Professionalising teachers for inquiry-based science education - challenges and limits

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PART 14: STRAND 14

In-service Science Teacher Education, Continued Professional Development

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STRAND 14: INTRODUCTION

IN-SERVICE SCIENCE TEACHER EDUCATION, CONTINUED PROFESSIONAL DEVELOPMENT

Strand 14 of ESERA addresses an internationally increasingly recognized complex field of science education research: in-service teacher education and continued professional development of science teachers. It is obvious that the value and success of any educational system strongly corresponds with the quality of its teachers' competences and practices. In this sense, it is not surprising that the strand on in-service science teacher education is always one of the most active strands of ESERA. Compared to the last ESERA conference proceedings, the number of papers presented in this strand was growing from 10 to 32 pieces.

Again, this edition of the ESERA conference proceedings portrays a singular, interesting array of research pieces addressing actual problems of science teacher education and continued professional development from sometimes similar, but quite often very different theoretical and methodological frameworks. Compared to previous editions of Strand 14 of the ESERA proceedings, we probably find here the most diverse representation in terms of internationalization. The 32 papers included in this section, come from all over the world. There is, on the one hand, a strong European presence with papers coming from research institutions in Austria, Germany, Greece, Ireland, Israel, Italy, Portugal, Sweden, Switzerland and UK. On the other hand, non-European, international presence and collaboration becomes visible by papers from South Africa, South-America (Brazil and Chile), Asia (Japan), Oceania (New Zealand). This collection forms a truly international character and confirms the fact that including research pieces from all over the world is a trend that is gaining momentum in each ESERA edition. We think, the ESERA community will strongly benefit from this global exchange of ideas. The visible internationality and number of papers underlines the increased worldwide relevance of this field of science education research and the need of common work on often similar problems.

Looking at the contents and approaches of studies we can find an interesting spectrum. There are theoretical studies as well as empirical ones, but also studies connected to innovations concerning specific course developments and applications including the investigation of its effects and the possibilities of evaluation of science teaching. That variety demonstrates very well, how the complexity of in-service science teacher education and continued professional development is scientifically approached by the ESERA community.

The theoretical studies at the beginning of this chapter, for instance, investigate and discuss the actual situation of science teaching and teacher education in the mirror of already existing studies and results by examining theoretical standards, focusing the linkage of PCK and practical teaching experiences in STEM teacher education. They investigate competencies required by teachers to ensure progression and continuity in students' learning.

Empirical studies to be found in this chapter deal with the professionalization processes of teachers in all phases of their careers. They look at needs, challenges and possibilities for individual support, in order to ensure progression and continuity including the potential of professional learning communities. In addition, structural challenges in the field of science teacher education are tackled. A number of empirical papers investigate effects of innovative teacher training courses for instance concerning the integration of ICT, and the development of teacher knowledge, beliefs and attitudes toward teaching science.

A larger number of papers communicates developmental activities. In the focus of interest are innovative courses and the investigation of specific variables and effects while applying these courses, mainly looking at teachers' competences and learning communities. The innovations presented comprise for example the initiation and investigation of collaboration between teachers and scientists or the implementation of learning communities.
Another group of studies deals with the transformation of pedagogical practices from didactic to dialogic teaching. There are training ideas addressing the use of experiments and the teaching argumentation.

The last (but not least) part of the chapter presents papers dealing with the development and application of methods and tools of evaluation.

Looking at the selection of papers one will find that the ESERA community within strand 14 tackles important issues in order to support improvement of in-service teacher education and continued professional development of science teachers all over the world.

Manuela Welzel-Breuer & Claudio Fazio

LINKING PEDAGICAL CONTENT KNWOLEDGE AND PRACTICAL TEACHING EXPERIENCES IN STEM TEACHER EDUCATION: A SYSTEMATIC REVIEW OF THE LITERATURE

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Teachers' professional knowledge is considered central to improving students' learning outcomes in science, technology, engineering, and mathematics (STEM) subjects (Abell, 2007; Magnusson, Krajcik, & Borko, 1999). Pedagogical content knowledge (PCK), introduced by Shulman (1986) as a very specific dimension of teachers' professional knowledge, is now a well-established construct in STEM education research. Findings in this research field suggest that teachers with well-developed PCK for teaching STEM subjects are more able to provide effective instruction, and professional development to enhance teachers' PCK in STEM education is now advocated (van Driel & Berry, 2012). Research also shows that teachers' PCK development hinges on professional practical experiences, e.g., classroom teaching (Carlson et al., 2019), inferring that provision of practical experiences in teacher education, which are linked to teachers' PCK can help prospective teachers to expand their professional knowledge (Carlson et al., 2019). However, while PCK features in many studies in STEM education research, empirical evidence that establishes a link between PCK and teaching practice in STEM is ambiguous because these studies conceptualise PCK and practical experiences inconsistently (Wilson, Borowski, & van Driel, 2019). To begin addressing this ambiguity and advance understanding of the link between PCK and teaching experiences, this study seeks to analyse how empirical studies link PCK and practical experiences of (preservice) STEM teachers. The analysis is done via a systematic literature review that focuses on N=97 empirical studies. Results suggest that most studies favour Magnusson's (1999) PCK model as a conceptual framework and almost always include the components 'knowledge of student understanding' and 'knowledge of instructional strategies and representations' in their analyses. The implications of these findings for further empirical research regarding links between PCK and practical teaching experiences are discussed.

Keywords: Pedagogical Content Knowledge, Teacher Professional Development, Teaching Practices

INTRODUCTION

Teachers' professional knowledge for teaching in science, technology, engineering, and mathematics (STEM) subjects has been identified as an important attribute for improving teaching and students' learning outcomes (Abell, 2007; Hume, Cooper, & Borowski, 2019; Magnusson et al., 1999). As a category of STEM teachers' professional knowledge (Shulman, 1986), pedagogical content knowledge (PCK) has been considered a key knowledge form for improving teaching (Hume et al., 2019; Loughran, Berry, & Mulhall, 2012), since it facilitates a transformation of subject matter knowledge into a more comprehensible form that is accessible to students (Shulman, 1986). Authors like Grossman et al. (2009), Magnusson et al. (1999) and Park and Oliver (2008) added refinements to Shulman's PCK construct including, amongst others, components of PCK for effective STEM teaching, i.e., orientations to teaching science (OTS), knowledge of student understanding (KSU/KS), knowledge of instructional strategies and representations (KISR), knowledge of curriculum (KC/CuK), knowledge of instructional strategies (KI), and knowledge of assessment (KA). Other knowledge categories should also be given due consideration for effective STEM teaching, including content knowledge (CK), and pedagogical knowledge (PK) (Shulman, 1986), and more recently knowledge of teaching context (CxK) (Fernandez-Balboa & Stiehl, 1995; Grossman, 1990) as a knowledge of the specific classroom circumstances and the students (e.g., ethnic background and gender composition). It is argued developing applicable PCK in professional development is presupposed upon effectively applying PCK in authentic practical teaching situations (Grossman et al., 2009; Shulman, 1986). Accordingly, some research studies began investigating effective ways for implementing practical teaching experiences in (preservice) STEM teacher professional development that promote development of applicable PCK. For example, the use of Content Representations (CoRes) by Loughran, Mulhall and Berry, (2004) and reflective writing after practical teaching experiences by Hume (2009) were found to be successful ways to make PCK explicit and promote professional development. Unfortunately, to date studies have employed a varied plethora of methods, research designs, and PCK conceptualisations for analyzing links between PCK and practical teaching experiences, resulting in findings that are difficult to integrate and reach consensus.

This paper reports partial findings from a systematic literature review we undertook in an attempt to compare and integrate methods and findings from studies that examine links between PCK and practical teaching experiences in STEM teacher education. In this paper, we address one of the research questions (RQ) from this study: How do STEM studies that link teachers' PCK and their teaching practice conceptualise PCK?

METHOD

The systematic literature review began by explicating the research interest (i.e., what links exist between PCK and practical experiences in STEM teacher education) and browsing through relevant electronic literature databases (peDocs, ERIC, WoS and PsycINFO) using the key terms "(knowledge AND practice) AND (teacher OR teaching OR "teacher education") AND (physics OR chemistry OR biology OR mathematics OR science OR STEM) AND ("Pedagogical Content Knowledge" OR PCK)". Peer reviewed articles from 1986 to 2018 that used a PCK conceptual framework and investigated a link between teachers' PCK and their practical experiences were included. Overall, N=97 studies were retained for analysis. For the data related to the RQ reported in this paper, content analysis was used, such that established PCK models (e.g., Magnusson et al., 1999, Park & Oliver, 2008, and others) formed the initial coding units and formerly unidentified PCK models were added in the process. Interrater reliability, as measured through Cohen's κ, was substantial: $\kappa = 0.93$.

RESULTS

Each of the reviewed studies adhered to one of two broad categories of PCK models as described by Park and Oliver (2008) and Kind (2009): either to more integrative models (N=9; 9.3%) or to more transformative models (*N*=88; 90.7%). The integrative model holds that PCK is comprised of different knowledge categories (and is therefore not in itself a unique knowledge form), while the transformative model considers PCK to be an independent knowledge category (Kind, 2009). In the first group, all studies examined PCK in combination with CK and PK, while KS, CuK, and AK were interspersed at times in these analyses (see Table 1). In the larger second group, almost a third of the studies used the PCK model by Magnusson et al. (1999) (*N*=30, see Table 2). The majority of these studies included all five PCK components, however OTS was most often left out in the minority that used fewer components. Another *N*=36 studies were identified that did not specify a particular PCK model but rather eclectically used different components of PCK, most often KSU and KISR.

Table 1. More integrative PCK models.

Model	*(N=9)*	*CK*	*PK*	*CxK*	*KS*	*CuK*	*AK*
Cochran et al. (1993)	*(N=1)*	*1*	*1*	*1*	*1*		
Grossman (1990)	*(N=1)*	*1*	*1*	*1*		*1*	
Shulman (1986)	*(N=3)*	*3*	*3*			*1*	
Not specified	*(N=4)*	*3*	*3*	*3*	*1*	*1*	*1*
Sum of References		*8*	*8*	*5*	*2*	*3*	*1*

Table 2. More transformative PCK models.

Model	*(N=88)*	*KSU*	*KISR*	*KA*	*KC*	*OTS*
Abell (2007)	*(N=1)*	*1*	*1*	*1*	*1*	*1*
Gess-Newsome (2015)	*(N=4)*	*2*	*4*	*1*	*3*	*1*
Grossman (1990)	*(N=2)*	*2*	*2*		*1*	*1*
Hanuscin et. al (2011)	*(N=3)*	*3*	*3*	*3*	*3*	*3*
Hill et al. (2008)	*(N=1)*	*1*	*1*		*1*	
Magnusson et al. (1999)	*(N=30)*	*27*	*26*	*22*	*22*	*18*
Park & Oliver (2008a)	*(N=1)*	*3*	*3*	*3*	*3*	*3*
Park & Oliver (2008b)	*(N=3)*	*1*	*1*	*1*	*1*	*1*
Rollnick et al. (2008)	*(N=1)*		*1*	*1*	*1*	
Saxton et al. (2014)	*(N=1)*	*1*	*1*	*1*	*1*	*1*
Shulman (1986)	*(N=8)*	*7*	*6*			*1*
Turner-Bisset (1999, 2001)	*(N=1)*	*1*	*1*		*1*	*1*
Not specified	*(N=32)*	*26*	*26*	*7*	*12*	*8*
Sum of References		*75*	*76*	*40*	*50*	*39*

DISCUSSION

The review revealed that studies examining PCK and teaching practice together employ a variety of PCK conceptualisations. Differentiation of studies into those with either an integrative or a transformative perspective of PCK was considered reasonable, where the former applies to a group of studies that view PCK as an integration of different knowledge categories rather than a separate entity, and the latter applies to studies that conceptualise PCK as an independent knowledge category. The group with the integrative perspective of PCK proved to be quite small, while the majority of studies adopted transformative models of PCK, most notably the model by Magnusson et al. (1999). Of particular interest with respect to links between PCK and practical teaching experiences was the finding that KSU and KISR are almost always included in the analyses, which is not surprising given these two components resonate most closely with those aspects of teachers' knowledge that Shulman (1986) originally identified as PCK. In our estimation, these choices for analysis are reasonable when considering the complexity of student thinking and the benefits gained from teachers learning to diagnose students understanding for effective teaching (Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013). In contrast, it was surprising that only a tiny minority of studies included CxK into their analyses. This was surprising because the context-dependency of PCK was emphasized from early on (Grossman, 1990; Magnusson et al., 1999).

Recently, a conceptual framework known as the Refined Consensus Model (RCM) has been proposed that integrates different PCK models (Carlson et al., 2019). We consider the RCM a useful advancement on existing PCK models, because not only does it comprise the most salient features identified in our reviewed studies that link PCK and practical teaching experience, it also recognises and is sensitive to the context-dependency of PCK. As such, the RCM differentiates three realms of PCK to acknowledge that PCK research shared amongst educational scholars is different to the PCK that a teacher holds, and in turn to the PCK that a teacher enacts in the moment of teaching. This differentiation also acknowledges that potentially teachers implicitly know much about teaching (Carpenter, Fennema, Peterson, & Carey, 1988), but may be unable to access this knowledge explicitly when reflecting on and enacting their teaching.

When studying links between PCK and practical teaching experiences, we suggest the following: 1) Since KSU and KISR are widely established focii in PCK analysis and teaching practice it might be opportune to hone in on particular mechanisms in the teaching context that trigger teachers' use of certain KSU- and KISR-related knowledge. Also, developmental trajectories (e.g., from more transmissive to more constructivist instructional beliefs) can be hypothesised and tested. Such investigations were not revealed in our literature review so a possible gap in the research exists, 2) Adopting the RCM in studies investigating links between PCK and practical teaching experiences seems fruitful, in order to determine what the field knows, what teachers in a certain developmental stage know, and how contextual factors might account for episodes where certain PCK is/is not utilised. Linking suitable research methodologies to the different realms of PCK would be beneficial as a next research task.

A more comprehensive summary of the present study is expected to appear in a peer reviewed publication. In that review, we will address further research questions regarding, employed methods, conceptualisations of PCK, the teaching cycle and other aspects. We will also discuss the limitations of such a literature review when investigating relationships between PCK and teaching practice.

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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.

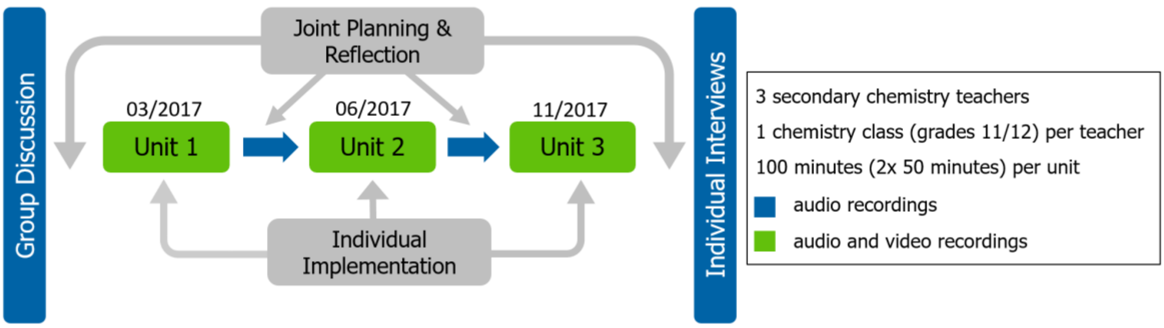

Figure 1. Design of the professional development programme.

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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SCIENCE TEACHERS CONTINUOUS EDUCATION THROUGH THE THREE PEDAGOGICAL MOMENTS

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This study aimed to evaluate the development of a continuous education course structured through the 3 Pedagogical Moments (PMs) with Science Teachers from Uruguaiana - RS, Brazil. The production of data occurred through numerous instruments. We noticed some limitations in relation to the teachers in following the proposal presented in the formative process, as well as in carrying out the implementation of the teaching plans in classroom.

Keywords: In-service Teacher Training, Teaching Practices, Science Education.

INTRODUCTION

It is increasingly essential for teachers to participate in spaces that foster their continuous education, because from these it is possible to promote reflections about their pedagogical practice, with an exchange of knowledge between professionals working in the same modality and educational levels, to reframe their teaching practice.

Researchers from different areas of education and teaching are investigating new ways of conceiving and organizing spaces for continuous education. In this sense, one of the studied proposals for this purpose are the 3 Pedagogical Moments (PM) that were proposed by the Brazilian researchers Delizoicov and Angotti (1994) as a transposition of Paulo Freire's dialogical-problematizing concept of education and that emerged from a dynamic planned to develop themes previously chosen in a science teaching project in Guinea-Bissau.

The 3 PM can be described the following way: the first PM is called "Initial Problematization" where real questions and / or situations that the students know and experience and that are linked to the content to be developed are presented. At this moment, the teacher will encourage discussions about the subject, allowing the exposition of alternative conceptions of students or instigating the understanding of other knowledge. The second PM is known as the "Knowledge Organization" where students will study the contents necessary to understand the theme and the first PM. The third PM is called "Application of knowledge", designed to perform the synthesis of the knowledge incorporated by the student, analysing and interpreting both the initial situations of the first PM and other situations that can be explained through the same scientific knowledge (Delizoicov & Angotti, 1994).

According to Fagundes (2013), the 3 PMs can be used to organize the lesson planning, contemplating current reality themes, allowing the contextualization of science teaching. On the other hand Muenchen (2010) and Giacomini and Muenchen (2015) mention that the 3 PM, beyond being used as didactic-pedagogical dynamics in the classroom, to build programs and curricula, can also be used to structure training processes, as long as changes are made to meet this proposal.

To work with the 3 PMs, it is necessary be present a theme in focus that is relevant to the social context in which it will be developed. In this sense, medicinal and toxic plants can be a possible topic to be used in science education, since according to data from the World Health Organization (WHO) 85% of people worldwide use these vegetables to treat diseases (Teixeira et al, 2014). Regarding Brazil, according data from the Ministry of Health, in the period from 2013 to 2015, the demand for treatments using medicinal plants and herbal medicines by the Sistema Único de Saúde (SUS) has more than doubled: a 161% growth was recorded (Portal Brasil, 2016). Besides that, the Sistema Nacional de Informações Tóxico-Farmacológicas (SINITOX, 2016) registered 363 cases of poisoning by plants in Brazil in 2016, and that 350 of them occurred in urban areas. It may seem like a small quantity of poisoning cases, taking in consideration the size of the Brazilian population, the problem is that many cases of plant poisoning are not even known.

If an analysis by Brazilian states is made, it will also be possible to check the presence of these vegetables in daily life, such as in the State of Rio Grande do Sul (RS), in which the population uses a variety of medicinal plants, for the most distinct therapeutic purposes (Dávila, 2011). One of the municipalities in which the use of numerous medicinal plants is verified is the city of Uruguaiana, in the border between Brazil and Argentina, according to the ethnobotanical study by Galvani and Barreneche (1994). In this same municipality, there were also several cases of intoxication by vegetables, as shown in the work of Dávila et al (2008) from their ethnobotanical study regarding toxic plants in the city of Uruguaiana - RS.

According to Silva and Santos (2017), the school represents an important space for the dialogue between popular knowledge and the concepts addressed in class, in addition to exercising the role of valuing students' personal experiences. Through the students popular knowledge, the teacher can (re) discover and (re) build knowledge necessary for scientific and technological literacy (Chassot, 2006).

