and attitudes "shape the way they interpret and respond to changes and challenges". Consequently, beliefs and attitudes crucially influence what instructional strategies teachers choose and how they implement these strategies in the classroom. In the following sections, we briefly discuss how beliefs and attitudes influence classroom practice, what beliefs and attitudes teachers hold regarding IBL and what features are characteristic for effective PDP.

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Beliefs and attitudes as antecedents for instructional practice

Investigating teachers' beliefs and attitudes has become a more prominent issue in educational research over the decades. However, the large number of studies has entailed an equally large number of terms in this context. Beliefs, attitudes, views, conceptions, values, perceptions – just to name a few – are terms used to describe aspects concerning a teacher's personal disposition. Unfortunately, these terms are neither defined uniformly nor are they used consistently (cf. Jones & Leagon, 2014; Jones & Carter, 2007). For this reason, we want to briefly clarify the terms we will use hereafter. By *attitude*, we understand “a predisposition to respond positively or negatively to things, people, places, events, or ideas” (Simpson, Koballa, Oliver, & Crawley, 1996, p. 212). This describes a “state internal to the person” (Eagly, 1992, p. 694) which determines “how favorable or unfavorable an individual feels about performing a behavior” (Jaccard, Litardo, & Wan, 1999, p. 103). In the context of teaching, an attitude can be considered as a kind of willingness (Eagly & Chaiken, 1993; Jaccard et al., 1999) to apply a specific teaching content, material, method, curriculum, instructional strategy or approach and, hence, is antecedent to classroom practice (Ajzen, 2001; van Aalderen-Smeets, Walma van der Molen, & Asma, 2012). Using the term *beliefs*, we talk about cognitive constructs, which are not factual or scientifically justified and, thus, differ from a teachers' *knowledge*. Teachers may hold diverse beliefs about various facets of teaching and learning, knowledge and science as well as about their self-efficacy (Jones & Leagon, 2014; Jones & Carter, 2007).

Studying three models from literature (Jones & Carter, 2007, p. 1076; Jones & Carter, 2007, p. 842; van Aalderen-Smeets et al., 2012, p. 176), we strive for providing a strongly simplified model which focuses merely on a few basic elements, but still indicates the relationship between a teacher's attitude (in the meaning we stated above) and their classroom practice (see Figure 1).

Figure 1: A strongly simplified model of the relationship between attitude, intentions and practice.

As illustrated above, an *attitude* emerges from three basic elements (*knowledge and skills*, *beliefs* and *affective factors*) which mutually interact with each other. These three elements may include both conscious and unconscious aspects and are strongly interlinked with the prevailing sociocultural context. The complex interaction between these elements results in an *attitude* which determines the *intentions* (plans, prospects, resolutions) a teacher has. These *intentions* may result in *practice* (implementation in the classroom) and, if so, in an experience which in turn influences the teacher's *knowledge and skills*, *beliefs* as well as the *affective factors*. Although we started our description at one specific point, it is important to recognize that this model illustrates a cyclical and dynamic process which may differ vastly depending on person and context.

Teachers' beliefs and attitudes toward inquiry-based learning (IBL)

When discussing the role of IBL in science classes, researchers identify two issues: firstly, teachers do not implement IBL (frequently) in their classes (e.g. DiBiase & McDonald, 2015) and secondly, teachers implement IBL differently than intended in policy documents like standards or curricula (e.g. Crawford, 2007). Both issues have their origin in teachers' beliefs and attitudes. In one case, teachers' attitudes (emerging from knowledge and skills, beliefs and affective factors) seem to inhibit the implementation of IBL. In the other case, the teachers adopt a positive attitude toward the implementation of IBL, but their knowledge and skills and/or beliefs seem to be different from those assumed in the policy documents.

