PROFESSIONALISING TEACHERS FOR INQUIRY-BASED SCIENCE EDUCATION - CHALLENGES AND LIMITS

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Even though inquiry-based science education (IBSE) has been considered as an indispensable element of contemporary science education, science teachers still refrain from implementing it in their own classes. One of the reasons teachers name for that is that they themselves would not feel confident enough to implement IBSE on their own – even after having participated in a respective professional development (PD) programme. An empirical review has shown that most of the offered PD programmes especially lack elements like authentic inquiry experiences or practicing lesson development. In this study, we present a PD programme, which focuses on lesson development linked with in-depth reflection and, in this way, strives for bridging the gap between theory and practice. Collaborating with three chemistry teachers, we examined what challenges we – as teacher educators – faced when planning and conducting this especially designed PD programme. Moreover, we investigated how far an "ideal" PD programme is realisable under the prevailing conditions and what boundaries teacher educators encounter in this context.

Keywords: Continuing professional development, Inquiry-based teaching, Instructional design

INTRODUCTION

For more than 10 years, elements of IBSE have been incorporated in the Austrian science education standards for grade 8 (BIFIE, 2011) as well as in the curricula for chemistry at lower (BMUK, 2000) and upper secondary schools (BMB, 2016; bm:bwk, 2004). Nevertheless – similarly to many other countries (Capps, Shemwell & Young, 2016; Crawford, 2014; DiBiase & McDonald, 2015; Engeln, Euler & Maass, 2013) – IBSE has found its way into Austrian science classrooms only rarely until now (Hofer, Lembens & Abels, 2016). Reasons teachers name for this are that schools would lack of sufficient resources (time, equipment, spatial resources etc.), the appropriate organisational framework (flexible schedules, project-based approaches etc.) and that IBSE would not be compatible with the requirements of final exams. Moreover, Austrian teachers argue to not be appropriately prepared to apply IBSE to their own science classes without further support (Hofer, Abels & Lembens, 2018; Hofer et al., 2016; cf. Anderson, 2002; DiBiase & McDonald, 2015; Wallace & Kang, 2004).

An analysis of the PISA 2015 results, however, revealed the consequences of this insufficient implementation practice. Austrian students are lacking inquiry skills, especially of those belonging to the procedural and the epistemic domain (Suchan & Breit, 2016). Furthermore, students' statements indicate that science education in Austria still focuses on transferring knowledge rather than on working on problems and developing inquiry skills.

To prepare teachers for implementing IBSE in their own science classes, Capps, Crawford and Constas (2012) suggest developing PD programmes according to the following nine 'critical features of effective PD': *Total Time*, *Extended Support*, *Authentic Experience*, *Coherency*, *Develop Lessons*, *Modeled Inquiry*[1], *Reflection*, *Transference* and *Content Knowledge* (see Table 1). Capps et al. (2012) gained these features from examining literature with regard to PD in both the fields of general education research (Darling-Hammond & McLaughlin, 1995; Desimone, 2009) and of science education research (Garet, Porter, Desimone, Birman & Yoon, 2001; Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003; Penuel, Fishman, Yamaguchi & Gallagher, 2007). Besides findings from empirical studies, they also included the suggestions given in the teaching standards, one part of the National Science Education standards (National Research Council, 1996, 2000), when creating their list of 'critical features'.

Table 1. Critical features of effective PD programmes for IBSE (Capps et al., 2012, p. 298).

Feature	Description of feature
Total Time	Amount of time allotted for the programme
Extended Support	Programmes providing sustained support for teachers over an extended period of time
Authentic Experience	Programmes in which teachers conduct their own inquiry study
Coherency	Programmes that align with standard documents
Develop Lessons	Programmes in which teachers design inquiry-based lessons for use in their own classrooms
Modeled Inquiry	Programmes offering teachers the opportunity to engage in classroom inquiry
Reflection	Programmes in which teachers are given the explicit opportunity to reflect on their experiences
Transference	Programmes in which teachers explicitly discuss about enacting the curriculum in the classroom
Content Knowledge	Programmes that focus on science subject matter and content learning for teachers

Referring to these nine features, Capps et al. (2012) analysed 17 empirical studies dealing with PD programmes for IBSE and found that none of them addressed all of the nine features. Especially the features *Authentic Experience* (5/17) and *Develop Lessons* (7/17) were considered only rarely. The authors therefore assume these two features being the "missing link in helping teachers enact inquiry-based instruction in their own classrooms" (p. 306). Based on this assumption, they recommend modifying or extending already existing PD programmes in such a way that they particularly emphasise these two features.