However, has been seen throughout Brazilian academic productions in the Science Education area, that teachers encounter difficulties and / or feel insecure about the use of other teaching strategies. One way of solving this problem can be through the use of continuous education of teachers, since from these spaces you can promote reflections about pedagogical practice, with exchange of knowledge between professionals working in the same modality and educational level, reframing their teaching practice.

This study proposes to evaluate the development of a continuous education course structured though the 3 PMs, where the Toxic and Medicinal Plants theme in association with the 3 PMs was addressed, verifying the potentialities and challenges of a formative process in this format.

MATERIAL AND METHODS

The subjects involved in this investigation were 30 science teachers from the municipal education network of the city of Uruguaiana - RS, Brazil (Image 1). The choice of the study subjects was intentional, since it were the teachers at this location that asked the first author to develop a continuous education course with them. From this interest, an initial analysis of the conceptions of these teachers about science teaching was made in order to structure the course (Dávila, Folmer & Puntel, 2017).

Image 1 – Location of Uruguaiana - RS.

Source: G1 (2011).

The initial idea was to carry out a training process within the monthly meetings of pedagogical training offered by the Secretaria Municipal de Educação (SEMED), to be developed throughout the year, with periodic meetings. However, due to the annual planning of the pedagogical training of this institution, two meetings were authorized and granted. For this reason, the course consisted of two meetings, each lasting four hours, with an interval of two months between them so that the teachers had time to apply the teaching plans in a school context.

We developed a continuous education course, structured though Delizoicov and Angotti's (1994) 3 PMs, as described in the table below.

Table 01 - Continuous training course organized methodologically through the 3 PMs developing the contextualization theme "Medicinal and Toxic Plants" in association to the 3 PMs.

3 Pedagogical Moments	Description
First PM: Initial Problematization	Presentation of the course structure to situate the teachers. Application of initial questionnaire. Questionings regarding the subjects of the course to problematize it.
Second PM: Knowledge Organization	Expositive and dialogic Presentation of the current reality of science teaching; presentation of data from the dissertation in relation to the academic production in the area of science education; explanation of the results obtained with the participating students in the "Medicinal and Toxic Plants" workshop , showing the evolution of the students' answers and drawings regarding Botany and the theme. Explanation of the 3 PMs theoretical references (who they are and how they are organized), using as reference the books "Metodologia do ensino de Ciências" (Delizoicov & Angotti, 1994) and "Ensino de Ciências: Fundamentos e Métodos" (Delizoicov, Angotti & Pernambuco, 2011). Explanation and discussion about the use of themes in classroom, using for that purpose the official Brazilian documents that govern the Elementary School Final Grades (Parâmetros Curriculares Nacionais (PCN, 1998) and the Diretrizes Curriculares Nacionais (DCN, 2013)).
Third PM: Application of knowledge	Elaboration of structured teaching plans in the 3 PMs to develop the "Medicinal and Toxic Plants" theme in a class of their school (realized in the first meeting). In the second meeting, two months after the formative process, the results of the application of the teaching plan were presented in the form of a "Pedagogical Experiences Sharing Seminar".

Source: the author

The final activity (Pedagogical Experiences Sharing Seminar) was recorded and teachers were invited to participate in a semi-structured interview to present their testimony about this pedagogical experience faced in the course of continuous education.

As for the data analysis methodology, we adopted Content Analysis by (Bardin, 2011). For this analysis a triangulation of the data obtained by the different instruments (field diary, questionnaires, teaching plans and semi-structured interviews) was performed.

RESULTS AND DISCUSSION

From the 30 teachers invited, 14 female teachers took part. All with initial formation in their work area, three of them with specialization, with length of professional experience varying from 1 to 20 years.

We noticed that the first PM of the course provoked concerns, a lot of discussion of the topics selected for the continuous education, with reports of situations that occurred in the classroom during their teaching time. It was interesting, because it provided dialogue between the researcher and the teachers with different time amounts of experience in teaching. This dialogue between the subjects involved in the process was also verified by Giacomini and Muenchen (2015) when working with a group of teachers from different areas of knowledge in a formative process also organized through the 3 PMs, considering that the dialogue was mobilized by the teachers' reflection and action.

In the second PM when addressing the scientific knowledge needed to understand the use of the theme and the 3 PMs in the classroom, there was interest in the subject, questionings being conducted when some point of the theoric referential had not been well elucidated.

In the execution of the third PM, some challenges and limitations for the present study appeared. The first challenge was due to the concern of teachers in continuing the curriculum of the school year of the class where the teaching plan of this course that would be developed, because for them, to subordinate the content to the theme, would mean developing a work in parallel and they did not agree with that. A similar occurrence was seen in the reports of Muenchen (2010) interviews with the trainers of the continuous education courses in the municipality of Santa Maria - RS, Brazil, being one of the reasons that some course planning had a more conceptual than thematic focus. This demand was tried to be met, even knowing that this fact could increase the chances of use of the subject only as an example, illustration or a pretext to continue the programmatic contents of that school year, as pointed out by Wartha, Silva and Bejarno (2013).

The second challenge concerns the difficulty of the teachers to relate the theme of the course to any area other than Botany, showing again that they were trying to associate it to school content and not to explain the theme with the necessary scientific knowledge.

The third challenge of the third PM refers to the few teachers who finished the course, of the 14 participants; only seven teachers implemented their teaching plans.

The fourth challenge is linked to the previous one, because it was found that no teacher was able to develop the proposal of the continous education course, classifying the teaching plans (presented at the Experience Sharing Seminar), into three categories:

1st) Subtheme associated with the 3 MPs: within this category were included the works that approached the proposal of the continuous education.

2nd) Subtheme only: activities that used a sub-theme of the theme presented on the course.

3rd) Did not perform as instructed in the course: works that explored neither the theme nor the 3 PMs, but used the theme as an additional classroom task.

In the first category, two teaching plans were contemplated, from a teacher (called P1) who worked in a rural school and the other from a teacher (represented by P2) acting in a school located in a socially fragile area of the city.

Both plans have in common the approach of subthemes, chosen by the teachers, related to the theme presented in the formative process. The teachers understood that they could do it this way because they needed to adapt it to work with the content envisaged for that school year, in which hey had chosen to implement the activity of the training course. It is noticed that the use of themes was subordinated to the syllabus of that year and not the opposite, as is recommended by Delizoicov, Angotti and Pernambuco (2011).

The teachers addressed subthemes that were part of the students' reality, that besides contemplating the specific programatic contents of that year, had cultural issues, social problems and that had the potential to motivate further study by the students.

When comparing these data with the classification used by Silva and Mortimer (2010) when developing the conceptual, contextual, phenomenological and epistemological aspects of chemical content in the classroom, it is suggested that the teachers of this investigation, to chose subthemes from a contextual dimension, because they aimed to approach scientific content with a social, technological, environmental or historical context.

Next, the teaching plans of teachers P1 and P2 are described.

Teacher P1's teaching plan – Subtheme: Drugs derived from toxic plants and their effects on the nervous system

1st PM – Awareness: Videos about drugs, their effects on the nervous system, the risks to the body, and withdrawal crises were used and after that there was a talk to discuss.

Establish relationships between drugs and their effects on the nervous system: class discussion, and notes on the subject.

2nd PM – Explanation and notes on the nervous system, its anatomy and physiology; visualization in models and boards of the main organs and functions.

Group research on the main plant-derived drugs, their effects on the nervous system and the effects of withdrawal.

3rd PM – Organization of data and construction of information panels on the main plants that give origin to legal and illegal drugs and their main effects on the body.

Presentation of the work carried out to classmates in the form of seminars.

Resumptiom of the videos of the 1st PM.

Discussion of some questions.

Explaining though the use of scientific knowledge.

Teacher P2's teaching plan – Subtheme: Mate Herb

1st PM – Questions and discussion about where the Mate Herb they buy from the market comes from.

2nd PM – Historical, cultural and geographical approach to Mate Herb.

Before introducing scientific knowledge of sciences, students had to answer a questionnaire that contained the following questions: “Do you have the habit of drinking mate?; How many times a day do you take mate ? Do you know any benefits of mate? Do you know any harm of mate?”.

Students had to apply this questionnaire to 15 people in their neighborhood and bring the data in the next class.

Creation of graphics with the data collected from the questionnaires.

Discussion of results.

Approach of the questions and answers of the questionnaire with the contents of the human body.

3rd PM – Application of recreational activities (crosswords, question-and-answer game related to the theme, memory game) to students as a way of evaluating the subject.

Regarding the second category “Subtheme only”, was composed by only one teaching proposal. The teacher (represented by P3) launched the theme in the classroom to reflect on it, because according to her, already worked with themes in the classroom, but the students chose them. By developing in this way with the theme “Medicinal and Toxic Plants”, students ended up leading the approach to “Energy”, because they were interested in the process of photosynthesis.

In the last category, four teaching proposals were included, that used the theme “Medicinal and Toxic Plants” as a complementary task to the content that had been addressed by the teachers, in which students should conduct a group research on the subject and after that, present it to the class in a seminar format. All teachers in this category have claimed that the time was a limiting factor to implementing their planned activities.

The activities carried out by each teacher are identified below:

Teacher P4 – from the theme proposed in the training course, she extracted a subtheme of it to carry out a work complementary to the content of human physiology. The chosen subtopic "Substances extracted from vegetables: Caffeine and THC (extracted from marijuana)" was due to an association with the History teacher who wanted to deal with the subject of Coffee. The activity developed by the students corresponded to the elaboration of a folder and a parody, both about caffeine and THC. Four questions were given to guide the work: "what were the drugs Caffeine and THC?"; "where they were found?"; "what are the effects of these drugs on the human body, both beneficial and harmful?" and "a curiosity about these drugs". The history teacher asked for the history of coffee. Students had to present these activities in the classroom.

Teacher P5 - Had the understanding that she should approach the concept of a plant and its structures before the theme, therefore, the demonstration activity was developed before, but even so, she did not finish her planning, went no further than the proposal that will be described. She took a plant and asked the students to observe it and compare what was there of similarities and differences with the human body. Soon after, she placed a plant in water with dye and another plant in a container with water without dye and asked them to observe and write what would happen to the plant that was in the dye. The students made graphs of the hypotheses of what would happen to the plant that was in the dye. After a few days, they looked again at the plant that was in the dye and wrote down the reasons for the vegetable to be showing colored petals, which were initially white. The students made assumptions regarding photosynthesis, that the plants had a "small pipe". After this practical activity, she made a comment in in the classroom about what medicinal plants were and which could become toxic and from this moment on she was unable to carry on working with medicinal and toxic plants.

Teacher P6 – She covered with the students the content of plant morphology to later address the theme, as she believed that students needed prior knowledge to later study the theme. She developed a research activity related to medicinal and toxic plants, that she had found in the textbook, with the students. After researching it in pairs, they had to present it in the classroom.

Teacher P7 – Divided the class into groups and each had a topic about plants (terrarium assembly; plant experiment in the dark; conducting vessels; plant reproduction; root development; germination) and a group with medicinal and toxic plants. The teacher, as well as the others in this category, believed that the students should first have a theoretical background in botany, because she considered her students immature, in the sense that they had no idea what a plant is.

When interviewing teachers about the elaboration and execution of teaching plans, it was found that the teachers had difficulties during the time allotted for this activity. The first one was related to the time to execute the teaching strategy in the classroom. It was found that two months had been a short time to implement their teaching proposal with the students. This hindered the development of plans as discussed in the continuous education course, leading all teachers not to implement the theme “Medicinal and Toxic Plants”, but to unfold it in subthemes and depending on the teacher, to approach it from the 3 PMs or not. This difficulty of lack of time to organize, plan and implement the teaching plan may be linked to the current conditions of teaching work, as evidenced in the study by Donatelli and Oliveira (2010) with basic education teachers in RS.

Another factor present in the teachers' statements that may have limited the execution of the teaching strategy in a satisfactory way: the current curricular organization in schools, which developed a feeling of imprisonment to school content among teachers, becoming a challenge for the implementation of the theme from the perspective of the 3 PMs, limiting the investigation of the potentialities of the proposed theme.

It may be that in this study, the short duration of the training process has failed to change teaching practice. Sauerwein (2008) emphasizes that courses with this characteristic may not allow the increment of this in the permanent education of the teacher, perhaps using it for a short time in their pedagogical practices. However, Neto (2014, p. 13) points out that although this training format “does not seem to offer enough time for the processes of understanding and acceptance to materialize, they are important as they present alternatives, they motivate, they show ways of how, why, where and when to use a particular activity”.

It can also be seen through the interviews, that even teachers did not use the theme as initially proposed in the training process; positive results were obtained regarding the implementation of teaching plans. Although the theme was unfolded in different sub-themes or developed as a complementary activity to the sequence of contents that the teachers were addressing, if it succeeded in instigating the students' curiosity, giving subsidies to promote a dialogue between teacher - student, student - student and between popular knowledge and scientific knowledge. Moreover, through these plans, it can be ascertained that contents and developments can emerge from the theme “Medicinal and Toxic Plants” and serve as a subsidy for future planning, where the theme can be seen as the object of study that disciplinary contents are organized from, opening possibility for an articulation of the different areas of knowledge to work around a common objective.

FINAL CONSIDERATIONS

It was found that the formative process presented did not allow teachers in the 3rd PM to elaborate and execute teaching plans in which the school content was subordinated to the theme, requiring a continous education course like this, which is structured in 3 PM, to be developed with a longer duration and longer meetings, giving a greater support to teachers. However, it provided, as far as possible, the discussion of the pedagogical praxis of teachers as well as a greater interaction between university and school, offering a space for sharing knowledge and getting closer to the academic material.

Another aspect that may have interfered with the success of the 3rd PM was the teaching conception and curriculum of the teachers in this study, as they were shown to be “imprisoned” to the school contents of the current curricular organization of school..

Even with the challenges faced in this continuous education, teachers were active subjects in this training process, in which their concerns, teaching knowledge and doubts were heard and discussed, through the promoted dialogue, in addition to bringing the subjects involved to reflect on their pedagogical practices, studying a different teaching methodology and trying to develop a teaching plan different from their usual.

The theme "Medicinal and Toxic Plants" allowed immersion in different social contexts, as seen in the work implemented by the teachers, but it is believed to have a much greater potential if we have public policies giving subsidies to have greater curricular flexibility in school institutions.

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THE TRANSITION FROM PRIMARY TO SECONDARY SCHOOL IN SCIENCE EDUCATION

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In science education, there are serious concerns about continuity and progression in students' learning at key points of transition especially during the transition from primary to secondary school. National and international studies show a lack of progress in students' learning as well as their loss of interest. One of the key issues seems to be a lack of teachers' competencies. Therefore, the aim of this study is to identify competencies required by teachers to ensure progression and continuity in students' learning. For this purpose, a Delphi survey is conducted which includes different experts related to the transition process in science education. In addition, guideline-based interviews with 5th grade students, who recently experienced the transition, will be used to capture the students' perspective. In a preparatory study, transition-related activities were derived deductively from the literature and summarised within a category system. The six main categories Knowledge of Curricula in Science Education, School Environment & Organisation, Assessment, Teaching Styles & Approaches, Cooperation *and* Empathy for Students' Transition Process *were used to structure and analyse the first round of the Delphi survey. First results show that experts demanded competencies in all these six categories.*

Keywords: Primary School, Secondary School, Teacher Professionalism

INTRODUCTION

In Germany, the education system is characterised by a number of transitions. The transition from primary to secondary school represents the first change that all students usually have to pass after the fourth grade at the age of 10. In particular, this transition is associated with changes within social, instructional as well as organisational aspects that might have an impact on students' learning (Ophuysen, 2009). With regard to science education, there are serious concerns about continuity and progression in students' learning related to the transition process.

Science Education in the Transition from Primary and Secondary School- Status Quo

In Germany, the transition from primary to secondary school is accompanied by differences in subjects' structure, teachers' education, as well as teaching styles. In primary school there is an integrative subject combining both natural and social sciences (called "Sachunterricht"; GDSU, 2003). That is why teachers at primary school need a broad (pedagogical) content knowledge in natural and social sciences. Therefore, they are known to be generalist teacher (Möller, 2014), often teaching subjects they did not formerly study themselves. In contrast, in secondary school, there are different science subjects (e.g. physics, biology, chemistry, geography and technology). Teachers of secondary schools are known to be specialist teacher (ibid.), due to their focus on one or two of those subjects. Furthermore, primary school's science education seems to be more student-centred including practical science, whereas secondary school's science education appears to be more teacher-centred (ibid.).

Difficulties associated with the transition process are investigated not only in Germany. International and national studies prove that there are key issues related to the transition from primary to secondary school, which affect students' learning (e.g. Galton, Gray, Rudduck, 1999, 2003; Ophuysen, 2009). In science education, studies across several countries indicated that students fail to manage the transition from primary to secondary school (Braund, 2008a; HMIe, 2005; Möller, 2014). In addition, there is also evidence that students' interest decline in the early years of secondary school. Especially in science education, various studies show the decline in subjects like physics (Walper, 2014). Moreover, the loss of interest when compared with students' interest at the end of primary school is worse in science than in math (Heine, Willeke, Best & Pospiech, 2013).

One of the key issues seems to be the lack of teachers' competencies. As a "co-constructive process" (Griebel & Hiebl, 2010, p. 18), primary and secondary school teachers must be capable of supporting a transition that ensures students' cumulative learning. Hempel and Maltzahn (2012) state, that primary and secondary school science teachers often are unfamiliar with each other's curricula. Moreover, secondary school science teachers are insecure of what to expect from their new students recently graduated from primary school. They even rate the primary school students' prior knowledge in the natural sciences to be quite low (ibid.) although there is no evidence. Instead, Dalehefte and Rieck (2014) indicate that primary school students learned scientific methods and possess a basic knowledge in sciences that are in line with the curriculum at secondary schools. Moreover, Hempel and Maltzahn (2012) point out that secondary school teacher often fail to refer to students' prior knowledge and learning experience. Racherbäumer and Kohnen (2014) declare that the diagnosis of prior knowledge at the beginning of the fifth grade is a rare exception, especially in natural science subjects. Galton, Gray and Ruddock (1999) as well as Braund and Driver (2002) state that teacher of secondary school distrust the students' levels of attainment that they have been assessed in the primary school. Moreover, it is their justification to "still cling to the principle of the 'fresh start'" (Galton, Gray, & Ruddock, 1999, p. 6). Therefore, basic skills and procedure as well as topics are often full repeated in secondary school (Braund, Crompton, Driver, & Parvin, 2003). Various models explaining the importance of teachers' competencies due to their influence on the quality of the transition process (Griebel and Hiebl, 2010; Ophuysen, 2005; Ophuysen & Harazd, 2014). However, the teachers' required competencies are still unkown.

Current Practice in Tackling Transition in Science Education– Review of Literature

The continuity and progression of students' learning at key points of transition have been considered at terms of curricula, administration and teacher training (Möller, 2016). Studies on the development and implementation of a spiral curriculum, so-called bridging units or materials show that a continuous curriculum is possible (e.g. Braund, 2008b; Burr & Simpson, 2006, 2007; McCormack, 2016). At the administrative level, the introduction of subjects which combining natural sciences at the beginning of secondary school was recommended, e.g. by Wodzinski (2006), but not implemented compulsory. Furthermore, joint activities or projects in primary and secondary schools are supported by regional projects (e.g. Demuth, Walther & Prenzel, 2011) and the development of regional school networks (e.g. Järvinen, Otto, Satory, & Sendzik, 2012). In addition, there are recommendations for pedagogic transitional-related activities, which are used in various ways already (Braund, Crompton, Driver, & Parvin, 2003; Galton, Gray, & Ruddock, 1999, 2013; Ophuysen, 2005). However, the transition in science education is rarely supported by teachers' transition-related activities (Hempel & Maltzahn, 2012; Rau-Patschke & Brüggerhoff, 2019).