Findings from the literature suggest that teachers' beliefs and attitudes concerning IBL are ambiguous. In their study, DiBiase and McDonald (2015) surveyed 257 science teachers and found that more than 90 % of them

agreed that IBL is an important instructional approach, suitable for developing students' critical-thinking and problem-solving skills. Moreover, about three quarters (78 %) of the respondents considered it important in exploring and constructing knowledge. Similar results are described by Wallace and Kang (2004), who investigated the beliefs of six experienced science teachers: These teachers stated that IBL would promote students' independent thinking and problem-solving skills as well as their conceptual understanding and their scientific thinking practices. The authors identified – as many others (e.g. Crawford, 2007; DiBiase & McDonald, 2015), however, – a tension between the teachers' beliefs in favor of IBL and their concerns regarding its implementation. These concerns include the compatibility of IBL with the prevailing conditions at schools, with the requirements for final exams or with personal resources like knowledge, skills, available time etc. (see also Anderson & Helms, 2001; Cheung, 2011; Crawford, 2014). Overall, the majority of teachers lacks of an elaborated model of IBL and has difficulties in grasping IBL as a complex instructional approach (e.g. Reiff, 2002; Rushton, Lotter, & Singer, 2011). Whether and in what way teachers implement IBL in their own classes depends on the teachers' attitudes emerging from their knowledge, skills and beliefs (specific to IBL and general to teaching, learning, knowledge, science, NOS etc.) as well as on the external constraints (rigor of curriculum, lacking resources, organizational framework etc.) they perceive (Capps, Crawford, & Constanas, 2012; Crawford, 2014; Wallace & Kang, 2004).

Professional development programs (PDP) emphasizing inquiry-based learning (IBL)

Various studies have shown that well-designed PDP are able to change teachers' beliefs and attitudes regarding IBL as well as their instructional practice. Capps et al. (2012) conducted an empirical review on literature addressing PDP for IBL in science education. According to existing models of well-designed PDP (i.a. Darling-Hammond & McLaughlin, 1995; Garet, Porter, Desimone, Birman, & Yoon, 2001; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2009; Penuel, Fishman, Yamaguchi, & Gallagher, 2007), the authors generated a list of nine "common features of effective PDP": *Total Time*, *Extended Support*, *Authentic Experience*, *Coherency*, *Develop Lessons*, *Modeled Inquiry*, *Reflection*, *Transference* and *Content Knowledge*.

It is generally recognized that the duration (*Total Time*) of a PDP is a strong predictor for its effectiveness. The higher the number of hours spent on active participation and the longer the period over which a PDP extends, the more effective it will be (Desimone, 2009; Garet et al., 2001). The duration of PDP emphasizing IBL is especially important as the participants will need time to become aware of and work on their own beliefs (*Reflection*) (Rushton et al., 2011). Only if a PDP addresses the teachers' beliefs in a constructive and sensitive way, will they be willing to implement IBL in their own classes (Capps & Crawford, 2013; Wallace & Kang, 2004). Another factor that crucially influences the teachers' involvement in a PDP is its *coherency* with the curricula, standards and assessments (Desimone, 2009; Garet et al., 2001).

Despite working on beliefs and attitudes, a PDP needs to support the participating teachers in developing and extending their knowledge and skills regarding IBL. According to Capps et al. (2012, p. 307), teachers "will need to possess a depth of science content knowledge, understand what inquiry is, have experience in both conducting scientific inquiry and teaching using inquiry-based approaches". To enable teachers to gain experience in inquiry processes, two main strategies are used: engaging teachers in research projects (*Authentic Experience*) (Herrington, Bancroft, Edwards, & Schairer, 2016; McLaughlin & MacFadden, 2014; Miranda & Damico, 2015) or making them experience predefined IBL units (*Modeled Inquiry*) (Brand & Moore, 2011; Lotter et al., 2016; Rushton et al., 2011). To bridge the gap between the PDP and the reality in school, discussing possibilities to use and modify material (*Transference*) as well as designing IBL units (*Develop Lessons*) has proven successful (Capps et al., 2012).

Having discussed the theoretical background on which this study is based, we will now foreground the context and design of the study before discussing the ascertained findings.

The context of the study

The starting point of this study was a PDP in the framework of the FP7-project TEMI.¹ This PDP consisted of workshop-series extending over a period of 4 months each and aimed at fostering the implementation of IBL in secondary science classes. For this purpose, the participating teachers were introduced to a theoretical framework comprising the definition of IBL according to the National Science Education Standards (National Research Council, 2000), the instructional goals formulated by Abrams, Southerland, and Evans (2008), the different levels of IBL (Blanchard et al., 2010) as well as the 5E instructional model (Bybee, 2009). Additionally, the teachers engaged in IBL from the perspective of both learners and teachers. In doing so, they explored various scientific phenomena, attempted to plan IBL units and reflected on their experiences and implications for their

own teaching. The data collected over the whole period of the PDP indicated that the participating teachers really liked TEMI; they did not, however, transfer these contents and strategies to their own science classes. They stated that they would not feel confident enough to implement IBL without further help. Furthermore, the results suggested several inconsistencies present in the teachers' conceptions of IBL (cf. Hofer, Lembens, & Abels, 2016; Lembens & Abels, 2016).