In the following, we present a PD programme, which emphasises the feature *Develop Lessons* (one of the two underrepresented features) and links it with in-depth reflection (*Reflection)*. After having briefly outlined the design of the PD programme, we discuss the difficulties we encountered when developing and conducting this programme. Moreover, we examine how far it is possible to realise an "ideal" PD programme for IBSE – according to the nine features suggested by Capps et al. (2012) – under the conditions prevailing in Austria.

[1] original spelling

THE PROFESSIONAL DEVELOPMENT PROGRAMME

Based on the data and experience gained in the course of the EU FP7-project TEMI (Hofer et al., 2016), we developed a PD programme that aimed at supporting teachers in implementing IBSE in their own science classes. For this purpose, the programme focused on the feature *Develop Lessons*. This includes designing and planning IBSE units and developing and preparing the material required for implementing them. As illustrated in Figure 1, the PD programme encompassed three IBSE units lasting 100 minutes (equivalent of two chemistry lessons) each. In cooperation with three Viennese secondary chemistry teachers, we collaboratively designed and planned the three units. In the following, these units were implemented individually by each teacher in their own chemistry classes (classes in grade 11 for the Units 1 and 2 and classes in grade 12 for Unit 3). Subsequently, a joint meeting was arranged in which the participating teachers exchanged the experiences they made during the implementation in their own classes and reflected on the findings they gained from this unit. Finally, the teachers discussed the implications and started with the planning of the following unit.

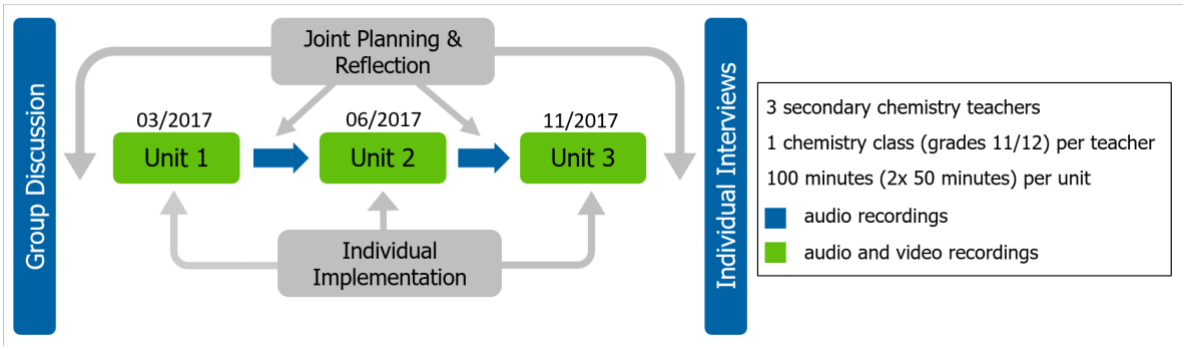

Figure 1. Design of the professional development programme.

In order to identify the emerging challenges and limits, the entire PD programme was accompanied by a continuous collection of data. The statements during the joint meetings (planning and reflection) were audio-recorded and during the individual implementation in the respective classrooms, both audio and video recordings were conducted (see Figure 1). Additionally, field notes were taken and observation protocols were filled in. For the purpose of data triangulation, audio recordings of both a preliminary group discussion and final interviews with the participating teachers were available.

INSIGHT INTO FIRST RESULTS

To discuss the challenges we were confronted with when developing and conducting the PD programme described above, we exemplarily refer to three of the nine 'critical features' proposed by Capps et al. (2012): (1) *Develop Lessons* and (2) *Reflection* (the features this PD programme focused on) as well as (3) *Authentic Experience* (that feature Capps et al. (2012) found to be underrepresented in most PD programmes for IBSE as well). Moreover, we examine how far it is possible to realise an "ideal" PD programme for IBSE – according to the nine features suggested by Capps et al., (2012) – under the conditions prevailing in Austria.

Feature 1: *Develop Lessons*

In the course of the PD programme, it became apparent that the participating teachers required a systematic support. Especially at the beginning, teachers needed to be accompanied step by step when designing and planning units for IBSE. For us as teacher educators, it constituted one of the most challenging tasks to develop (further) teachers' knowledge and/or skills in several areas (subject matter, scientific inquiry, Nature of Science (NOS) / Nature of Scientific Inquiry (NOSI)) simultaneously. Additionally, knowledge about and skills in these areas had to be linked to the general steps of lesson planning (defining goals, planning lessons from "back to front", considering the process of gaining knowledge from investigations etc.). Due to the participating teachers' beliefs regarding IBSE, NOS/NOSI and science education in general (e.g. investigations are not preceded by a question to be answered; hypotheses can be proved by one experiment; after students have conducted an investigation, the teacher explains the results), it took a great amount of effort and persuasion to align the developed units with the 'Essential Features of Classroom Inquiry' (National Research Council, 2000) at some points.