RESEARCH QUESTIONS

The research aim of this study is to determine teachers' required competencies in order to ensure a continuous development of knowledge, interest and motivation during the transition in science education. Therefore, the central research questions of this study are:

Research Question 1: Which competencies do teachers require in order to ensure continuity in the student's learning process and in the development of knowledge, interest and motivation during the transition in science education?

Research Question 2: What recommendations can be derived from students' own experience during the transition in science education and which issues still need to be addressed to ensure the well-being of the students?

The following information relate to Research Question 1.

METHODS & DESIGN

To answer these questions, a three-stage Delphi survey was designed. The characteristics of the Delphi technique are the anonymous group interaction and responses, the iterative process and the feedback (Linstone & Turoff, 1975). Linstone and Turoff (1975) define the Delphi technique "[…] as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (p. 3). The complex problem of the present study is the identification of previously unknown competencies required by teachers to ensure the continuity and progression in students' learning in science education. Since the variety of experts determines the quality of the results of the Delphi survey, members of the present Delphi expert panel were selected to represent a community who possess a wide range of expertise in the field of transition, science education as well as teacher training. Individuals from four areas within this community were involved in the study (hereafter called 'expert panel'):

- Science teacher of primary and secondary school
- Researchers in natural science education
- Teacher trainers of primary and secondary school in natural science education
- Headmasters of primary and secondary school

In a preparatory study, transition-related activities were deductively derived from the literature. These activities are used to formulate a first set of teacher's required competencies. They are summarised within a category system. The six main categories *Knowledge of Curricula in Science Education*, *School Environment & Organisation*, *Assessment*, *Teaching Styles & Approaches*, *Cooperation* and *Empathy for Students' Transition Process* are used to structure and analyse the first round of the Delphi survey (Rau-Patschke & Brüggerhoff, 2019).

In Round I, the experts were asked to answer open-ended questions related to these six categories. The main question was:

What are the characteristics of teachers who are capable of supporting a transition that ensures a continuous development of knowledge, interest and motivation during the transition in science education?

The responses are collected and analysed using qualitative content analysis (Mayring, 2015). The analysed skills, abilities and attitudes complete the category system.

In Round II, based upon these qualitative results, a questionnaire with closed questions will be developed and sent to a bigger expert panel (*N*=300). The experts are asked to rate the items on a 5-Point Likert Scale according to their relevance.

In Round III, the same expert panel is given the opportunity to reconsider and, if necessary, change their own opinion based on the group response. Finally, the results are analysed with regard to the consensus between the expert subgroups. Figure 1 illustrates the procedure of the present Delphi survey.

In the pilot phase *N*=16 experts took part of the open-ended questionnaire, equally divided in all four subgroups. For the first round of the Delphi survey a sample size of *N*= 140 experts is addressed. For the second and third round, a sample size of *N*=190 experts is aimed, in which the experts participate in both, the second and third, survey round.

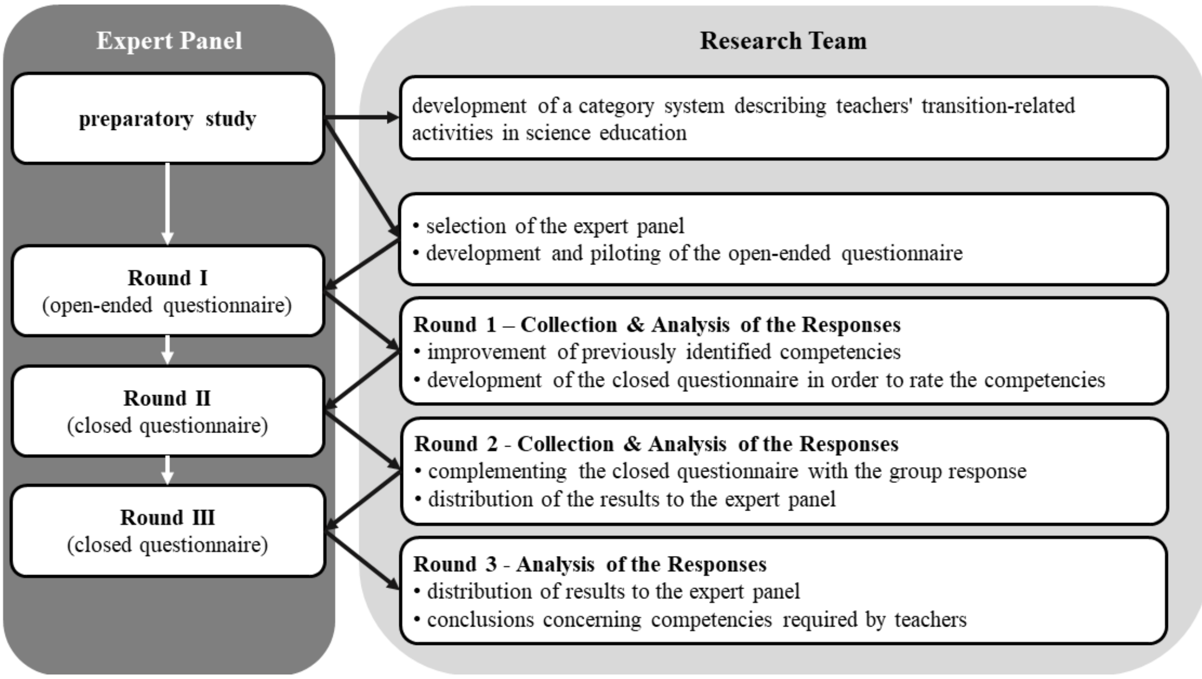

Figure 1. Flow chart of the Delphi study (based on Carabias et al., 2015)

RESULTS

The results show that experts demand skills, abilities and attitudes in all six categories (Figure 2). Especially in the categories *Knowledge of Curricula in Science Education*, *Assessment* and *Teaching Styles & Approaches* the experts require different skills and abilities that deal with knowledge about school policies, prior knowledge, core ideas, contents, methods and subject structures. So far, the demand skills and abilities in the categories *School Environment & Organisation* and *Cooperation* have remained nonspecific related to transition in science education so far. In particular, in the category of *Empathy for Students' Transition Process*, the experts demand specific attitudes and positions from teachers at primary and secondary school, which focus on the empathy of the teachers.

Knowledge of Curricula in Science Education	Primary and secondary school science teachers are familiar with each other's science subject structures.
School Environment & Organisation	Secondary school science teachers make the work in subject rooms a topic of discussion.
Assessment	Primary and secondary school science teachers advise students regarding their performance at key points of transition in science education.
Teaching Styles & Approaches	Secondary school science teachers use well-known methods of science education of primary schools.
Cooperation	Primary and secondary school science teachers are aware of the benefits of cooperation between primary and secondary schools in science education.
Empathy for Students' Transition Process	Primary and secondary school science teachers give attention to the differences between primary and secondary schools in science education.

Figure 2. Skills, abilities and attitudes demanded by the expert-panel

CONCLUSION

As the discussion about continuity and progression in students' learning at key points of transition the aim the study is to determine teachers' required competencies in order to ensure a continuous development of knowledge, interest and motivation during the transition in science education. Related to the categories *Knowledge of Curricula in Science Education*, *School Environment & Organisation*, *Assessment*, *Teaching Styles & Approaches*, *Cooperation* and *Empathy for Students' Transition Process*, the experts require abilities, skills and attitudes. However, they do not only seem to be of high relevance for the continuity and progression in students' learning at key points of transition, but also in everyday teaching. Therefore, the question arises if there are competencies already mentioned in models of teachers' profession which are important especially for transition. In order to answer this question, the main study will involve a larger sample size. In addition, by answering the second research question, the perspective of 5th grade students will also be captured. In guideline-based interviews, they will be asked about their requirements regarding transition-related activities.

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THE STRUCTURAL CHALLENGE IN BRAZILIAN TEACHER EDUCATION: THE PHYSICS TEACHER SHORTAGE

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Studies have indicated the pivotal role that qualified and experienced teachers play in students outcomes as well as in curriculum reforms. Nevertheless, it is reasonable to say that the critical aspects of teacher education such as recruiting and retaining good teachers are commonly overlooked. The main goal of our broader study is to provide an accurate empirical picture about the Physics teacher education in Brazil, which might help to enrich a more international discussion on processes of teacher recruiting, retention and attrition in Science Education. Findings indicate that the distribution of qualified teachers across Brazilian states is uneven with a couple of them with less than 10% of the teachers with adequate qualification in Physics teaching. Moreover, roughly 5% of those who entered in the teacher education programs end up teaching Physics in high schools. It is a massive leak which has its major challenge in filling the gap between higher education institutions and the high school classrooms. To sum up, the study makes possible to empirically ground the debate over Physics teacher shortages and evaluate the extent to which there is, or is not, sufficient supply of teachers in this field. Besides the Physics teacher shortage is huge compared with developed countries, the numbers seem relatively stable throughout the years. It is, on the one hand, a relevant confirmation that the problem is not getting any worse, on the other hand, it is evident that all the effort to improve Physics teacher retention have been achieving little effective results. Today, there is a growing consensus coming from quantitative and qualitative studies that improvements in salary and working conditions are key to change the whole scenario. From an accurate picture of Physics teachers situation, it is possible to understand and work with the concrete educational scenario.

Keywords: Teacher education, teacher shortage, Physics teacher

INTRODUCTION

There is a growing consensus among researchers, policymakers, and practitioners that initial teacher education is a key factor in changing the current state of affairs in Science Education (Bauer & Prenzel, 2012). Even though curricular design, integration between teacher education programs and schools, teachers' knowledge are indisputably at the core of teacher education concerns, it is important to address the nature as well as the current state of Science teacher attrition and retention (Buchanan et al., 2013).

The lack of qualified teachers is especially critical in implementing any substantial change in Brazilian Science Education. Studies have indicated the pivotal role that qualified and experienced teachers play in students outcomes as well as in curriculum reforms (Borko et al., 2002; Delandshere & Arens, 2001). Although, the relevance of well trained teachers in the educational processes has become common sense in research and educational practice, it is reasonable to say that the critical aspects of teacher education as well as attrition, recruiting, and retaining teachers are commonly overlooked (Borko et al., 2002; Buchanan et al., 2013).

The scenario of shortage and to some extent inadequacy of initial teacher education, commonly referred as out-of-field teachers, is not restricted to Brazil. This issue has been the subject of several studies around the world, including in economically developed countries (du Plessis et al., 2014; Ingersoll, 2003). According to Du Plessis; Gillies and Carrol (2014), in Australia 16% of Science and 24% of Mathematics teachers are not qualified, whereas in England 31.4% of Physics teachers are framed in the same problem. As we will see in this study, the Brazilian scenario, with regard to the physics teacher, it is much more worrying and the numbers are not encouraging.

Moreover, since educational data started to be collected covering a variety of aspects, it is possible to identify struggles in Brazilian educational system to improve its general quality (Avalos, 2011), from general indicators like graduation rates to specific ones like the students' achievement in the Programme for International Student Assessment (PISA). We expect that by addressing the shortage of Physics teachers in Brazil might help to shield light in the general issue of teacher retention around the world. To better understand the concrete and structural challenges that developing countries are facing today regarding improving Science education indicators, it is important to build an accurate picture of what are the situation of Brazilian Physics teachers' formation and practical experience (Villani et al., 2009).

STUDY GOALS

The main goal of our broader study is to provide an accurate empirical picture about the Physics teacher education in Brazil. Although the data presented is mostly on national level, the study as might help to enrich a more international discussion on processes of teacher recruiting, retention and attrition in Science Education.

In this study we acknowledge that teachers' education and experience play a pivotal role in different aspects of Science education from pupils learning to curriculum reforms. Therefore, there is an underlying need to substantiate the Science Education research with data and evidence of the challenges that professional development faces today. We focused on two dimensions of teachers situation in Brazil: (i) teachers' undergraduate degree; and (ii) the number of incoming and concluding students in Physics teacher undergraduate programs, and in-service qualified teachers. We looked for relations between this two dimensions in order to understand how the professional choice is maintained or not when they initiate their professional life.

SOME REMARKS ON INITIAL TEACHER EDUCATION IN BRAZIL

Before addressing the Physics teacher situation, it is important to have an overview of how teacher education is structured in Brazil which might have some contrast with European programs, mainly after Bologna (Flores, 2011). Physics teaching is basically concentrated in the high school level and the qualification to teach is a higher education degree -- university level. There are little alternative paths to becoming a high school teacher and even though the design in the teacher education programs might vary, in the general outline al future teachers have to entry the university level of initial teacher education program.

The main implication is that future teachers must have a career decision early on in their academic lives, which might be too early for many. This characteristic of decision making has implications for the process of recruiting new students for teacher education programs and the ways students and institutions find to avoid dropouts. Most of the students take the decision to become a teacher while in the teacher education program and most of them do not go to work as teachers, even if they have completed the four years program (Gatti, 2013).

METHODS AND DATA GATHERING

The study is grounded on the governmental education data at national level in Brazil which stems from the datasets of basic schools and higher education census both publicly available by the Ministry of Education. The study is centered on the descriptive statistic adequate to build the empirical picture of teacher education (Agresti & Finlay, 2009). Most of the effort consists in assembly the data set from the last decade and inquiry about the concrete situation of Physics teachers in schools regarding their qualification.

This empirical picture created with a descriptive statistic might work as a starting point for investigating the concrete situation and public policies as well as provide the bases for models in broader studies.

FINDINGS

It is not uncommon that policymakers, curriculum designers and researchers set their actions and propositions based on an idealized teachers that may not find support in the concrete life of schools. One of the central issues is: who is actually conducting the Physics lessons?

In Brazil, since 2007 is known that Physics is the subject matter that lives the most critical scenario with 26% of its teachers with proper qualification -- i.e. higher education degrees in Physics teacher education (Pestana, 2009).

Table 1 - Percentage of the Physics teachers by each higher education degree | Source: 2018 Brazilian School Census

Teacher education in Math	Teacher education in any other field	Teacher education in Physics	Any other higher education degree	Higher education student	Teacher education in Sciences	Pedagogy
18,801	13070	12,597	5,358	3,238	2,829	3,048
31.9%	22.2%	21.4%	9.1%	5.5%	4.8%	5.2%

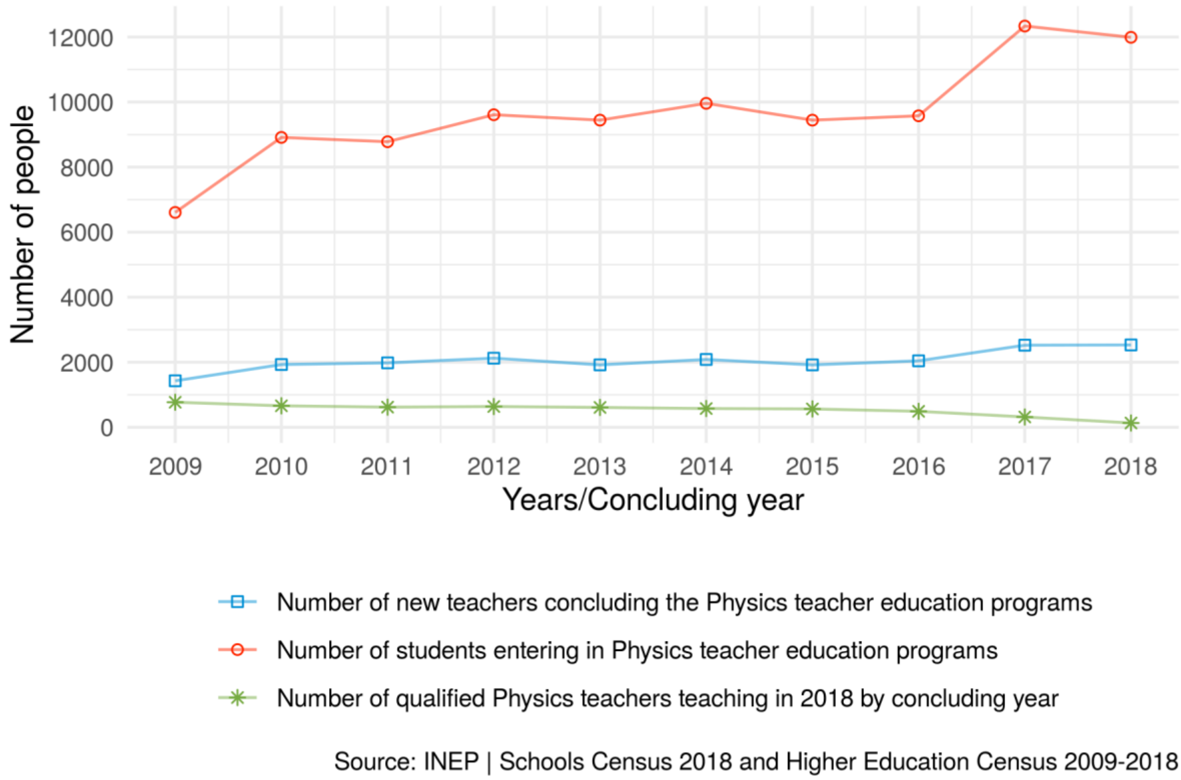

Figure1 - Graphic of the number of students entering in Physics teacher education programs by year, number of new teachers concluding the Physics teacher education programs by year, and number of qualified Physics teachers teaching in 2018 by concluding year.

Table 1 shows the percentage of the Physics teachers by each higher education degree. The largest group is formed by teachers has a background in Mathematics. In the national level, they correspond to 32% of the total number of Physics teachers. The qualified teachers correspond only to the third largest group and it is possible to estimate that 79.5% (more than 46,000) Physics teachers are non-qualified.

The distribution of qualified teachers across states is uneven with a couple of states with less than 10% of the teachers with adequate qualification. For instance the federal district has the best mark with 61% of qualified teachers while São Paulo, the most populous state, has 16.3 %.

The number of students entering into Physics teacher education programs roughly doubled from 2009 to 2017. What is mainly explained by the expansion of the higher education system and the growing number of teacher education programs in almost all subject matters. Although it is possible to observe a tendency of growing in the last year for students entering and new teachers leaving from teacher education programs, only one-quarter eventually concludes. Additionally, only one-fifth of new teacher go to classrooms in public and private schools. It means that roughly 5% of the those who entered in the teacher education programs end up teaching Physics in high schools. It is a massive leak which entails challenges in filling the gap between higher education institutions and the school classrooms as well as improving the ratio between the entering and the concluding in Physics teacher education programs.

Table 2 - Percentage of the Physics teachers by each higher education degree per region | Source: 2018 Brazilian School Census

Region	Teacher education in Math	Teacher education in any other field	Teacher education in Physics	Any other higher education degree	Higher education student	Teacher education in Sciences	Pedagogy
Center-West	1,179 26.3 %	741 16.5 %	803 17.9 %	737 16.4 %	272 6.1 %	492 11.0 %	260 5.8 %
Northest	4,956 31.2 %	4438 27.9 %	2,751 17.3 %	1,209 7.6 %	1388 8.7 %	474 3.0 %	685 4.3 %
North	1,913 33.1 %	1,399 24.2 %	1,093 18.9 %	257 4.4 %	301 5.2 %	325 5.6 %	497 8.6 %
Southeast	2,464 26.6 %	1,596 17.2 %	2,891 31.2 %	1,302 14.1 %	469 5.1 %	380 4.1 %	153 1.7 %
South	1,968 26.4 %	1,323 17.7 %	2,095 28.1 %	374 5.0 %	374 5.0 %	232 3.1 %	1,094 14.7 %

Some regional differences are shown in table 2. It may indicate that the demands and their solutions might be regional driven. regions like South which has historically better education indicators along with Southeast which is known for been a highly industrialized region has the higher rates of qualified teachers with 28.1 % and 31.2 % respectively.