In order to examine the teachers' knowledge, beliefs and attitudes regarding IBL in more detail, we conducted a group discussion ($N = 5$, ~45 min) with former TEMI participants. The data from this discussion (Hofer et al., 2018) showed that the teachers still had great difficulty to conceptualize IBL as an instructional approach. They reduced IBL to a specific instructional method (cf. Reiff, 2002; Rushton et al., 2011), which can be used to pursue goals beyond those of regular lessons. Whilst the teachers described IBL as an important and valuable approach, they considered its implementation as almost unrealizable under the prevailing conditions (cf. Crawford, 2014; Wallace & Kang, 2004). Once again, they emphasized their own insufficient knowledge and skills in order to plan and implement IBL by themselves. These results implied that even though the participating teachers already held a positive attitude toward IBL, nonetheless, they refrained from implementing it in their own science classes (cf. DiBiase & McDonald, 2015).

Purpose of the study

Considering these findings, we decided to design a further PDP focusing on the realization of IBL units in the participating teachers' own classes. In the framework of this PDP, a regular and intensive collaboration should be established in order to accompany the teachers in planning and implementing IBL units as well as in reflecting on their experiences. By providing *Extended Support*, the teachers should be able to cope with the barriers they perceive when implementing IBL and, as a result, they should be more willing to implement IBL in their future classes.

In order to evaluate the effectiveness of this PDP the following questions were formulated:

1. How did the teachers' beliefs and attitudes regarding IBL change over the period of the PDP?
2. What intentions do the teachers have regarding the implementation of IBL in their own classes after participating in the PDP?

Design and method

Analyzing the findings from the group discussion, we discovered a number of different beliefs and attitudes regarding IBL. To change them in a way that teachers would be more willing to implement IBL after participating in the PDP, we selected three of the major concerns to be focused on in the PDP. As a next step, we reflected about how these concerns could be addressed in the planned PDP (see Table 1).

Table 1: Concerns selected to address in the PDP.

Concern	Justification of the concern	Addressing this concern in the PDP
IBL is not realizable under the conditions prevailing at my school.	IBL is a time-consuming approach in which students use extraordinary material. To realize IBL, block units or project-based work is required.	The teachers work in their own classes with the available materials and the given organizational framework (including the ordinary schedule).
IBL is not compatible with the requirements of the curriculum and the final exam.	Both the curriculum and the final exams require a great deal of content knowledge. Using lessons for IBL takes time from teaching obligatory contents.	As a first step, IBL units are applied at Level 1 (structured IBL) and deal with prominent content aspects of the curriculum. Additionally, the relevance of the competency model is emphasized.
IBL is neither applicable nor useful in classes with "ordinary" students.	To be able to engage in IBL, students need to have a comprehensive content knowledge as well as advanced practical and methodical skills.	The teachers implement IBL in their own classes with their own students. To consider the students knowledge and skills, suggestions for scaffolding measures are made.

Considering the selected concerns as well as the common features of effective PDP (Capps et al., 2012), we specified the general procedure we aimed for the PDP: The PDP should expand over a period of about 9 months (*Total Time*) and the units designed in the course of the PDP will deal with prominent content aspects of the curriculum (*Coherency*). To ensure compatibility with the teachers' beliefs and daily practice, we agreed to implement IBL units at Level 1 (structured IBL; Blanchard et al., 2010), based on investigations and experimental material the teachers already use in their lessons. In general, the PDP was supposed to engage teachers to design units and material and to apply this in their own lessons (*Developed Lessons, Transference*). The PDP should provide sufficient opportunities to introduce and pursue the teachers' own ideas and interests. Moreover, the teachers should have the possibility to discuss arising questions concerning both content (*Content Knowledge*) and methodical issues and to exchange experiences from classroom practice (*Reflection*). The theoretical framework for IBL was partly adopted from TEMI (characteristic features, instructional goals, levels, 5E model) and supplemented by basic ideas of scaffolding (Hammond & Gibbons, 2005; Quintana et al., 2004).