Feature 2: *Reflection*

To allow the teachers to reflect systematically on the experiences when implementing IBSE units in their own science classes, relevant knowledge and skill as well as sufficient time are required. In the course of the PD programme, it turned out that the participating teachers were lacking in both. On the one hand, lacking knowledge and skill regarding planning, conducting, observing and reflecting lessons led to subjective and superficial impressions instead of evidence-based observation and reflection. And on the other hand, teachers had such a tight schedule that reflecting on the implemented unit was only possible at the end of a day – six to eight hours after the respective lessons took place. As a result, teachers just wrote down their first impressions in note form instead of reflecting on their experiences in a profound and systematic way. These incomplete records, in turn, made it difficult for the teachers to introduce detailed information and differentiated descriptions of specific issues in the joint sessions. At this point, it was indispensable having available the field notes taken by the researcher. Referring to these records, teachers had the ability to reconstruct selected situations of the unit.

Feature 3: *Authentic Experience*

Capps, Crawford and Constas (2012) identified – in addition to the feature *Develop Lessons* – especially the feature *Authentic Experience* to be underrepresented in most of the PD programmes they analysed. When attempting to enable teachers to engage in *Authentic Experience*, we primarily faced organisational obstacles. In addition to a lack of time on the part of the teachers, it was challenging to find institutions that were willing to cooperate in this setting. The reasons for this are multifarious. One the one hand, there are legal issues (insurance, disclaimer of liability, non-disclosure agreement etc.) that refrain many institutions from cooperating with teachers in these settings. On the other hand, institutions would need to spend resources in order to accompany and support the teachers; however, they receive no (financial) compensation in exchange for their participation. Beyond this, teachers would need support in order to be able to transfer the experiences they made to their own working environment. Only if they get the opportunity to apply aspects of their experiences to their own teaching strategies, there will be sustained impact to their classroom practice.

Obstacles to realise an "ideal" PD programme

It became apparent already during the design and planning of the PD programme that it is hard to create several of the prerequisites considered being especially beneficial for teacher PD at once. At this point, we are going to discuss two aspects, which result in a situation in which several of the 'critical features of effective PD' are realisable only with difficulty, great effort, or limited scope.

A considerable number of teachers in Austria are allowed to participate only in PD programmes, which are arranged as one-day workshops and/or take place outside teaching time. For this reason, PD programmes that are scheduled to extend over a longer period of time (*Total Time*) and include several full-day and/or multi-day modules are met with little response. Thus, the educational institutions responsible for teacher PD in Austria do not offer long lasting PD programmes already from the outset, reasoning that these programmes would not attract wide interest anyway. Consequently, it is considerably more challenging to conduct programmes that are more comprehensive regarding time (*Total Time*) and overall content (*Content, Knowledge, Authentic Experience*) and thus, support effective and sustainable PD.

Despite the limited duration of most PD programmes, many headmasters allow only one teacher to participate in the same PD offer. For this reason, teachers need to stay in contact with colleagues from other schools in order to make it possible to continue developing their own knowledge and skills in the framework of professional learning communities (cf. Darling-Hammond & McLaughlin, 1995; Garet et al., 2001; Loucks-Horsley et al., 2003). In such communities, teachers would have the opportunity to concentrate on transferring the contents of the PD programme to their own science lessons (*Transference*) and reflect on the experiences (*Reflection*) they gain in the course of application. Depending on professional learning communities outside of a teacher's own school implies a substantially higher effort in terms of both time and organisation.

CONCLUSION

To summarise, conducting the presented study revealed challenges in two main areas: firstly, teachers' prior knowledge, skills and beliefs regarding IBSE and secondly, the framework conditions for teacher PD in Austria. As many Austrian teachers have only little or no experience with IBSE, designing and planning units for IBSE (*Develop Lessons*) constitutes an enormous challenge not only for the teachers participating in the PD programme, but also for the teacher educators who need to support them according to their individual needs. Referring to Capps et al. (2012), the findings from this study would strengthen the hypothesis that the feature *Develop Lessons* could be one "missing link in helping teachers enact inquiry-based instruction in their own classrooms" (p. 306).

Finally, it can be stated that teacher PD in Austria must no longer be regarded as necessary evil, but as an essential element of teachers' professional responsibilities. Only then can we create appropriate framework conditions to realise long-term PD programmes, which build upon one another and, thus, ensure the effective, purposeful and sustainable professionalisation of teachers for IBSE.

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