FINAL CONSIDERATIONS

As data shows there is a shortage of Physics teachers in general and it is particularly aggravated for qualified teachers (Araujo & Vianna, 2011). Although such a shortage magnitude is known since 2006 with studies on the 2003 school census (INEP, 2006), there are few studies address the most particular characteristics and issues related to the physics teacher specially in recruiting and retaining in the initial teacher education program. Based on the 2009 school census, Gatti (2014) highlights that among all school subjects, Physics is the one with the lowest percentage of qualified teachers.

Besides the Physics teacher shortage is more acute compared with developed countries, the numbers seem relatively stable throughout the years. It is, on the one hand, a relevant confirmation that the problem is not getting any worse. On the other hand, it is evident that all the effort to improve Physics teacher retention have been achieving little effective results. There is a growing consensus coming from quantitative and qualitative studies that improvements in salary and working conditions are key to change the whole scenario (Richardson & Watt, 2005).

Furthermore, the dominant presence of teachers with Math background may help to explain the strong identification or reduction of Physics teaching to mathematical problems solving. This problem added by the uneven distribution of qualified Physics teachers across regions, allows to hypothesize that Physics teaching could have different characteristics in different regions. Another commonly neglected consequence of the critical Physics teacher shortage is that teachers can not create teachers study groups becoming isolate in his work at school, what may undermine professional development programs grounded on pair exchange and networking within the disciplinary field.

Finally, with a more accurate picture of Physics teachers situation, it is possible to understand and work with the concrete educational scenario and at the same time to propose ways to change it.

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SUPPORTING PROFESSIONAL LEARNING COMMUNITIES TO DEVELOP CONTENT KNOWLEDGE FOR TEACHING AND LEARNING PHYSICS AT LOWER SECONDARY LEVEL

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Participation of physics at upper secondary level in Ireland, particularly among girls, is a matter of national concern. However, the situation in Ireland is not unique, with many countries seeking to address the low numbers of students continuing in physics at upper secondary level or at University level. In addition, many countries suffer from insufficient numbers of teachers qualified to teach physics at lower secondary level and this directly impacts on the retention rates at upper secondary level. This study reports on findings from a two-year collaboration, between physics education researchers and eleven science teachers, focused on enhancing the teaching and learning of physics at lower secondary level. Two professional learning community case studies are presented in this paper that examine the impact of a school-based professional development programme with all science teachers in two Irish second level schools. In the first year, a series of workshops with teachers were facilitated with three core objectives; namely, increasing teacher's confidence and specific content knowledge for teaching physics; raising their awareness of unconscious biases and career opportunities in Physics. In the second year, teachers and researchers collaborated to co-design a sequence of lessons in physics that embedded these three objectives. Using the Ambitious Science Teaching framework, we have measured the impact of this collaborative approach on teacher's planning of sequences of lessons to enhance the teaching and learning physics at lower secondary level.

Keywords: Teacher Professional Development, Inquiry-based teaching, Physics.

INTRODUCTION

The effect of fostering student and teacher identity in physics in increasing student engagement and participation in science, technology, engineering and mathematics (STEM) has been discussed in recent literature, e.g. Hazari reports that secondary level physics teachers can positively impact on physics identity development among their students (Hazari et al., 2010). Understanding the factors that influence students' interest in STEM, highlights processes that may selectively dissuade females from pursuing STEM career paths (Ito & McPherson, 2018). In particular, female experience of conceptual understanding and real-world/contextual relevance is reported lower than their male counterparts (Hazari et al., 2010). Therefore, increasing teacher awareness around the influence of stereotypes and biases on students' engagement is pivotal in enhancing the teaching and learning of physics at lower secondary level.

In Ireland, the 2019 statistics reported by the State Examinations Commissions show that 14% (7942) of the Irish Leaving Certificate student cohort choose to study and complete the physics examination at upper secondary level. Of the total student cohort (56,008) taking physics for the Leaving Certificate Examination only 4% (2116) of were girls (State Examinations Commission, 2019). The STEM Education Review group reported that 22% of the 723 Irish secondary level schools do not offer Physics as a separate subject at upper secondary level (STEM Education Review Group, 2016). This data highlights the need to encourage more students, particularly girls, to continue in physics at upper secondary level and the urgent need to promote physics teaching as a future career for young people nationwide.

Sustaining the pipeline of physics students in upper secondary school (ages 15-18 years) must begin with improving the student experience with physics at lower secondary level. Currently, in Ireland, teachers registered with the Teaching Council (Regulatory body for professional standards in teaching) with any one science subject in their final degree e.g. Physics, Chemistry, Biology to upper secondary level are also recognized to teach science at lower secondary level, to students aged 12-15 years. As there are only 1259 teachers who are recognised with qualifications to teach Physics, often the teaching of lower secondary level physics (as an integrated strand of science), is facilitated by teachers who have a Biology (3878 teachers) or Chemistry (2376 teachers) science specialism (STEM Education Review Group, 2016). Supporting these teachers so as to improve the quality of the teaching and learning of physics at lower secondary level and to respond to increasing diversities in classrooms is the core aim of this research.

In schools, hours dedicated for science department planning hours are commonly focussed on the upper secondary level science specialisms. However, a lack of collaboration among teachers who teach the same common lower secondary level curriculum and an absence of teacher professional learning communities (PLCs) in schools is widely reported. McLaughlin identifies strong professional communities as those teachers who share a sense of common mission and negotiate principles, policies and resources for their practice. She attributes, a community of teachers who work together and explore ways of improving practice in order to advance learning, to generating knowledge of practice (McLaughlin & Talbert, 2001). Dana & Yendol-Hoppey specify that PLC's unlike department meetings have a central focus on student learning and teacher professional learning. With the power to change school culture, teacher impact and student achievement, PLCs engage in deliberate and purposeful professional dialogue to learn from practice (Dana & Yendol-Hoppey, 2015). The aim of this study addresses this need to foster professional learning communities with teachers from the same science departments and enhance the teaching and learning of physics at lower secondary level.

THEORETICAL BASIS

Implementing teacher professional development programmes that are effective in increasing science teachers' confidence and content knowledge for teaching specific physics concepts at lower secondary level is challenging. The Ambitious Science Teacher (AST) framework outlines pedagogical approaches for engaging science through supporting intellectual engagement and promoting attention to equity (Windschitl et al., 2012). This framework supports teachers professional learning using four key practices: planning for engagement with important science ideas, eliciting students' ideas, supporting on-going changes in thinking and pressing for evidence-based explanations. The first practice, planning for engagement with important science ideas, outlines a design instruction for planning to engage students in big science ideas (Windschitl et al., 2012). Facilitating teachers to construct plans and deepen teachers' understanding of physics content is difficult to balance within teacher professional development programme (Banilower et al., 2006). The Ambitious Science Teaching framework supports teachers to design learning experiences focused on anchoring/big science ideas. Using conceptual tools for exploring big ideas through inquiry-based learning, teachers can frame activities for students in science classrooms (Thompson et al., 2013). Guidelines for teaching science, technology and society from the upper secondary Irish physics curriculum were adapted into the dimensions of planning framework to promote equity by highlighting the need to raise awareness of careers in STEM (National Council for Curriculum and Assessment, 2002).

In the context of the AST framework, this study will address the following research questions:

i) How can teachers be supported to develop their content knowledge for teaching physics at lower secondary level through planning sequences of lessons?
ii) How is teachers' awareness of unconscious bias, gender stereotypes and careers in STEM addressed in their planning of physics at lower secondary level?

METHODOLOGY

This study reports on a collaboration with two Irish second level schools, that are part of a wider research programme aimed at implementing a whole-school approach to addressing gender imbalance in upper second level physics and is further described in recent publications (O'Neill, McLoughlin & Gilheany, 2018). The three key objectives of this research programme are to;

i) Deepen science teacher's confidence and content knowledge for teaching physics,
ii) Increase awareness of STEM and careers in STEM;
iii) Adopt a whole school approach to addressing unconscious bias and gender stereotyping and build confidence and resilience for students, particularly girls, to continue with Physics.

The focus of this collaboration with science teachers was to facilitate workshops with science teachers that model inquiry-based teaching, learning and assessment practices that are appropriate for teachers to adopt in their own classroom practices. The participants in this study were eleven science teachers from two Irish secondary schools identified as PLC1 and PLC2. PLC1 consisted of three teachers qualified to teach Biology, one qualified to teach Chemistry and one qualified to teach physics. PLC2 consisted of three teachers qualified to teach Biology, two qualified to teach Chemistry and one qualified to teach Physics.

During the first year, science teachers participated in both guided and open inquiry-based workshops (Bevins & Price, 2016), that address specific concepts in Physics as identified by the collaborating teachers; Energy, Electricity, Light, Speed, Earth & Space, Forces, Density.

Teachers were facilitated to work in small groups (typically 3-4) to co-design these concept-based workshops alongside the researcher as part of a professional learning community. It is suggested that professional development models facilitate teachers becoming part of professional learning communities for fostering sustained collaborative practices among teachers in schools (Dana & Yendol-Hoppey, 2015).

During the second year, the teachers and researchers collaborated to co-design a sequence of lessons in physics that embedded all of the objectives of the programme; deepen teacher's confidence and content knowledge for teaching physics, increase awareness of careers in STEM and address unconscious bias and gender stereotyping. The co-designing of sequences of lessons consisted of one two-hour planning session with both PLC1 and PLC2 cohorts. The Ambitious Science Teaching (AST) protocols were adapted as a scaffolding tool to support collaborative planning through dimensions of planning (Windschitl et al., 2012). The dimensions of planning; causal explanation, essential question, scientific concepts, lesson activities, links to curriculum and how is the learning assessed were adapted from the Ambitious Science Teaching - Unit Planning Tool to fit the context and language used in the Irish education system (Table 1). Inclusive practices were also included in the approach adopted in this study and included a focus on fostering physics identity, raising awareness of unconscious biases and gender stereotyping (Hazari et al., 2010) and promoting STEM careers (National Council for Curriculum and Assessment, 2002), see Table 1. Teachers used a wind-up toy car, that moved non-linearly and gave off sparks, to anchor the planning of their sequence of lessons. Each sequence of lessons were evaluated using the AST framework to determine if the three key objectives of this research were achieved. The intellectual requirement for teachers in terms of planning questions and tasks in the classroom were classified as low-cognitive demand (focus on memorization, procedural tasks, recall understanding only) and high-cognitive demand (sense-making, no discrete answers, using evidence to support claims etc.) as defined by the cognitive demand in questions and tasks in Ambitious Science Teaching (A Discourse Primer for Science Teachers, 2015). Teachers' sequence of lessons were evaluated according to these criteria to establish patterns in teacher planning for engaging physics.

Table 1. Mapping Dimensions of Planning according to Ambitious Science Teaching and inclusive practices

	Dimensions of Planning	Description
Ambitious Science Teaching	Causal Explanation	• What's happening (description)? • Why is it happening (explanation)? • Detailed (researched) description of the phenomenon
	Essential Question(s)	• Record all questions relating to a phenomenon • Identify essential / investigable questions • Turn questions into investigative questions
	Scientific concepts	• Identify a range of physics/science concepts – related to causal explanation • Student conceptual difficulties
	Lesson activities	• Design experiments to support student learning • Sequence activities/experiments to construct • Consider effective instructional strategies
	Links to curriculum (cross strand)	• Identify learning outcomes on curriculum (in any of the strands) • Create links across the strands of curriculum
	How is learning assessed?	• Outline how the learning will be assessed

		• Develop/adapt rubrics/questions etc/
Inclusive Practices	Career/Societal Awareness	• Suggest similar phenomenon in everyday life that can be explained using this phenomenon • Identify careers in which this information could be helpful • Research/name someone you know who works in this area
	Unconscious Bias Awareness	• Creating awareness of stereotypes that surround different career types • Being aware of how one's own perceptions might influence the teaching process • Identifying any gendered language that may be connected to the topic (difficult, "maths-heavy" etc.)

FINDINGS

Table 2 and 3, present evidence on the dimensions of planning present in the sequences of lessons of two teacher professional learning communities, PLC1 and PLC2. For the specific examples included, the level of cognitive demand was determined and is expressed in each sequence of lessons within the dimensions of planning. Although both groups of professional learning communities received the same resources (access to ambitious science teaching resources, sample sequences of lessons, planning time with department) to work with, very different sequences of plans emerged from their work.

Different elements of the framework were absent on both sets of PLC plans. PLC1 had no evidence of a causal explanation or essential question and focused solely on scientific concepts to build their sequence of lessons. Lesson activities showed a high level of cognitive demand, in PLC1s plan, with activities focused on student inquiry learning and designing learning experiences around learning goals. Key experiments and investigations that were relevant to the development of ideas and practices were included. Assessment practices were clearly described within each activity along with specific questions outlined as appropriate. Curriculum links and reference to careers were specified within activities, however these links were not well described and their connection to success criteria or measurable outcomes were lacking.

Table 2: Evidence of Dimensions of Planning in PLC 1 Sequences of Lessons

Dimensions of Planning	Specific Examples in Plans	Cognitive Demands Questions and Tasks
Causal Explanation	Not Present in plan	
Essential Question(s)	Not present in plan	
Scientific concepts	Forces, Combustion, Light, Torques, Heat, Energy Transfer	
Lesson activities	• E.g. Students design their own lever and explain	Higher Cognitive Demand

	in their own words how it works. • E.g. Light: Design an instrument that will allow you to see objects on the other side of the desk from a variety of different materials.	• Processing Ideas: tasks required students to use ideas and information in ways that expanded understanding. • Connected activities with Ideas; Selected tasks that required some thought and the task solution was not self-evident from the solution.
Links to curriculum (cross strand)	• E.g. Investigate patterns of physical observables – but patterns are not outlined	• Specific cross strand curriculum links highlighted but not linked to success criteria of activities.
How is the learning assessed	• E.g. Questioning: How many mirrors will you use and why? What does this [experiment] tell you about the way light behaves?	Higher Cognitive Demand • Approach outlined with specific questions/connections to activity described
Career/Societal Awareness	• E.g.	• Specific careers linked with each individual activity. No links made with the content specifically.
Unconscious Bias Awareness	• E.g. Fireman/woman	• Bias in gender specific careers mentioned - misconceptions and differentiation included in bias (may be a misunderstanding)

In the sequence of lessons produced by PLC2, most of the dimensions of planning were evident. A causal explanation was described with a strong focus on what was happening rather than a scientific explanation of why it happened. There was some indication that teachers attempted to expand their description to include more in-depth explanation e.g. “When there is an odd number of gears, the last gear will always turn in the same direction as the first one”, but this led to new ideas which caused more confusion among PLC1 members and was the explanation remained without further commentary or clarification.

Table 3: Evidence of Dimensions of Planning in PLC 2 Sequences of Lessons

Dimensions of Planning	Specific Examples in Plans	Cognitive Demands Questions and Tasks
Causal Explanation	• E.g. Adjacent gears are connected to either a chain or belt that is connected to a spring which moves in opposite directions. • E.g. When there is an odd number of gears the last gear will always turn in the same direction as the first one…but why?	Lower Cognitive demand • Seeking only a “what” explanation. • Some consideration of “why” explanation for one specific aspect of the phenomenon but with little detail.
Essential Question(s)	• E.g. How long will the toy work? Does friction stop the toy from working?	Lower Cognitive demand • Does not lend to developing an explanatory model to answer the question.
Scientific concepts	Heat transfer, Graphs and Slopes, Friction, Potential Energy, Kinetic Energy, Speed, Metals/Non-metals	
Lesson activities	• E.g. Write a plan indicating how long it takes to walk 15 metres……Consider why some people walk faster than others.	Medium Cognitive Demand • Connected activity with ideas. Selecting tasks that require some thought, however, approach does not suggest that the task solutions are not self-evident to student.
Links to curriculum (cross strand)	• E.g. for Heat transfer activity link to conductivity in the curriculum is not specified in the activity.	• Specific cross strand curriculum links highlighted but not linked to success criteria of activities.
How is the learning assessed	• E.g. Grouping, Peer assessment and Self-assessment	Lower Cognitive Demand • Assessment methods listed but not connected to activities
Career/Societal Awareness	• Six broad careers listed with no link to context of phenomenon.	
Unconscious Bias Awareness	• Not present	

It was evident from the plans and collaborating with the PLCs on developing these plans, that the two PLCs had very different priorities when planning their sequences of lessons. PLC1 focused their planning on student learning and student outcomes, e.g. "Students design their own lever and explain in their own words how it works". There was clear evidence to suggest that PLC1 had concerns around how students process ideas. This PLC also engaged fully with the need to raise career awareness in their classroom practice. PLC2 were more focused on the teachers' content knowledge for teaching physics and approached the planning as if the teachers themselves were the learners e.g. When there is an odd number of gears the last gear will always turn in the same direction as the first one…but why?". This resulted in a much more disjointed written plan, however, the discussions and sharing among PLC members provided an opportunity for teachers to identify the gaps in their own knowledge and learning.

DISCUSSION

From our analyses of teacher's plans for sequences of physics lessons, it was evident that teacher written plans lacked detail. All eight aspects of the dimensions of planning, six from Ambitious Science Teaching and two from inclusive practices, were evident to some degree, however all aspects of the dimensions of planning were not evidenced in any single plan. These findings highlight the need for further PLC activities to co-design, implement and reflect on lessons and to consider what refinement is necessary to engage students in physics concepts at lower secondary level.

Our findings indicate that these teachers lack specific content knowledge for teaching physics, and this impacted on their ability to propose complete causal explanations and investigative essential questions. Probing specific content knowledge for the purpose of deepening non-physics science teachers content knowledge for teaching is required to promote teacher confidence and competence in teaching physics at lower secondary level (Etkina et al., 2018).

Finally, enhancing teachers' reflective and collaborative skills in order to support groups of teachers in planning for engaging science needs to at the goal of a professional learning community. Adopting a research practice partnership model, as proposed by Penuel, that encourages mutualistic relationships between the researchers and teachers through shared learning goals could see an evolution in the support needed to facilitate groups of teachers in designing, planning, implementing, reflecting and refining sequences of lessons for lower secondary level physics (Penuel & Gallagher, 2017).

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LEARNING ACTIVITIES TO FOSTER SCIENTIFIC COMPETENCES: A COLLABORATION BETWEEN HIGH SCHOOL TEACHERS AND PHYSICS RESEARCHERS

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Our group has carried out a collaboration project with a group of high school physics teachers engaged in a PLS (Progetto Lauree Scientifiche) professional development course promoted by the Department of Science and High Technology (DiSAT) of Insubria in Como, Italy. The aim of the course was to enable teachers to create balanced and effective learning activities to be used in class to reinforce the scientific competencies and skills required in the Final Exam of the Italian Secondary School (Esame di Stato). The aim of this paper is to present the result of this collaboration to understand how to better support the collaboration between physics researchers and high school teachers in order to design teaching and learning materials that could be effectively integrated in the daily classroom activities. We focused our attention to problem solving and data interpretation skills and the relationship between theoretical models and measurements process as requested in the last education reform for Italian secondary school final exam.

Keywords: Teachers, Experiments, Competences

INTRODUCTION

The last EU recommendations on key competences for lifelong learning encourage educational institutions to strengthen the collaboration between physics researchers and secondary school teachers in order to implement competence-oriented education, training and learning. The PLS project (Progetto Lauree Scientifiche) promotes teachers training programmes for the educational staff in Como and Varese school district: faculty members and physics researchers in different fields of theoretical and experimental physics have been actively involved in the professional development programme. One of the aims of the PLS project is to support teachers in improving the way physics is taught in Secondary School.