After having defined the structure and aims of the planned PDP, we determined to conduct an explorative case study in cooperation with three teachers. To align the planned PDP with their demands and expectations, we organized a preliminary meeting. In this meeting, we specified the timeframe, the participating classes and the structure of the PDP. As illustrated in Figure 2, the PDP included three IBL units which were planned and prepared jointly but implemented individually by each teacher, starting in March 2017. Each unit was followed by a meeting where the teachers exchanged their experiences, reflected on the implementation and specified their plans for the upcoming unit.

Figure 2: Research design.

Sample

The three participants are chemistry teachers at grammar schools² in Vienna (Austria). The teachers are female³ and took part in TEMI, in the follow-up group discussion and in the described PDP. All three teachers finished their studies in the field of the natural sciences and have about five years of teaching experience. The classes we selected for the PDP were in grade 11 (Units 1 and 2, standard age ~ 16-17 years) and grade 12 (Unit 3, standard age ~ 17-18 years), respectively, and differed in terms of school type and socioeconomic status (see Table 2).

Table 2: Characterization of the participating teachers and chemistry classes.

Teacher	Professional career	Class	Type of school	Lessons per week
Teacher A	Diploma degree in pharmacy	Regular class, 22 students (50 % female, high socioeconomic status)	Grammar school with focus on language learning	2
Teacher B	Diploma degree in chemistry	Lab course, 12 students (50 % female, low socioeconomic status)	Grammar school starting in grade 9 with focus on science	2 + 1 (lab)
Teacher C	Diploma degree in teacher education, PhD in chemistry	Regular class, 23 students (approx. 40 % female, no particularities)	Grammar school with focus on science	3

Methods of data collection and analysis

Since the literature considers interviews to be an appropriate method for capturing teachers' beliefs and attitudes (e.g. Herrington et al., 2016; Lakin & Wallace, 2015; Luft & Roehrig, 2007), we decided to conduct a semi-structured interview (~60 min) with each of the participants at the end of the PDP (see Figure 2). In this way, we pursued two goals: firstly, we wanted to enable the teachers to describe and explain their statements and secondly, we wanted to have the possibility to request and stimulate the conversation by introducing guiding questions. In order to decrease the teachers' perception of being obligated to answer in a socially desired

manner, the interviews were carried out by a researcher not involved in the PDP. To determine whether and how far the teachers' beliefs and attitudes changed over the period of the PDP, we contrasted the results from the final interviews with those from the group discussion prior to the PDP (see Figure 2).

In order to analyze the data, both the group discussion and the final interviews were fully transcribed. These transcripts were analyzed applying a qualitative content analysis following Kuckartz (2014). Considering the initial findings from the group discussion (see above) and reviewing relevant literature resulted in a couple of questions (see Figure 3, Appendix). These questions served as the basis to develop a tripartite coding scheme considering the teachers' beliefs and attitudes regarding IBL as well as their intentions regarding its implementation (see Table 3).

Figure 3: Development of the tripartite coding scheme from the emerging questions.

Table 3: The tripartite coding scheme.

Part 1: beliefs	Part 2: attitude	Part 3: intentions
Efficacy of IBL	General attitude toward IBL	General willingness to implement
Capability of IBL	Affective disposition	Intentions for implementation
Practicability of IBL	Effort vs. outcome	Already realized implementation

According to this scheme we developed a coding manual which was applied deductively to both the group discussion and the final interviews. Even though we coded all statements of the group discussion ($N = 5$), the further analysis referred only to the statements of the teachers who participated in the final interview ($N = 3$). Due to the complexity of the transcripts (simultaneous talking, referring to others' statements as well as to situations in class) we decided to use the method of peer debriefing (Creswell & Miller, 2000) for validating the analysis. Both the coding scheme and the analysis process were reviewed by at least three researchers external to the study.

Results

The results of the qualitative content analysis are presented following the structure of the coding scheme. Relating to the three parts (Beliefs, Attitude, Intentions) one after another, we contrast the results of the group discussion with those of the final interviews.