The last education reform in Italy is promoting new curriculum design practices that should help teachers change their role in student's learning process: from operating as mere reviewers of knowledge acquisition to becoming facilitators of scientific competencies development processes. This change of perspective have raised many concerns among teachers, mostly related to the gap between the way physics curriculum is developed in classroom and the framework of the Final Exam Paper (Seconda Prova dell'Esame di Stato per il Liceo Scientifico). Since the last twenty years the Final Exam Paper was mathematics only, structrued as a list of exercises and problems related to a precise syllabus that need to be covered by the school year. Physics was only part of the oral examination: students are supposed to answer a couple of questions about the last year topics (electromagentism, special relativity and quantum mechanics). However “exam simulation papers” published in the last three years focused the attention on scientific competencies and skills such as hypothesizing, interpretation of experimental data and making conclusions more than on content knowledge. In addition to that, in 2018 a new school legislation introduced the possibility of having an exam paper only about physics or with problems that integrates mathematics and physics topics.

To support teachers in this transition between “knowledge – oriented” and “competences - oriented” educational practices, at the beginning of 2018/19 school year the PLS project at DiSAT promoted a collaboration with a group of about 40 mathematics and physics teachers of the Como school district in order to support them in defining appropriate teaching activities to prepare students for the Final Exam Paper. In this way the analysis of learning needs and goals will be easily extended to all the entire physics curriculum and be used to design and plan learning activities since the first year of high school. This PLS project focused its attention to the scientific competencies related to the analysis and interpretation of experimental data and the relationship between physical models and experimental results. The purpose of this paper is to present the results of this collaborative project and to give suggestions on how to foster the process of scientific competencies acquisition and to orient teacher training programs.

Theoretical framework

Long terms experiences and recent researches in physics education in Italy show how high school teachers can be productively engaged in renewing instructional methods if they feel the need of enlarging their own view and understanding of the topic (Besson et al., 2010). Nevertheless the past collaborations between DiSAT and local schools have shown that the transfer process of learning and teaching material from physics researchers to teachers has not been effective in terms of implementing the use of new teaching strategies. A relevant element that has been pointed out by physics researchers at DiSAT, during internal evaluation meetings about their long experience in teachers training in the Como area, is that teachers are often simply delegating to researchers the role of explaining complex topics or running experimental activities in extra-curricular workshops. On the other hand teachers are often concerned about a feasible educational transposition at schools of what they learn in the training courses especially regarding the intrinsic difficulty of the topics, generally labeled as “to difficult for the students”, or pointing out the lack of time and resources to perform the laboratory activities presented in the training courses.

In the theoretical framework of active learning (Fraser et al., 2014) the training courses promoted by physics researchers in this project aim to improve conceptual understanding and promote a meta-reflection about the role of scientific competences. In order to renew instructional methods, the training course also include “hands-on/minds-on” workshops using a guided inquiry methodology (Rönnebeck et al., 2016) so teachers can immediately have the perception of the didactic applicability of what they have experienced in the workshop.

Project actions

Between December 2018 and February 2019, our group organized a series of 5 meetings (2 hours each) for a group of 40 high school teachers. On average, 20 teachers attended each meeting. In the first three seminars physics researchers and teachers solved together the problems of the exam paper simulations that were published in December 2018. This activity allowed the participants to define which parts of the test were particularly challenging for the students, pointing out the main skills and competences (problem solving, data analysis and interpretation) needed to tackle the problems. Teachers also shared teaching experiences and materials they used to prepare last year students for the final exam paper.

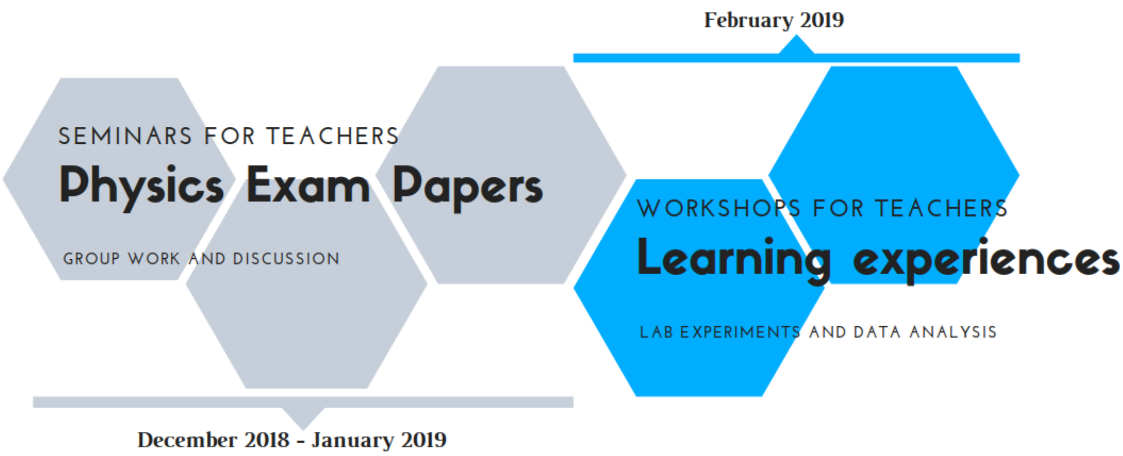

Figure 1. Project structure

In this first three meetings, teachers had the opportunity to discuss and share their view about the problems solving skills needed to solve the exam questions. In the last two sessions, teachers took part in two different physics workshops performing two experiments using simple materials and smartphone sensors. The first learning experience was about the measurement of the magnetic field of a little magnet. The second learning experience was about the measurement of the time collision of a ping pong ball with a table. Both those experiences were selected because the topics are part of the physics curriculum (mechanics and electromagnetism) and give the possibility to easily gather real data that can be analyzed and then discussed with students with different methodologies.

DATA ANALYSIS IN EXAM PAPER PROBLEMS

As mentioned before the first three meetings of the teachers training was dedicated to the analysis of the three exam paper published by the *Ministero dell'Istruzione dell'Università e della Ricerca* to help teachers understand the characteristics of the new exam format. What was relevant in the discussion with teachers was the reflection about the assessment criteria indicators attached to the Exam Paper (table 1) and their relation with specific scientific competences.

Criteria	**Description**
Analyze	Examine the problem identifying the significant aspects of the phenomenon and formulating the explanatory hypotheses through models, analogies or laws.

Resolution process application	Problem formalization and application of the concepts, mathematical methods and appropriate disciplinary problem solving strategies, performing the calculations needed.
Interpret, represent and elaborate data	Process the data, proposed or derived from experiments, checking the relevance to a chosen model. Representing and connect the data using the necessary graphic-symbolic codes.
Argue	Describe the resolution process adopted, the solution strategy e the fundamental steps. Communicate the achieved results evaluating the consistency with the problems and using disciplinary specific languages

Table 1. Assessment Criteria for the Physics Exam Paper

The criteria are not only related to the ability to solve the problem numerically, but also to the skills and competencies needed to analyze the problem, modelling and interpreting data.

Discussion about the quality of a fit

During one of the seminars the discussion between teachers and researchers was focused on how to fulfil the assessment criteria related to one problem that ask students to show that a give data set could be fit using a linear model. This kind of question allows students to explore the connection between experimental data and the theoretical model used to fit the data. This is worth to be done in a didactical context to foster a more general reflection about nature of science, in particular on how physics researchers' experimental results contribute to the development of interpretative models of physical phenomena.

Unfortunately, as reported by teachers, experimental activities that involve data analysis and interpretation are not part of usual curriculum activities. The lack of materials and resources in school to adequately incorporate performing experiments into curricular activities planning has also been taken into account. Statistic literacy is generally part of mathematics curriculum: as a result, the basic techniques of data analysis, such as the linear regression, are not fully covered during the instruction programme. In addition to that, most of the teachers admitted that they had never been properly trained to run experiments and do not feel competent enough to perform experiments with students.

What makes a measurement a "good one" was the first point of discussion. The conclusion was that a scientifically reliable estimation of a physical variable could be obtained only with a correct measurement procedure that estimates uncertainty from multiple measurements. Than what to do in when the experiment "is not working" and the data are not in accordance with the theoretical model? In that case students should be able to use their measurement device correctly in order to reduce the effect of systematic uncertainties. Following the result of this discussion, the group of teachers took part in two workshops about low cost physics experiments that could be used to recreate the condition presented in the exam paper question and to reflect on the scientific experimental inquiry process.

To promote a more active approach, teachers follow the same learning activity path designed for secondary school students, but they are guided to reflect not only on the content but also on the difficulties that can arise in performing the activity in the class with the students. The two learning experiences have been structured as a guided inquiry learning activity so the participants (divided in small groups of three) have to use a proper theoretical model to describe the physical phenomena to guide the measurement process during experimental activities.

LEARNING EXPERIENCE 1: DATA ANALYSIS

The first workshop was about the measurement of small magnet magnetic field using smartphone sensors (Arribas et al., 2015). The experimetal activity worksheet are also available at https://ls-osa.uniroma3.it/ This experience have been chosen because of its connection with the previous teachers work groups where the necessity of a reflection about the relationship between theoretical physical models and experimental data have been repeatedly pointed out. The inquiry question in this case was abouthow is it possible to fit a set of data using a specific theoretical model?

A specific attention have been payed to the data acquisition process using smartphone app and to the data analysis techniques. The aim of the learning activity is to support students' reflection on the relation between the theoretical model of a physical phenomenon and the experiments related to it.

Activity description

The purpose of the practice is to determine the dependence on the distance of the component x of the magnetic field produced by a small cylindrical magnet. The measurements are taken using the magnetic sensor of a smartphone and an app for the data acquisition: we used Phyphox and Physics Toolbox. The activity also requires a pencil, a sheet of paper and a ruler. The activity took two hours and involved about 15 teachers. The activity structure is intended to mimic the sequence of an experimental scientific inquiry: starting from the elaboration of a theoretical model, moving to the preparation and calibration of experimental set-up and data collection and finally to data analysis and interpretation. During the workshop we focused on the different aspectes of experimental activities.

Development of a physical model

Following teachers' request of being properly introduced to the physics of the small cylindrical magnets magnetic fields, the experimental activity have been preceded by a short lecture by a faculty member of DiSAT. This part of the activity made it possible to analyze in detail the theoretical model underneath the relation between the physics variables used to describe the phenomena. As reported by the teachers during the discussion, this introduction is consider a useful and essential tool to engage the student into the laboratory activity: in their experience, students seem to prefer to infer the interpretation of a single phenomenon from a general model instead of inductively built a scientific model from observations.

The modeling of the magnetic field gives also some elements about the type of magnets that could be used. The field generated by a permanent magnet of cylindrical shape is calculated on the axis of symmetry *x*-direction at distance much larger than its radius *a* (but not necessarily larger than its length *l*). The permanent magnet is schematized as a collection of circular loops crossed by a current of intensity *I* that can be identified with the superficial magnetization currents. Under this conditions the magnetic field in the *x*-direction is given by

$$B_x(x) = \frac{\mu_0}{2\pi} m \frac{x}{\left(x^2 - \frac{l^2}{4}\right)^2} \qquad (3)$$

where m is the magnetic moment of the magnet and μ_0 is the magnetic permeability of free space. If then $l << x$ the x-component of the magnetic field becomes:

$$B_x(x) = \frac{\mu_0 m}{2\pi} \frac{1}{x^3} \qquad (4)$$

Becoming familiar with experimental devices

An important part of the experience was about learning how to properly use the data acquisition device. Teachers spent time to learn how to use the smartphone app, focusing the attention on how the device collects data. The first problem is to determine the position of the sensor inside the device. Secondly, the smartphone sensors need to be properly calibrated, taking into count that the measurements are strongly dependent on the device orientation and distance between the smartphone and the magnet. The possibility to verify the consistency of a theoretical model is bounded by the possibilities given by the characteristics of the experimental devices: this is something students need to understand to properly evaluate the results of their experimental activities. Teachers reported that they could not collect data when the smartphone was too close (less than 5 cm) to the magnet, due to the sensor saturation (when $x < 5$ cm the value of B did not change): that implies that the model could be verified only in a specific interval of distances from the device.

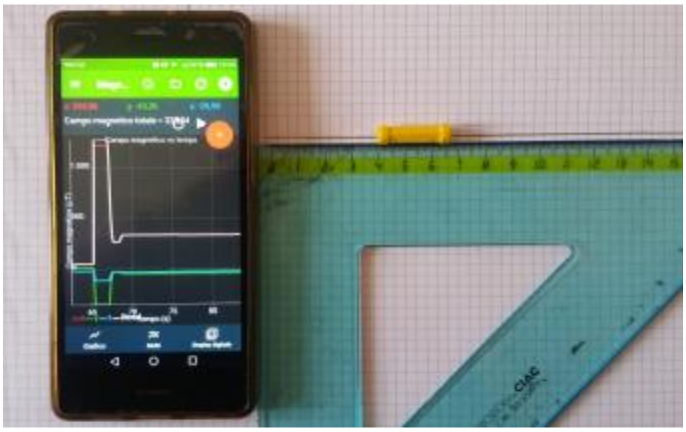

Figure 2. Experimental setup

For the same reason the evaluation of the experimental uncertainty is part of the data acquisition process: every device, even digital ones, collect data with a specific uncertainty. This aspect was reported by the teachers during the practice: the value of the magnetic field measured by the smartphone fluctuates rapidly and this required an adjustment of the acquisition procedure. The values of the field for each measurement could be only obtained by averaging the values recorded in a specific period of time. In this way, an error corresponding to the uncertainty of the mean was associated with each value of B_i.

Data elaboration process

The discussion generated around the problem of data elaboration was about how to fit the function that corresponds to the theoretical model (equation (4)). The spreadsheet used in schools (i.e. MS Excel, LibreOfficeCalc, GspreadSheet) give the opportunity to fit power functions, but some teachers noticed that it would be useful to have the possibility to fit the data using a function using multiple parameters like the following

$$\boldsymbol{B(x)} = \frac{\boldsymbol{k}}{\boldsymbol{x^b}} \qquad \text{or} \qquad \boldsymbol{B(x)} = \frac{\boldsymbol{k}}{\boldsymbol{x^b}} + \boldsymbol{c} \qquad (5)$$

where the parameter could be related to specific physics constant (k) or instrumental offset error (c). As suggested by some teachers during the group discussion, a possible way to tackle this problem is to use a “logarithmic version” of the function in equation (5): in this way the fit function becomes linear and data could be analyzed using familiar the least square method.

$$\boldsymbol{ln(B)} = \boldsymbol{ln(a)} - \boldsymbol{bln(x)} \qquad (6)$$

In this case the gradient of the line represents the specific power dependence of the field intensity on distance. As suggested by physics researchers who participated in the meetings, a parametric function fit could be easily done using Matlab or Mathematica. Unfortunately the licences for those softwares are out of the public school budget. A more affordable alternative could be the use of Phyton and its data analysis libraries like NumPy and SciPy or the Python module Pandas. As suggested by teachers, the Python programming language could be also an opportunity to interact with computer science teachers and ICT experts in school. In figures 4 and 5 there are two examples of data elaboration made by the teachers with the data collected during the laboratory activities.

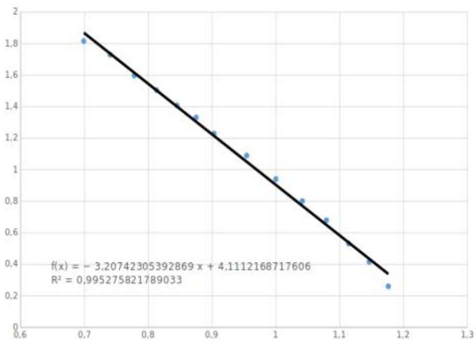

Figure 3. Graph from the data using *ln*(*B*) vs *ln*(*x*) with MSExcel

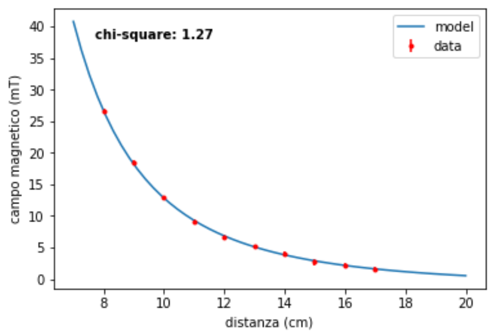

Figure 4. Graph of parametric function from data with Phyton

LEARNING EXPERIENCES 2: MODELS AND MEASURES

The second learning activity had been proposed by one of the teachers and was about the measurement of the time collision of a ping pong ball with a table (Oladyshkin & Oladyshkina, 2016). The same experiment as also been part of the project “Olimpiadi italiane della Fisica – Gara Nzionale, Prova Sperimentale 2018”(https://www.olifis.it/). This experience have been structured as a guided inquiry learning activity so the participants (divided in small groups of three) have to built a proper theoretical model to describe the physical phenomena in order to guide the measurement process during experimental activities. The inquiry question was about how to estimate the time of collision of a freely falling ping-pong ball and a table. During the activity a model of the collision process have been developed, identifying the physical variables that determine the system dynamics during the collision so the measurements have been taken in accordance with the theoretical model.

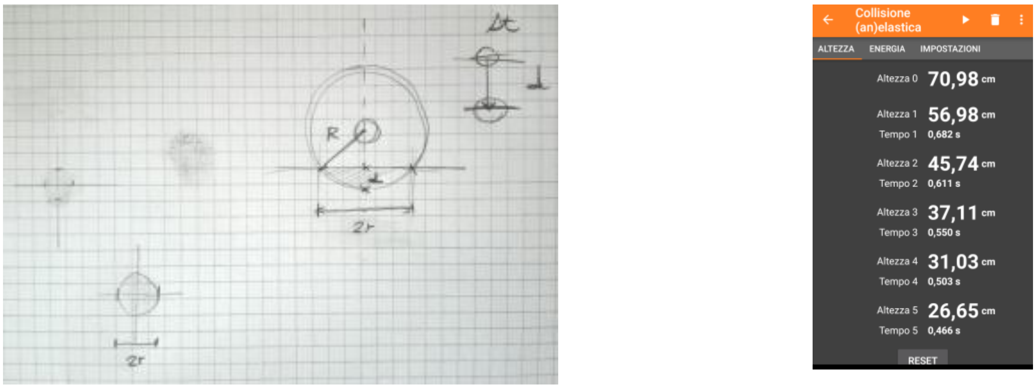

Figure 5. Teachers' notes during group activity and Phyphox App – (in)elastic collision

In the first part each group should explicit the hypotheses used to model the collision between the ball and the plane. The collision is not completely elastic so it is necessary to first determine the coefficient of restitution e_V . Due to the fact that the able is not moving, in this case e_V is the ratio of the velocity of the ball after and before the collision. Also assuming the mechanical energy conservation before and after the collision it possible to determine e using the following formula:

$$e_V = \sqrt{\frac{h'}{h}} \tag{7}$$

where *h'* and *h* are the vertical position of the ball before and after the collision. Using Phyphox "(in)elastic collision" app it is possible to perform multiple measurements of *h'* and *h* and get an estimation of e_V and its uncertainty. In the second part each group painted the ball using a pencil and directly estimate the diameter *2a* of the round shape imprint of the ball on a blank paper.