Part 1: Beliefs

Beliefs on the efficacy of IBL

Prior to the PDP, the teachers stated that experimenting would be an effective method of chemical education, because the students become active and take part in practical work. However, they questioned whether there would be a difference in the efficacy of experimenting under direct instruction or in an IBL environment. In the final interviews, the teachers suggested that especially the combination of hands-on and minds-on generate added value. In this regard, they emphasized the additional learning opportunities arising from the inquiry process.

Before the PDP, the teachers deemed IBL to be suitable for developing skills, but not for constructing content knowledge. After the PDP, they did not hold this view any longer. They talked instead about developing comprehensive skills as an additional outcome beyond dealing with content knowledge. Apart from this, the teachers still assessed IBL as being particularly beneficial for developing methodical, organizational and social skills, as summarized by Teacher C: *“They [the students] gained a wealth of experience, [and learned] things that do not really concern chemistry, like to recognize connections, to organize themselves, to communicate, to exchange with each other and to document things immediately (...) (03:35–03:52)”*.

The concerns that the students would use their time inappropriately and just a few of them would engage in working and thinking during the IBL units, have not been confirmed – on the contrary – as described by Teacher B (38:37–38:50): *“In all phases of the units (...), it could be seen that all students took part in these things. Normally, that is not the case.”* Nevertheless, Teacher A stressed the need of a permanent assessment as a prerequisite for all effective instructional strategies once more.

Beliefs on the capability of IBL

Previous to the PDP, the teachers considered IBL as being enormously challenging for both students and teachers. As prerequisites for teachers implementing IBL, they named extensive content knowledge and extraordinary methodical skills. On the students' side, the teachers complained about insufficient content knowledge and methodical skills, lacking familiarity with IBL and a poor work ethic.

After the PDP, the teachers made fewer generalized statements. Instead, they provided more specific proposals for how to deal with the available knowledge and skills. In doing so, they emphasized the importance of gaining experience with IBL for both students and teachers. Teacher C explained: *“One has to practice specific settings or processes again and again. It needs to become a routine (44:52–44:58)”*. Moreover, she recommends young colleagues to start with IBL at Level 1: *“When you have implemented IBL for two or three times and you are able to assess your students' abilities, you can go one step further (35:27–35:34)”*. According to the teachers, the students successively acquire the required methodical skills and familiarize themselves with IBL quickly.

The teachers find it difficult *“to design investigations in such a way that it [the process of gaining findings] really works (Teacher B, 20:48–20:53)”*. It is challenging for them to properly assess their students' knowledge and skills and to anticipate the actions they perform in the course of an inquiry process. Aligning IBL units with the students' capabilities, however, is regarded as decisive for the success of IBL. This requires knowledge of inquiry processes and instructional strategies as well as a certain degree of creativity on the part of the teacher.

Beliefs on the practicability of IBL

Before participating in the PDP, the teachers named several obstacles for IBL: the rigor of the curriculum, the inappropriate organizational framework, the lack of resources etc. After the PDP, they considered IBL as an effortful, but practical instructional approach. They clarified that IBL can be realized in regular lessons to some extent. *“Well, it is not the case that you cannot do anything (Teacher C, 55:58–56:03)”*. Factors limiting the frequency of implementation, include, they named the time needed for preparing and applying IBL, the requirements of the curriculum and the final exams as well as the openness of IBL. A higher age of students, a small group size, blocked units, additional lab courses and a higher amount of instruction (e. g. IBL at Level 1) are deemed to be advantageous for implementing IBL in regular chemistry classes.

Part 2: Attitude

Teachers' attitude toward IBL

Before the teachers had implemented IBL in their own classes, they queried whether IBL creates an added value compared with direct instruction. Teacher A (23:50–24:02) stated: *"I cannot say how much they [the students] know afterwards, whether they effectively know more than usual (...) but I do not really expect even more knowledge."* The teachers had the opinion that students enjoy conducting hands-on laboratories, but dislike analyzing and interpreting data from investigations. Nevertheless, they agreed that instructional strategies such as IBL would be important to make the students think and question.