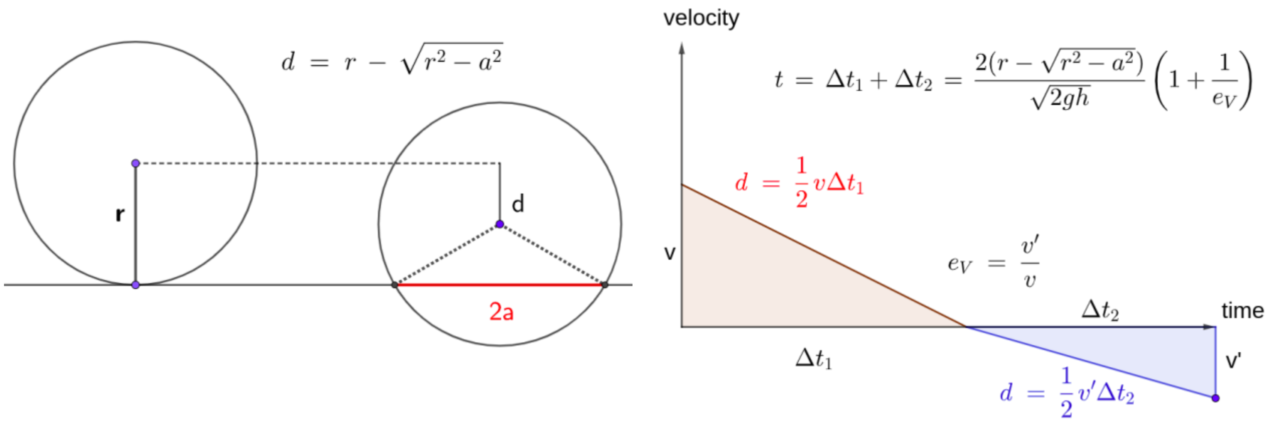

Figure 6: Collision process geometrical analysis and kinematics

In the last part the groups have discussed their conclusions comparing their results, in particular what kind of systematic uncertainty can affect the measurements.

In this activity the connection between the physical model and the measurement process is explicit in the way different theoretical hypothesis (i.e. uniform acceleration, neglecting energy dissipation, during the collision) have been used in order to have measurements sufficiently accurate to get a reasonable estimation of collision time. During the activity teachers have discussed on how to help students to understand the role of those hypotheses in determine systematic errors, generating an overestimation of the duration of the collision.

CONCLUSION

The collaboration between researchers and teachers is crucial to promote the development of science competencies. The activities presented in this paper have showed how school teachers are determined to improve the level of their teaching through collaboration. The meetings have been good opportunities to share teaching experiences and materials. The teachers agreed that high quality, scientifically-based learning activities need to be implemented into the curricular classroom activities and then become part of daily teachers' practices in order to be effective: in this sense teachers need to be more committed to the design of their curricular instructional laboratory activities and processes. On the other hand physics researchers need to foster that design process, promoting collaboration activities with teachers and supporting the creation of an active educational ecosystem.

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SCIENCE TEACHERS' PEDAGOGICAL DEVELOPMENT: FOCUSING ON LESSON STUDY

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This study examines how Japanese science teachers pursue pedagogical development. The research questions investigated were (1) what is 'traditional science teaching in Japan'?; and (2) how do Japanese science teachers acquire orthodox teaching values and intentions within their professional learning communities? We focused on 'lesson study', which is a comprehensive and well-articulated approach to examining teaching practices within professional learning communities. A literature review and three empirical research studies were conducted to answer these questions. Quantitative data from questionnaires comparing teachers in Japan and England were summarised in tabular form and statistical tests were applied. The results demonstrated that science teachers' pedagogical development reflects the culture in which they teach. Data sources included life story interviews with five experienced teachers and questionnaires completed by 177 science teachers, focusing on the topic of lesson study for professional development. Furthermore, the results demonstrated that science teachers acquired norms of the teaching profession and orthodox teaching values and intentions through lesson study. We suggest that, to challenge orthodox beliefs, it is important for teachers to recognise that lesson study is one of many effective vehicles for pedagogical development.

Keywords: Pedagogical development, teaching values, lesson study

BACKGROUND, THEORETICAL FRAMEWORK, AND RESEARCH QUESTIONS

Background

Dillon and Manning (2010) argue that science teachers' pedagogical development relates to their challenge of orthodox 'teaching values and intentions' (p. 14), which can be described as 'traditional science teaching' (p. 14). This means that teachers' pedagogical development is a sociocultural activity situated within a professional learning community, and is thus affected by professional norms.

What is traditional science teaching in Japan? As an example, let us consider the National Center for Education Statistics (NCES; 2006), which stated that Japanese science lessons at the eighth-grade level perform the following tasks: (1) focus on developing scientific ideas by making connections between ideas and evidence through an inquiry-oriented, inductive approach, in which data are collected and interpreted to formulate a main idea or conclusion; and (2) be conceptually coherent, with an emphasis on identifying patterns in data and making connections between ideas and evidence, and conducting practical work as a central role in developing main ideas. This is one typical way of teaching Japanese science lessons. Science teaching practices in laboratories and classrooms are partly based on the knowledge base and expertise of teachers. Japanese science teachers have engaged in 'Lesson Study or lesson study', a professional practice that has become deeply embedded in teachers' professional culture (Isozaki, 2015; Isozaki & Isozaki, 2011). Japanese teachers experience the system of lesson study since their pre-service teacher education (see Figure 1), recognising that their knowledge base and teaching competencies are enhanced through lesson study as a part of continuing professional development (CPD).

Theoretical Framework

This study focuses on two theoretical frameworks: first, the socio-cultural perspective of science teaching and science lessons, and second, lesson study (or Lesson Study) in the professional learning community. The NCES (2006) examined the science teaching of five countries through a video study and demonstrated that each country had a different approach to science teaching. This means that science teaching is a socio-cultural activity. Davis, Janssen and Van Driel (2016) reviewed the literature on science teachers and science curriculum materials and pointed out that much of the teacher-curriculum research adopts, either implicitly or explicitly, a sociocultural perspective.

Stigler and Hiebert's (1999) book introduced one reason why lesson study was an important key approach to obtaining a higher score in international comparisons, such as the Trends in International Mathematics and Science Study (TIMSS), which had a strong impact on Japanese educators. We focused on lesson study, which is a comprehensive and well-articulated approach to examining one's teaching practice that Japanese teachers engage in as an essential part of their CPD within their professional learning community. Of course, there are other vehicles for teachers' CPD, such as workshops, action research, and self-study. Isozaki (2015) highlighted the differences amng lesson study, workshops, and action research as follows. First, lesson study should be considered a process that begins with a research question driven by the participants, whereas workshops often begin with answers while being motivated by outside school experts. Second, lesson study emphasizes the process involving collaboration with colleagues (sometimes including outside advisors, such as professors and consultant teachers of local boards of education) and a common focus. In contrast, action research examines teachers' own teaching and students' learning by engaging in research projects in their classrooms, although working with colleagues is usually optional. They, therefore, can learn professional norms through lesson study as well as in schools. This is the reason why we focus on lesson study as the way in which Japanese science teachers challenge orthodox 'teaching values and intentions'.

Research Questions

This study investigated Japanese science teachers' pedagogical development from a sociocultural perspective. The following research questions were investigated: (1) what is 'traditional science teaching' in Japan; and (2) where and how do Japanese science teachers challenge orthodox 'teaching values and intentions' within their professional learning communities? Resolving these research questions will, therefore, contribute to the support of teachers' pedagogical development.

METHODS AND DATA

To address the research questions delineated above, we conducted a literature review on science teaching and lesson study from different sociocultural perspectives. First, we reviewed the literature on science lessons/teaching from international and sociocultural perspectives; for example, The Third International Mathematics and Science 1999 Study Video Study (NCES, 2016), Trends in International Mathematics and Science Survey (TIMSS) 2015 (Mullis, Martin, Foy, & Hooper, 2016), and Stigler and Hiebert (1999). Second, we reviewed the literature on lesson study from international and sociocultural perspectives; for example, Doig, Groves and Fujii (2011), Isozaki (2015), Isozaki and Isozaki (2011), and Lewis and Hurd (2011), Teaching and Learning International Survey (TALIS; OECD, 2014).

We then conducted the following three empirical research studies. First, we conducted comparative research on three dimensions of science teaching–science teachers' beliefs, approaches used in designing lessons, and methods used in teaching science–with 84 science teachers in lower secondary schools in Japan and 24 science teachers at comprehensive schools in England in 2013. The quantitative data from the questionnaires were summarized in tabular form, and statistical tests were applied (Nozoe & Isozaki, 2018). Next, we collected qualitative life-history data through semi-structured interviews with five experienced Japanese secondary school science teachers in 2015, whose teaching careers included more than 30 years of experience to investigate changes in their beliefs about the goals and purposes of science teaching over time. The life history interview data were analysed in terms of the Steps for Coding and Theorization (SCAT; Ueda & Isozaki, 2016). Third, we collected quantitative data in lesson study for Japanese secondary science teachers of all ages (N = 177) in Hiroshima by using a questionnaire survey with multiple choice and short essay questions conducted ion 2016 (Isozaki and Department of Science Education, and the Research Project Centre for the Next Generation Science Education, 2016; Ochi, Ueda, & Isozaki, 2018). We obtained permission from all teachers who contributed to any of these empirical studies.

RESULTS OF EMPIRICAL RESEARCH

Table 1 supports the findings by NCES (2006), Mullis, Martin, Foy and Hooper (2016), and Stigler and Hiebert (1999) that science teaching is a socio-cultural activity. By comparing the data from Japan with data from England, the results indicated that a science teacher's pedagogical perspective depends significantly on the country in which they teach. This demonstrates evidence that the educational culture of that country regulates science teachers' pedagogical development.

The results of the SCAT analysis of the interview data from the five experienced teachers demonstrated that 'the development of beliefs about the goals and purposes of science teaching throughout a teacher's professional career can be perceived as part of the science teacher's consecutive learning both inside and outside of school' (Ueda & Isozaki, 2016, p. 44). This means that experienced teaches initially participated enthusiastically in lesson study both formally and informally, aiming for self-improvement in their teaching, and to acquire the norms of the teaching profession.

Table 1: The most important learning objective in school science

Country	1. Skills of laboratory work and observation	2. Knowledge and understanding about science	3. 'Decision making' ability based on scientific evidence	4. Scientific thinking	5. Interest in science	6. Ability to explain scientifically	7. Investigation and inquiry	8. Relationship between science and daily life	9. Others
Japan (N=74)	3 (4.1)	9 (12.2)	11 (14.9)	10 (13.5)	16 (21.6)	1 (1.4)	4 (5.4)	19 (25.7)	1 (1.4)
England (N=17)	0 (0)	7 (41.2)	0 (0)	1 (5.9)	2 (11.8)	2 (11.8)	0 (0)	5 (29.4)	0 (0)
Total (N=91)	3 (3.3)	16 (17.6)	11 (12.1)	11 (12.1)	18 (19.8)	3 (3.3)	4 (4.4)	24 (26.4)	1 (1.1)

Note: Figures in parentheses are percentages of n or N values relating to each row.

(Source: Nozoe & Isozaki, 2018)

The questionnaire data demonstrated that 72.3% (N = 177) of the Japanese science teachers surveyed responded that they participated in lesson study for professional development in teaching and learning science. This trend was observed in the results of the TALIS, in which Japanese teachers reported higher-than-average participation rates (51%) for professional development in terms of observation visits to other schools (as compared to the TALIS average of 19%) (OECD, 2014). Through lesson study, teachers in their 20s to 40s indicated that they intended to learn how to conduct the 'research and development of new teaching materials' (*kyouzai-kenkyuu* in Japanese), and apply new teaching materials produced by others, while those in their 50s intended to learn new pedagogical methods in science. The data from the short essays on the preparation phase of lesson study demonstrated that teachers primarily concentrated on: (1) reflection on previous teaching materials, (2) development of new materials, and (3) development of a lesson plan according to students' understanding and skill levels.

DISCUSSION

What is traditional science teaching in Japan?

Generally, Japanese science lessons from elementary (the first to the sixth grade) to upper secondary school (the tenth to the twelfth grade) consist of three phases: introduction, development, and conclusion (Isozaki, 2015). As Stigler and Hiebert (1999) have observed, one of the main activities in the introduction phase is to review the previous lesson to grasp student understanding. The other important activity is to motivate students regarding today's lesson topic. The introduction phase generally takes up between five and ten minutes of the lesson time.

Japanese science teachers tend to consider the following questions during the preparation phase of lesson study and regular lessons: (1) Why is this unit's topic valuable to students?; (2) What do I want students to gain from this unit?; and (3) How can I provide a successful learning experience to students? To answer these questions, science teachers review their previous teaching and the resources gained through participating in the lesson study and other activities. They interpret the course of study, which is similar to the national curriculum and textbooks, as well as contemplate the scientific and educational values of the unit and teaching materials (Isozaki, et al., 2016).

At the beginning of the development phase, Japanese science teachers usually provide *one* question (*toi* or *hatsumon* in Japanese) extracted from today's topic; sometimes this question shares the same meaning as today's task, directly connecting students to the task before they engage in practical work. After providing this question, and before students embark on practical work, teachers often require students to work in a group or as individuals in forming a hypothesis or making a prediction. Indeed, the TIMSS 1999 video study (NCES, 2006) demonstrates that a higher percentage of Japanese students make a prediction as compared to students in Australia, the Czech Republic, the Netherlands, and the United States. According to the results of Isozaki et. al., (2016), and Ochi et. al. (2018), lower secondary school (the seventh to ninth grade) science teachers emphasize a set of objectives that should be achieved by learners in one lesson to formulate a question that is appropriate for the ability of learners. In designing a science lesson, they carefully consider the coherence between the objectives of the lesson, its *one* question, and the single conclusion to be drawn. Science teachers have to use various types of teacher knowledge, especially pedagogical content knowledge (PCK; Shulman, 1987) when formulating this question. It is noteworthy that Japanese science teachers recognise that formulating an adequate and appropriate question is one of the most important parts of designing a lesson.

After forming a hypothesis, students engage in practical work in conducting and resolving the task. Science teachers require students to collect and record data from practical work carefully. During practical work, science teachers must instruct each group, inspect their notebooks or worksheets to grasp their level of understanding and practical work data, as well as hear their 'thinking aloud' or 'muttering' (*tsubuyaki* in Japanese) as they walk around the classroom or between students' experimental desks. Doing this is considered as an important activity for teachers and called *kikan-shidou* or *kikan-jyunshi* in Japanese. If they discover that students (individuals or groups) are engaging in practical work incorrectly during walking around the classroom or between students' experimental desks, they must correct them accordingly. Of course, walking around the classroom or between students' experimental desks involves other important roles, including, for example, identifying students' degree of understanding, providing guidance to slower groups or students, and carefully observing that students are working safely. Science teachers can also grasp students' latent ideas by careful listening to their thinking aloud.

When engaging in practical work, students follow the worksheet created by the teacher. Some worksheets describe the practical work's objectives, procedures, and the point of discussion. After practical work, students are required to manipulate the data. According to the results of the TIMSS 1999 video study (NCES, 2006), Japanese and Australian students were guided by the teacher or textbook in manipulating data. Such practical work has been criticized as guided inquiry. Discussion after practical work leads to the development of a main conclusion or scientific idea as an answer to a question. Therefore, science teachers carefully consider the objectives of the lesson, leading question, and conclusion drawn, ensuring that they cohere appropriately. In other words, when 'making and revising a lesson plan' (*gakushuushidouan-sakusei* in Japanese), teachers create a narrative story or scenario for the lesson. The development phase generally takes up approximately thirty-five or forty minutes of the lesson.

In the conclusion phase, based on the results of practical activities, small group and whole-class discussions are conducted to pursue the development of one main conclusion; finally, the science teacher summarises the lesson. This conclusion phase takes up the final five to ten minutes of the lesson.

As a result of the analysis of the literature on science teaching in Japan, these processes can be identified as a typical Japanese science lesson from elementary to secondary school level.

Where and how do Japanese science teachers challenge orthodox 'teaching values and intentions'?

Where and how do Japanese science teachers learn this process of a typical science lesson? Prospective teachers experience the nuance of lesson study including the above-mentioned typical Japanese science lessons under their mentors during their short-term teaching practice in schools. After becoming a teacher, science teachers intended to participate in lesson study, which is deeply embedded in Japanese teachers' culture (see Figure 1).

Isozaki (2015) argued that lesson study should be divided into three phases, as illustrated in Figure 1: preparation, research lesson, and reflective meeting. The main activities at the preparation phase of lesson study include the research and development of teaching materials and making and revising a lesson plan. Research and development of teaching materials encapsulate these processes of internal didactic transposition, involving the important process of examining both teaching materials and the students' main activity task. Japanese lesson plans represent a teacher knowledge base, such as pedagogical knowledge, content knowledge, and pedagogical content knowledge, as proposed by Shulman (1987). Teachers believe that to design a good lesson, a teacher must create a question/task that will engage and motivate students (Isozaki et.al., 2016; Ochi et.al., 2018).

In the preparation phase of lesson study, science teachers consider scientific and educational values, reflect on their individual values as science teachers, and consider their students' learning perspectives, such as their needs and interests. If science teachers do not deeply engage in research and development of teaching materials that integrate both scientific and educational values and students' perspectives, there is no meaning for students in conducting the task, which would then be of no value to them (Isozaki, in press). As demonstrated by the results of our empirical research and the results of TALIS (OECD, 2014), Japanese teachers spend significant time on lesson preparation and learn from colleagues through lesson study. Lesson study helps to form a teacher/professional culture that provides opportunities to share the dominant values (Isozaki, 2015). The consideration of various educational values included in a lesson plan is key to a science teacher's role in designing lessons in Japan.

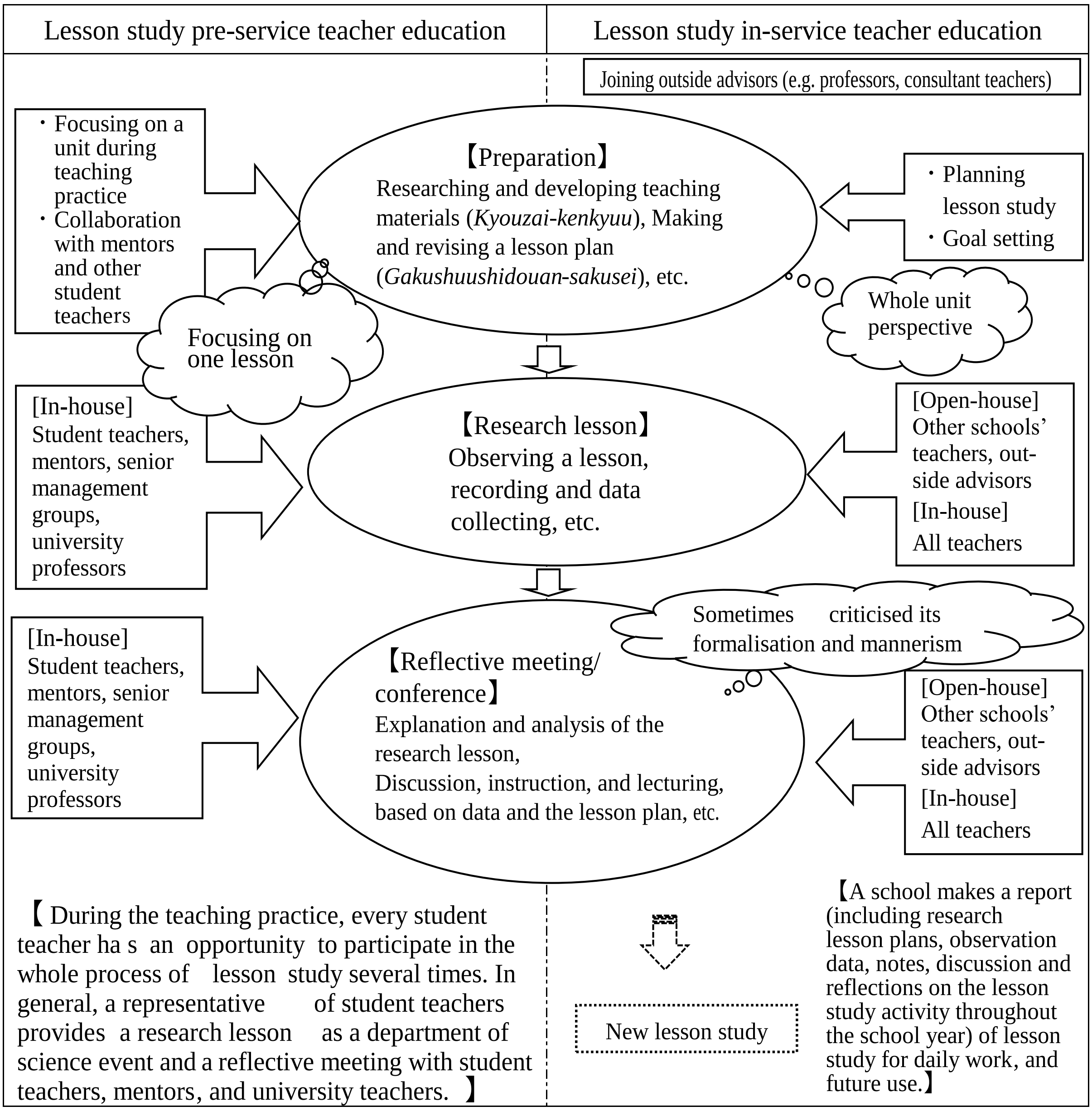

Figure 1: A typical process of lesson study in pre-and in-service teacher education

A research lesson in lesson study has similar processes to a regular lesson, with many science teachers employing an inquiry-based approach (Isozaki, 2015). However, while a science teacher will make and revise their lesson plans, as well as research and develop the teaching material for a regular lesson by themselves, collaboration with colleagues is a fundamental aspect of lesson study. Therefore, a science teacher conducting a research lesson will often consult with their colleagues–including senior school management and outside advisors, such as a professor–in the preparation phase of lesson study (Isozaki & Isozaki, 2011). Participants of lesson study carefully observe the research lesson with the revised lesson plan. While a reflective meeting is held with observers from within and outside the school after a research lesson, a reflective meeting is not held after every regular lesson. Therefore, science teachers need to reflect by themselves or through analysing students' achievements and performances, via notebooks, worksheets, and tests.