After the PDP, the teachers particularly stated their own pleasure when implementing IBL. They liked to see their students working and thinking intensively and appreciated the additional learning opportunities emerging from IBL, such as discussing the methods, procedures, reliability of data etc. Apart from this, the teachers were still convinced that their students would prefer traditional labs as they would be much less exhausting for them. Moreover, two of them raised concerns about the teachers' lack of courage to get involved in situations in which they do not have answers to all the questions possibly arising.

Is IBL worth the effort?

In the group discussion, the teachers agreed that IBL would be a desirable instructional approach, however, the extra effort would be disproportionate to the efficacy of IBL. This conclusion from the group discussion was relativized by the teachers in the final interviews. They still considered IBL as a challenging and effortful instructional approach, but they acknowledged that the beneficial effect on students' involvement, learning and attitudes outweighs the extra effort. Teacher C admitted that, within the 'usual' setting, *"it probably takes only half of the time, but again, they [the students] do not learn only content knowledge (06:38–06:46)"*. In this context, Teacher B (21:08–21:21) stated: *"It [IBL] has to be planned carefully. However, seeing how students approach to the tasks and how they experience this shows that it is worthwhile."*

Part 3: Intentions

Before their participation in the PDP, the teachers proposed to implement IBL units in the framework of science projects as well as in courses especially for interested or talented students – however, none of them had implemented IBL units so far. As a reason for this, Teacher A (37:48–37:56) stated that *"the general framework is not suitable"* and, hence, *"IBL can be applied only in the course of projects"*.

In the individual interviews at the end of the PDP, the teachers stated to plan the implementation of IBL in both regular lessons and additional lab courses. They intend to repeat particularly those units designed in the course of the PDP: *"I will repeat all the things. Now, we have developed all these things anyway, of course I will implement these units again (Teacher C, 51:02–51:08)"*. Two of them had already transferred the designed units (slightly modified in some parts) and instructional strategies to several of their other chemistry classes. Furthermore, the teachers asserted having in mind the idea to successively rearrange some of their already existing units and materials towards IBL, like explained by Teacher B (09:01–09:14): *"Now is the time for extending the repertory successively. (...) Adding new things and slightly changing the program according to this method [IBL]"*.

Discussion

In this study, we analyzed three chemistry teachers' beliefs and attitudes regarding IBL and, based on this, we developed a PDP following the "common features of effective PDP" by Capps et al. (2012). As the results show, this approach has proven successful and the teachers positively changed their beliefs and attitudes regarding IBL as well as their intentions regarding its implementation. It became apparent that the influence of a teachers' attitude on their intentions and practice is dynamic and cyclical and involving teachers immediately in implementing IBL in their own classes (practice) may be effective to subsequently change their attitude, intentions and practice.

After the PDP, the teachers did not longer consider IBL as a contradiction to secondary chemistry education, but as an important and valuable instructional approach. They assumed IBL to be an effortful but worthwhile instructional approach and stated to continue the implementation of IBL in their own classes. Contrasting the

results from the group discussion and the final interviews showed that participating in the PDP decreased the teachers' uncertainty regarding the implementation (capability and practicability) of IBL as well as their concerns regarding its efficacy. The "importance of seeing students learn through inquiry experiences" (p. 268) is also one main finding of the study by Lotter et al. (2016). Experiencing ways to deal with their students' knowledge and skills as well as with the prevailing conditions made the teachers talking rather about challenges than about obstacles when implementing IBL.

Miranda and Damico (2015) conducted a study in which science teachers engaged in research projects (*Authentic Experience*) and participated in a one-year professional learning community thereafter. The PDP was similar regarding several features of effective PDP (Capps et al., 2012) and the authors state that the participants were able to positively change their beliefs. However, the changes in their practice were rather meager. When discussing the results, Miranda and Damico (2015) suggest to guide and support teachers in the course of PDP, especially when planning IBL units for higher level science courses. This is possibly one of the main reasons why the participants in this study did not only change their beliefs and attitudes, but also their intentions and practice. Capps et al. (2012) identify a lack of studies focusing on the features *Develop Lessons* and *Transference* as well. Moreover, the opportunities for exchanging, discussing and reflecting with colleagues seems to be another crucial factor for the success of PDP regarding IBL (cf. Lebak, 2015; Lotter et al., 2016; Wong & Luft, 2015). Clarke and Hollingsworth (2002) illustrate the complex interaction between enactment and reflection in their interconnected model of professional growth and emphasize the importance of collaborative groupwork in this context.