Consequently, Japanese science teachers can develop their teacher knowledge and skills within their professional learning community. By participating in lesson study, formally and informally, even experienced science teachers can learn from others and improve their teacher knowledge and teaching competencies.

Subsequently, traditionally, science teachers of Japanese secondary schools have the opportunities to share and learn professional norms and values within their professional learning communities, and to be able to challenge orthodox 'teaching values and intentions'.

CONCLUSION

Through lesson study within the professional learning community, Japanese science teachers can acquire the norms of the teaching profession and values in science teaching. As a result, they can challenge orthodox 'teaching values and intentions'. However, the standardisation of lesson study results in its stylisation (Isozaki, 2015). Therefore, to challenge such orthodoxy, it is essential that science teachers recognise that lesson study is one of the vehicles for science teachers' pedagogical development, and the values shared by science teachers sometimes are not up to date with the latest research trends. Using a comparative study, we need to consider other potential vehicles, such as self-study, to improve science teachers' pedagogical development from socio-cultural perspectives.

Isozaki, Isozaki, Kawakami, and Sawai (2015) demonstrated the qualitative and quantitative differences of PCK between novice and experienced science teachers and concluded that lesson study is potentially effective for developing teachers' professional knowledge base, and it must be an important vehicle for teachers' CPD. Despite its application history, neither teachers nor researchers seemed interested in investigating lesson study in Japan until Stigler and Hiebert's *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom* was published in 1999. Clivaz and Takahashi (2017) argued that theorizing lesson study could help researchers and teachers outside of Japan understand its specific cultural norms. As lesson study is embedded in Japanese teachers' culture (Isozaki, 2015), there is space for non-Japanese science researchers to identify social and cultural norms in the Japanese school context. This means that Japanese researchers and teachers have to provide sufficient information to educators outside of Japan who wish to design similar lesson study projects for professional-pedagogical development to challenge Japan's success rate.

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TRANSFORMING THE PEDAGOGICAL PRACTICES OF ETHIOPIAN PHYSICS TEACHERS FROM DIDACTIC TO DIALOGIC TEACHING

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This paper reports on the Transforming the Pedagogical Practices of STEM Subjects project (TPSS) which trialled and implemented a national intervention to change the prevailing lecture-dominated teaching practices of physics teachers in Ethiopia. 60 teachers in fifty upper-cycle primary schools (Grades 5-8) received training on the principles of scientific reasoning, argumentation and dialogic teaching. 80 video-recorded physics lessons from a sub-sample of 40 teachers were analysed quantitatively and qualitatively to examine the impact on pedagogical practice and physics learning of students, including a control group. In-depth interviews with participants were also conducted to glean teachers' views on the training provided, the contextual constraints and the impact on student learning. Findings show that the teachers who received the project combined training (pre-service and in-service) implemented the most significant pedagogical changes. This includes the adoption of a wider repertoire of talk and affording students with opportunities to engage in classroom activities. The contextual challenges facing Ethiopian teachers continue to have an impact on their abilities to deliver the intended aims of the learner-centered curriculum. Implications arise for the introduction of pedagogical practice interventions in low income nations

Keywords: Dialogic Teacher education, physics

INTRODUCTION

Within science classrooms, effective teacher talk plays a central role in maximizing students' abilities to learn scientific concepts and reasoning processes. Verbal classroom discourse and its importance in student cognitive, communicative, social, and cultural development have received much attention from researchers (e.g. Alexander, 2018; Kind, 2017). Teacher talk in science classrooms gains particular significance in contexts that are under-resourced, over-populated, and linguistically-diverse, representative of the Ethiopian context. Several studies concluded that a typical traditional classroom in East Africa (and beyond) is marked by the pervasiveness of 'triadic dialogue' or recitation recipe (Frost & Little, 2014; Lemke, 1990). This creates a closed circuit of communication referred to as Initiation-Response-Feedback or IRF structure and the ensuing teaching practices are dubbed 'didactic teaching' which often comprises one-way lecturing and closed teacher questions as brief evaluations. This is regarded as problematic because active student contributions are discouraged, contradicting socio-cultural learning theory, which suggests knowledge and mental functions are internalized through language and social interaction (Wertsch, 1991).

Over-reliance on didactic teaching may apply to any nation or school subject, but is particularly dominant in STEM subjects (science, technology engineering and mathematics) as these typically teach "facts" given to students. In the UK, for example, Driver and Newton (1999) found that on average more than 75% of teaching time in science classrooms involved passive listening, copying and performing set exercises. Teacher-student dialogue comprised only 13% of teaching time, and mainly involved teacher-led questions. In developing nations, such as Ethiopia, didactic teaching is even more dominant because class sizes are larger, resources are scarce, and cultural traditions set expectations for this style. This restricts and constrains students' learning, and impacts negatively on recruitment and retention in STEM subjects beyond compulsory schooling (Osborne, Simon and Collins, 2003). Developing nations rely on STEM subjects as means to build economic success, and transforming the pedagogy to become 'dialogic' is therefore important to ensure a better future.

The current study draws on disciplinary dialogic teaching, which has additional elements to dialogical teaching, rooted in the socio-cultural theory of learning (Vygotsky, 1978). The additional elements in disciplinary dialogical teaching draw on reasoning and argumentation typical to the science community. Scientific knowledge is the outcome of debate in the 'science community of inquirers' (Peirce, 1934). Science educators have adopted this (philosophical) perspective and merged it with socio-cultural learning to form a strand of research and teaching known as scientific argumentation. In scientific argumentation, focus is on accountable talk, which follows norms and criteria established in the science community (e.g. Driver, Newton, & Osborne, 2000; Duschl & Grandy 2008; Michaels, O'Connor, & Resnick, 2008). Disciplinary dialogical teaching, accordingly, combines Alexander's theory of dialogic teaching and the concept of scientific argumentation: dialogical teaching in science should reflect the cultural ways of arguing/debating that is typical to science. Intervention studies gathering empirical evidence about the influence of dialogical teaching on students' learning of STEM subjects demonstrate significant gains (e.g. Mercer, Dawes, Wegerif, & Sams, 2004; Osborne, Simon, Chistodouluo, Howell-Richardson and Richardson, 2013; Venville & Dawson, 2010). A key aim for dialogical teaching is establishing exploratory talk, which makes students' ideas explicit as a stepping stone towards further conceptual change and development (Mercer, 2008).

The rationale for introducing argumentation-based dialogical teaching in science education rests on claims that informal reasoning is crucial to science inquiry (Latour, 1987). Barmby, Kind & Jones (2008) indicate that students' attitudes to science declines as they progress through secondary education, suggesting that positive experiences in the upper primary/ lower secondary (as used in this project) stage are critical for retaining interest. Dialogue and argumentation permit resolution of misunderstandings, tests students' reasoning, and ultimately prompts satisfaction from learning correct concepts, particularly when directed by a pedagogically skilled teacher. Another theoretical rationale underpinning the study explains conditions for professional development of teachers. It is well respected that many approaches to teacher development has had little sustained impact and that in-service training do not automatically transfer to classroom practice (Opfer & Pedder, 2011; Cazden, 2001). Success depends to a large extent on establishing a practice of collaborative reflection within a supportive community focused on professional learning (Horban, 2002).

CONTEXT

The study was carried out in Ethiopia, which is a low-income nation with many economic, cultural and pedagogical challenges. Traditional educational reforms in Ethiopia focused on enrolment and capacity building i.e. “mass” rather than “elite” education (Woldehanna & Gebremedhin, 2016). In response to that and since 1994, the Ethiopian Ministry of Education (MOE) has designed and implemented a series of Education Sector Development Programmes, in which classroom pedagogy has been the main focus. Compulsory education in Ethiopia is comprised of 8 years of primary education from grades 1 to 8 (7-14 in years) followed by 4 years of secondary school education from grades 9 to 12 (15-18 in years) with both numeracy and language literacy forming its focus (MoE, 2011). Based on the results of their obtained marks in the national Grade 10 Exam, students can either continue to higher education or join vocational training including teacher education. A significant number of primary school teachers come from students scoring lower marks in Grade 10 exams (Joshi & Verspoor, 2013). In addition, secondary school students who fail their 12 Grade National Exam enrol in one of the Colleges of Teacher Education where both groups (graduates of Grade 10 and Grade 12) study the same curriculum for 3 years (Alemu et al, 2019). Since 1994, the Ethiopian MoE introduced and implemented four major teacher education reform initiatives with the aim of expanding, standardizing and improving the quality of teacher education provision across the country. Mixed results were reported on the success of these initiatives in transforming traditional lecture-based teaching to student-centered and active teaching and learning.

Starting from this context, the research study looked towards a teacher education programme for the upper cycle of primary education (Grade 5-8) and sought to answer the following questions:

- To what extent and in what ways does a programme for transforming pedagogy introduced in CTE and as CPD in primary schools, or a combination of these in Ethiopia improve pupils’ ability to reason scientifically?
- To what extent and in what ways does a programme for transforming the pedagogy introduced in Ethiopian CTEs and later in schools improve the teaching in primary schools towards disciplinary dialogical teaching? (Will pre-service teachers who have experienced and been trained in using dialogical teaching in ITE transfer this to their own teaching in schools?)

These research questions are related to the strategies of implementing disciplinary dialogical teaching into physics classroom, and if/how these works. We find it important to focus on changes in classroom practice and teachers’ orientation/thinking and not just students’ attainment. Improving attainment may have to go through many stages of development before we know more exactly which strategy is best, and to understand these intermediate stages we then have to learn from the changes that happens to practice and orientation. We also have to look at the wider perspective and take into consideration contextual factors.

RESEARCH METHODS AND DESIGN

Based on the study context, the study developed three models of training: the first was an initial training programme (pre-service) to implement argumentation-based dialogical teaching into physics courses in a three-year teacher education programme offered by Colleges of Teacher Education (CTEs) in Ethiopia. This was followed by the second training that introduced dialogic pedagogy through a programme of continuous professional development (in-service) to groups of teachers in schools. A third model arises from a combination of pre-service and in-service. This model provides pre-service and in-service to a cohort of teachers over two years, enabling impact on practice to be carried through from pre- to in-service.

The study used the same design repeated in two phases (CTE phase and school phase). It can be characterised as a quasi-intervention study, i.e. an intervention study, but without random allocation to the experimental and control groups. The present paper presents data from video-recordings of whole lessons in the school phase. These were captured simultaneously using two cameras, one recording the teacher with a fly-microphone, and the other recording the whole class. Each teacher in the treatment group was recorded twice, early and late in the academic year. Several sets of data are collected over two phases to investigate the extent to which the intervention enhanced teachers' pedagogic practice. Following candidates from Phase 1 to Phase 2, and dividing teachers in phase 2 into four groups (i.e. Pre-service, In-service, Combined and Control), allowed us to test the project strategies.

80 video-recorded physics lessons from a sub-sample of 40 teachers were collected and analysed quantitatively and qualitatively to examine the impact on pedagogical practice and physics learning of about 1200 students, including a control group. Data was analysed using NVivo 11 and SPSS. Another set of data came from interviews of each teacher after the lesson to ask about their rationales for and experiences of the teaching. Teachers in the experimental group also kept diaries of their lessons. Table 1 gives an overview of used methods, study samples and analysis.

Table 1. Overview of data collection and analysis in the school phase

Phase	Method	Sample	Analysis Procedure
Schools	Video-recording of whole lesson	N= 40 teachers 80 cross-sectional lessons	Recordings translated, transcribed and coded in NVivo with synchronised text and pictures. Quantitative data analysed using SPSS
	Teacher interviews	40 interviews	Narrative analysis used to identify and explore themes

Analysing the video recordings started with translating and transcribing dialogues into English using NVivo 11. Translation was needed because teaching was carried out in a mixture of English and Amharic. Next, transcripts were coded in the same software for time duration using a framework to identify different types of teaching (e.g. lecturing, working in groups, whole class discussions, teacher introducing lessons, teacher summarising lessons, etc.). The data was used to capture volume, i.e. percentage of lesson time spent within each category. We used NVivo for analysing the distribution and duration of teaching and learning activities based on self-developed framework e.g. how long time on lecturing (Rajab et al, 2018). The framework was designed to capture eight main categories based on a thematic analysis for a sample of 40 lessons. This was later statistically analysed using SPSS. During analysis, examples were extracted to illustrate answers to the research questions. Data was collected from a representative cross-sectional sample from many provinces across Ethiopia.

ANALYSIS AND DISCUSSION

Observational data from phase 2 of the study were analysed quantitatively and qualitatively. More often, treatment lessons show teachers demonstrating the intervention teaching, but teacher might exhibit more traditional teaching when not being observed i.e. the Observer's Paradox (Labov, 1994). Teachers, however, presented teaching material and their plans from all lessons and we did find the observed lessons representative of what most teachers did throughout the academic year. In the observed lessons, the average lesson time in the observed school lessons was 34 minutes. The longest lesson lasted around 50 minutes while the shortest recorded was 15 minutes (Figure 1).

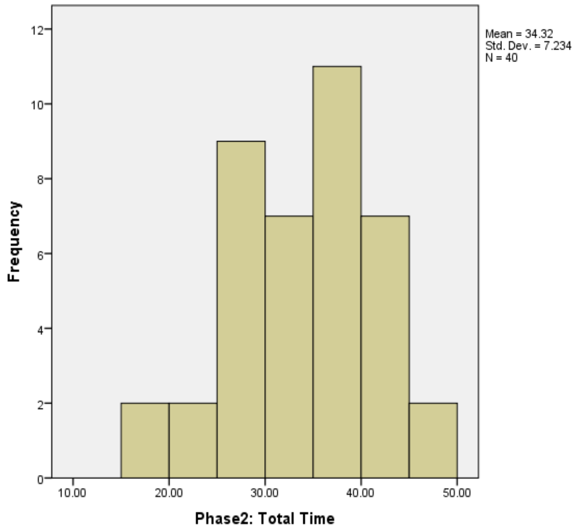

Figure 1. Phase 2: Average lesson time in observed schools

As shown in Table 2, treatment teachers significantly used more whole class dialogue than the control group. Intervention teachers spent more time in whole class discussion, demonstration and summarising student work. They demonstrated higher levels of engagement with the material, the available resources and students. In the control group, however, students spent on average 26% of class time carrying out individual seat-work such as copying the board silently or solving in-class homework. This was reduced to less than 10% in the intervention group. In the intervention group, student-led group work showed a significant increase up to 20% of the lesson time while this took less than 10% in the control group. Students in the intervention group were given more time to talk individually 13% while students' contribution in the control group did not exceed 5%. Lecturing at high levels, however, remains a persistent feature of the observed lessons across the two groups.

Table 2. % Lesson Time Spent on Different Teaching Activities at Schools (Ss: students; S: Student; T: Teacher, Intro: Introduce)

Group		Whole Class Dialogue	Group Work	Ss Seatwork	S Talk Individually	T Revise	T Summarize	T Lecture	T Intro
Control	N	10	10	10	10	10	10	10	10
	Mean	6.9	7.6	18.3	5.3	10.4	35.3	6.3	6.3
	Std. Deviation	6.6	15.6	20.9	8.8	5.5	21.3	3.1	3.1
Treatment	N	30	30	30	30	30	30	30	30
	Mean	13.6	18.7	8.7	5.2	9.3	35.6	5.4	5.4
	Std. Deviation	9.2	19.7	12.1	9.7	7.8	28.02	7.4	7.4
Total	N	40	40	40	40	40	40	40	40
	Mean	11.9	15.9	11.1	5.2	9.6	35.5	5.7	5.7
	Std. Deviation	9.04	19.2	15.1	9.4	7.2	26.2	6.6	6.6

Across the different teaching moves, the intervention group tended to engage students actively in whole class dialogue where scientific reasoning language was increasingly used e,g. how did you get to this answer? Intervention teachers allocated more time for both teacher-led and student-led group work. Students in the intervention group were noticeably afforded more time to express their views/responses while students in the control group spent more time either copying the board silently or solving problems alone. Within the intervention group, teachers showed improvements in balancing the different teaching moves where group work happened at a rate twice of the control teachers. In particular, the majority of intervention teachers managed to keep students engaged, thus avoiding the creation of 'silence pockets' during the course of the lessons. Silence pockets, where teachers chalk the board silently while students copy it, continued to be a major feature in the control group. Also, dialogic teaching, where teachers engage in a true whole class dialogue, was almost none-existing in the control group, but occurred in 11.45% of the time the treatment group as seen in Figure 2. Compared to control teachers, teachers in the treatment group spent more time on summarising tasks and lessons.