Despite these positive developments we identified some obstructive beliefs that are persistent in the teachers' minds: The teachers consider only the content-related aspects of the curriculum – skills and competencies still play a minor role. Because of this perception, the teachers identified the rigor of the curriculum as one of the major obstacles for implementing IBL regularly into their chemistry classes (cf. Miranda & Damico, 2015; Lebak, 2015). Moreover, the model of the all-knowing teacher was prominently represented in the teachers' minds. One factor they considered as challenging when implementing IBL was being prepared for various questions emerging over the course of an IBL unit.

In the final interviews, the teachers mentioned that they had no opportunities to gain experience with IBL or inquiry in their studies (with the exception of the research project in the PhD study of Teacher C). This is consistent with the findings of Wong and Luft (2015) and the claim of Herrington, Yezierski, Luxford, and Luxford (2011), in which they state that "yet most high school chemistry teachers did not learn science through investigation, but rather by sitting in lectures and participating in 'cookbook' laboratory experiences". Thus, it is hardly surprising that teachers refrain from implementing IBL. As Teacher B stated, it requires courage to apply an instructional approach that is totally unfamiliar to both the students and the teacher.

Like for every instructional strategy, the ability to deal with IBL depends on the teachers' individual knowledge, skills, beliefs, attitudes and experiences. The results of this study indicate that Teacher A, who has no degree in education or chemistry, faced many more challenges than the others. Particularly the lack of pedagogical skills (lesson planning, classroom management etc.) seems to have a large impact on the attitude, intentions and practice regarding IBL. Additionally, Lotter et al. (2016) highlight the impact of the teachers' self-efficacy beliefs for implementing IBL. This also appears in the statements of Teacher A and Teacher B who both confessed that they feel uncomfortable when imagining situations in which they themselves do not know the correct procedure or answer.

Due to the design of this study, the findings of this article have to be seen as explorative. Firstly, the participating teachers can be regarded as especially committed and enthusiastic. Secondly, they dealt only with commonly developed IBL units at lower levels. It ought to be examined how greatly the PDP influences the teachers' daily practice or if they just keep applying the already developed units. However, as Herrington et al. (2011) state: "for a teacher who does not use any inquiry activities in their classroom, including two new activities should be considered an advance". Additionally, it remains open to what extent the specific design of the PDP influenced the teachers' beliefs and attitudes.

Conclusion

This article aims to show how far a collaboratively designed PDP changed the participating teachers' beliefs and attitudes regarding IBL and its implementation in their own chemistry classes. After participating in the PDP, the teachers had a much more differentiated view of IBL. Instead of stating whether or not IBL is an effective, capable or practical instructional approach, they explicitly named aspects which facilitate or complicate and promote or inhibit the implementation of IBL, as well as strengthen or weaken its efficacy. The results show that supporting teachers in planning, implementing and reflecting upon IBL units enables them to become familiar with both the processes of inquiry and the implementation of IBL as an instructional approach. Moreover, the

findings underline the importance of PDP, which support the teachers when they gain experience in their own classes and under the conditions prevailing at their schools. Contrasting the present findings with data from other studies shows that the features *Develop Lessons*, *Transference* and *Reflection* (in peer groups) seem to be especially beneficial for changing teachers' beliefs and attitudes regarding IBL positively and, perhaps, they even outrank the features *Authentic Experience* and *Total Time*. In a next step, we strive for examining the impact of this PDP on the participating teachers' knowledge and skills through analyzing the audio and video data from the implemented IBL units.

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Notes

- 1 TEMI (Teaching Enquiry with Mysteries Incorporated) was a project under the Seventh Framework Programme (FP7) of the European Commission (Grant Agreement N. 321403), term: 2013–2016.
- 2 Austrian grammar schools usually start in grade 5, but there is one specific form which starts in grade 9. Both types end in grade 12 with the final exam, which allows the students to begin an undergraduate degree at a university. Chemistry is not a compulsory subject for the final exams; the tasks are not standardized, but compiled by the teachers.
- 3 About 75 % of Austrian teachers are female (Bundesministerium für Bildung und Frauen (BMBF) [Ministry for Education and Women], 2015).

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