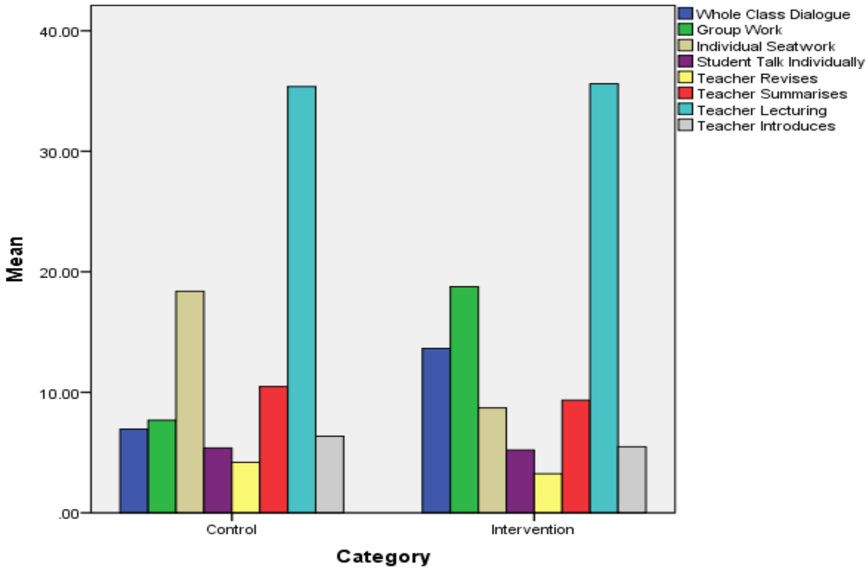

Figure 2. Percent of lesson time spent on different teaching activities at schools

For us, it became apparent that there are considerable changes in the pedagogical practices of intervention teachers as they noticeably reduced lecturing while giving students more space to talk and voice their opinions in the classroom. On the other hand, control teachers continued to use individual seatwork, marked by lengthy chunks of time where teachers were chalking the board silently or assigning tasks for individual problem solving in the classroom. Intervention teachers varied their teaching practices more and had a better balance across the class time.

While intervention teachers' practices changed to become more interactive, lecturing was still dominant across the whole sample as shown in Figures 2 and 3. With the exception of the combined group, lecturing continued to be the highest feature of pre-service and in-service groups. In the combined group, this was replaced with an even balance of teacher and student-led group-work. Even though lecturing (17%) was the third most recurring move in the combined group after group work (35%) and whole class discussion (21%), the control group was dominated by the lecturing at (35%) and individual seatwork (19%). Overall the three intervention groups managed to reduce individual seatwork in favour of diversifying the teaching activities to include granting students more time to express their views (student talk individually) or present their findings in front of the class, or summarising the main points.

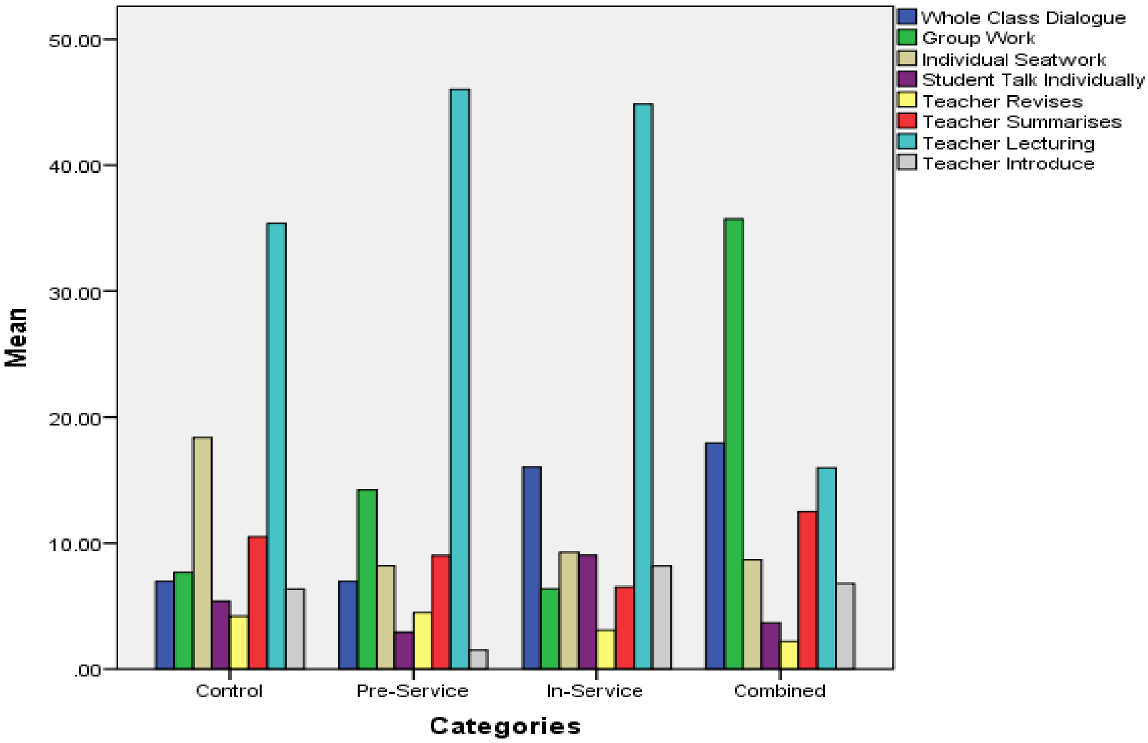

Figure 3. Teaching moves across categories in Phase 2

In discussing the results from Figure 3, it seems that the pedagogical practices of both the combined and in-service teachers were the most dialogic across the group while pre-service and control teachers were close in their use of whole class discussion practices. Individual seatwork was higher in the control group while in-service teachers exceeded other teachers across the whole round in giving individual students to talk more in the form of student presentation.

The video analysis showed a significant contrast between intervention and control teachers. While individual interventions teachers showed significant progress and pedagogical transformative features, the majority of teachers showed little signs of progress. Within the sample, teachers who received pre- and in-service (combined) and teachers who received in-service training were the most interactive and dialogic. In these two groups, teachers used high order reasoning and argumentation questions to probe the student learning process. Students were given the floor to voice out their opinions either individually or in small groups presenting in front of the class.

However, traditional pedagogical practices marked by unbalanced lengthy group work that in some cases occupied more than 65% of the class time prevailed in the control and intervention pre-service teachers. Within these two groups, teachers were not able to move away from the habit of silent chalking on board while students were passively copying the board.

Teachers from the combined group used open and reasoning-seeking questions (e.g. how, agree/disagree). They encouraged students to justify their responses by using why-questions or asking ‘what is your reason?’ In other cases, they asked students to think together by inviting other students to join the discussions. The majority of teacher questions from other groups (pre-service and in-service) continued to be mostly low-level re-call questions, aiming to check student basic understanding and test memorisation skills. The following example (Extract 1) illustrates a combined teacher’s use of good questioning techniques:

Extract 1. Excerpt from Teacher A's using some high-order questioning techniques

1	**T**	Discuss in your 1 to 5 groups. For example if a magnet is cut in two [Teacher is drawing on the board.] Now assume this magnet is cut into 2 parts. Then what will happen? Eve.
2	**T**	**What would you say happen if** a magnet is cut into 2?
3	**S**	[inaudible]
4	**T**	If it is cut north and south are cut, Yulia, do you agree with his assessment?
5	**T**	Do you agree? Badr, Rosa what do you think. Now this is a magnet. And if we cut it into 2 does it attract nails and other materials as it used to before. David what about you guys. Debate on this matter in your groups.

In the extract above, the teacher used a variety of high-order questions such as hypothesis-testing questions 'what would happen if'. He also uses agree/disagree questions encouraging other students to join the discussion. We also found that female teachers showed the most systematic progress with the deepest noticeable pedagogical transformation. The majority of teachers who were interviewed believed that more training would be good to enhance his understanding of dialogic teaching as they acknowledged the importance integrating such discourse in their practices. They believed that dialogic teaching enabled them come up with better questions and encouraged student critical thinking. In order to build on and internalise the pedagogical orientation introduced to intervention teachers, a top-up or refresher training between the two rounds of observation could have showed deeper and more consistent changes.

CONCLUSION

The analysis of the school data raised the main question about which educational strategy was most effective for changing the pedagogy and improving students' learning: training students in CTEs (Pre-Service), doing in-service training (In-Service) or doing both of these combined (Combined). The intervention comprised activities relating to physics concepts taught to 11 – 14-year olds. Data showed that teachers in the combined group presented the most significant changes to practice. Some teachers changed to use more scientific argumentation. Others changed a little and some not at all. There remains a gap between intended and attained curriculum in Ethiopian teacher education. This in turn leads to teachers' poor understanding of the subject matter. Education policy makers need to attend to bridging this gap in order to transform teaching within science subjects within Ethiopian schools.

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ADOPTING KNOWLDEGE BUILDING PEDAGOGY TO SUPPORT EPISTEMIC AGENCY AND COLLABORATVE CONTRIBUTION IN SCIENCE CLASSES: A CASE STUDY IN NEW ZEALAND SCHOOLS

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This paper draws on how secondary science teachers from three schools have helped to develop a Knowledge Building community with their junior classes. The following themes will be discussed:

Theoretical frameworks of Knowledge Building; adopting Knowledge Building as a pedagogy to support epistemic agency and collaborative contribution in science learning; initial findings of the research.

The aim of a Knowledge Building community (KBC) is to produce new ideas and knowledge, which is useful to, and useable by the community (Scardamalia, 2002). There is an emerging prospect for science teachers where teaching programmes could be developed for students to improve knowledge, even to create knowledge not just reproduce it. Knowledge Building has been described as a community process where students are empowered in knowledge creation as legitimate contributors (Lai, 2014). This phase of idea creation and improvement is at the heart of the Knowledge Building pedagogy.

Rather than teaching programmes demonstrating science content and verification, there was opportunity to participate in an inter-school collaborative project, gain critical insight into theoretical understanding about knowledge synthesis, and contribute to the approaches and innovations which have been the key in realising the objectives of the pilot study. A design-based research methodology was employed in the multi-site case of Year 9 (13-14-year-old students) studying science in their first year at secondary school. Qualitative data was collected from teacher interviews and professional learning meetings. Audio taped student recordings in class interactions were integrated into the analysis.

Integrating a Knowledge Building community into a science programme was both challenging and complex, however through the exploration on classroom pedagogy using the 12 KBC principles (Scardamalia & Bereiter, 2010), notable shifts were revealed in the quality of student discourse, informed sense making across curricular links and greater epistemic agency.

Keywords: Collaboration, knowledge building, epistemic agency

Introduction

Knowledge Building is a model developed by Scardamalia and Berieter (2003) to support students to be knowledge creators. Knowledge Building may be defined simply as the creating, testing and improvement of conceptual artefact, it is not confined to education but applies to creative knowledge work of all kinds (Scardamalia, 2002). Educators have long been advocating that young people will not be prepared to face the social, political, economic, health and environmental challenges in today's society and indeed the future (Collins & Halverson, 2010; Facer, 2011; Gilbert, 2005). It is argued that there should be opportunities for students to be able to not only share knowledge but invent new knowledge (Lai, 2014). Moje (2008) contends that students' understanding of how knowledge is created is perhaps as important as knowledge itself. Pellegrino and Hilton (2012) view 21st century skills as knowledge that can be transferred or applied in new situations. This transferable knowledge includes both conceptual knowledge within the explanatory domain of a discipline and also epistemic knowledge of how to apply knowledge in order to construct new knowledge. Where emphasis is placed on creating new solutions, new methods to solve problems rather than applying previously learned actions to solve new problems. Conventional teaching and learning centring on transmissive, routine, and reception of existing knowledge, will no longer be adequate in preparing our students to tackle multifarious and interconnected problems. Future-focussed pedagogies in science education should focus on supporting students to be innovative, explorative, and capable of building knowledge collaboratively as a class community or even further, as a community of classes. Consequently, future science education is charged with the responsibility to devise and develop pedagogies to increase young people's innovative capacity in order to meet the challenges of current times.

The Knowledge Building model

The Knowledge Building model stands out from inquiry learning and problem-based learning practices sometimes seen in science or modern learning environment programmes. On the surface, some of the features are similar to inquiry learning, and teachers can have difficulty in distinguishing between these two approaches. The Knowledge Building model goes further, to support students to go beyond sharing and reproducing knowledge. Lai (2014) maintains that the goal of Knowledge Building is to create new ideas and public knowledge communally. It builds a suite of student perspectives, gathering ideas and questions from all. There is an intentional phase of idea improvement, where students have opportunity to develop and create ideas. In this specific pedagogy, the students are supported to contribute their ideas as a community. A digital space is implemented into the learning and teaching programme to support the developing inquiry, where students post their ideas. Knowledge Forum, Moodle or Padlet web-based software have been designed and modified to support Knowledge Building using a set of scaffolding tools. Students can show their classmates their science inquiry over the entire course of lessons and to disclose new ideas created as they proceed in the topic. There is also opportunity for Knowledge Building classes from different schools to work on the same science inquiry, and potentially, whole school involvement to be developed across curriculum areas.

Young people as knowledge creators

Knowledge Building is a pedagogical model described by 12 principles (see appendix) developed by Scardamalia and Bereiter (2010). One of those clearly illustrates that ideas are improvable, able to be improved, and the setting is for young people to have the opportunity to perform this improvement practise as a community, rather than as individuals. Students take control of the inquiry, they are given autonomy to set, plan, have goals, engage in creating further questions and responses. It allows students to take over a significant portion of the responsibility for their own learning including planning, execution and evaluation. Another hallmark of the Knowledge Building model is that it makes an important distinction between learning and knowledge creation. For Bereiter and Scardamalia (2010), Knowledge Building is a means for students to create and develop communal ideas, however, it will also deepen individual understanding of content knowledge and help students become self-directed learners. Learning is seen as a personal, internal, cognitive process of knowledge representation for individuals, whereas Knowledge Building is an external progression of producing ideas, and where students collectively create and improve ideas, ideas are being treated as external, public artefacts (Lai, 2014). Gilbert (2017) reinforces the case that young people can be knowledge creators. She signals Knowledge Building does not focus on how disciplinary knowledge is constructed by experts, nor is it personal construction of content knowledge. Conversely, it provides a sense of autonomy for students to operate in a space between those concepts of personal construction and disciplinary knowledge.

Future-oriented capacities

An intention of future-oriented science education is developing knowledge with learners which considers implications for a human and potentially non-human society (Kurzweil, 2005). Scientific and future technologies come packaged with a variety of moral, political, ethical and indeed practical decisions. Future oriented examples could include: artificial intelligence, natural disaster relief, space travel, human genetic modification, synthetic life, nuclear fusion and renewable energies. Hodson (2010) urges the value of explicitly featuring socio-political contexts in science teaching programmes. Consecutively if current social and environmental problems are to be solved, there is necessity of future generations of scientifically and ethically literate citizens. As science teachers we can place prominence on using topics of personal and societal issues. This takes a much more future-oriented direction to help foster learner capabilities of personal construction using these topics of interest. My viewpoint, is that personal knowledge of socio-political contexts is an active, participatory practice, where learners construct ideas together, where they can make sense of different viewpoints, grapple with conflicting arguments and justify them. The Knowledge Building model develops these specific learner capacities of manipulating knowledge, and working collectively to create and improve ideas. The other important aspect of a future oriented capacity is for students to be encouraged to be responsible for other student's science learning. The Knowledge Building model does this specifically in terms of all student viewpoints are considered through community. Students can take roles in the inquiries, working in teams in the class with specific duties such as technician, researcher and director. They can support each other in the way they learn, using these roles.

Knowledge Building supports epistemic agency

A purpose of studying science defended in the New Zealand Curriculum (Ministry of Education, 2007), is for students "to use their current scientific knowledge and skills for problem solving and developing further knowledge" (MOE, 2007, p.28). Students determining what information is valid and reliable is a necessary part of becoming informed. Authentic scientific inquiry depends on making decisions about whether information is justifiable and posing questions to establish its validity (Barker, 2011). Students could use questions such as: How could we critique this evidence? How could we redesign this investigation to ensure we have not overlooked any issues that may compromise our findings? Scardamalia and Bereiter (2014) argue that Knowledge Building actively supports learners to have agency or the capacity to act and make decisions about knowledge. The concept of epistemic agency is where students have responsibility for the knowledge that they are investigating. This learner capacity to have awareness of and to have insight into the development of knowledge appears to be critical in both Nature of Science (Lederman & Lederman, 2004) and Building Knowledge ideologies.

What did Knowledge Building look like in the science classes?

Knowledge Building involves students using an inquiry progression of scaffolding and building ideas together as a class community (Scardamalia & Bereiter, 2010). This particular Knowledge Building community model developed by Lai (2014) required specific pedagogy that supported movement between analogue and digital experiences. In the early phase of the project students were encouraged to take on the role of knowledge creators, this was carefully discussed and integrated into the lessons by the teachers. Following this, students had experiences of real face to face practical inquiries, integrated with a set of digital affordances or possibilities offered by digital tools such as software programmes: Padlet, Moodle and Knowledge Forum. Prominence was placed on sharing questions and ideas collectively, using digital software. They drew on their experiences and were given opportunity through the digital mechanism to be able to communicate these. Initially the preliminary investigation inquiry involved a start-up question and associated background information, posed by the teacher or student, to evoke interest in a topic. The virtual discussion space was called a "view", and "notes" were posted by the students in the class, to develop a collective noticeboard which displayed the posted notes to all classmates. With support from the teacher students arranged the posted notes into themes, they refuted claims and acknowledged ideas from their peers. The view page simultaneously captured the questions and these were displayed from all members of the class. There was opportunity for small teams of students to collaborate together and consider specific sub-topics, developing side investigations to enable to respond to questions which they have been identified as significant. Other stages of the Knowledge Forum/Padlet/Moodle process were where students posed their own theories, they made notes, identified what they needed to understand, and had the opportunity using the digital medium to improve on the knowledge. Stages were communicated and viewed on specific pages of the software used. At these stages, students read literature; constructed real models with cardboard and paper; searched the internet for information; consulted their teacher/s; discussed their ideas with community experts; and conducted practical tasks. Students used the thinking prompts available or developed their own to support theory building or progressive problem solving.

Initial findings

The participating teachers in this pilot study identified six enablers that supported integration of a Knowledge Building community in their science class. These were signalled through a series of teacher interviews after the Knowledge Building programme was implemented, and from a final discourse where an agreed summary took place. First, teachers must have a good understanding of the Knowledge Building principles and know how to communicate these principles to their students. Without a good ***understanding*** of the Knowledge Building principles, teachers may use this approach just as a form of inquiry learning. Following discussions with the teachers-all commented that it was challenging process and it cannot be accomplished in a short time. The second was to encourage regular focussed episodes of ***evaluation*** where the students (working in small teams) would present to the class in a more formal manner what their current findings were. This was duration of a 30-45-minute progress meeting, usually each week, depending on class and teacher. Teachers noted that the students used this regular event to convey current ideas and questions; to discuss their digital view page; to develop their confidence in speaking to the class using the digital view page; to reflect on how they worked as a group; to use scientific language in the forum; and to hear alternative views on a topic. The students justified their opinions and discussed new questions that had arisen in their study. Students also noted the evaluation meetings as an important opportunity to talk about group dynamics, to call for any changes to the makeup of the teams. Third was ensuring that students had a clear understanding of topic purpose, that there was ***clarity*** around the learning context. Topic examples are as follows: How good is New Zealand's recycling program? Future space travel; and Keeping ourselves safe in a tsunami. Students had viewed for example, the introductory You-Tube clips and read the associated resources such as an introductory information pack that described the context and/or scenario. Teachers said it was important that students were acutely aware of the quality of posting onto the digital platform, and this meant time in class to develop the posts. Occasionally some students could be absent for a lesson or two, hence on return to class, they required an update from their working group. Fourth, that even though the classes had been divided up into small teams of two-three students, each team contributed to the class (see Appendix points 1 and 2) and there was responsibility to ensure all ideas were aired. Hence there was teacher expectation of a ***community of learners*** working together. Examples of this emphasis include: posters up in the room which stated expectations; PowerPoint slides discussing group roles; information packs which had guidelines about working as a team and as a class. Fourthly, each team had the responsibility of generating new questions, taking photos of their investigations, collecting ideas from each team member and writing up new ideas to show evidence that Knowledge Building progress was being made. This was logged into a ***knowledge portfolio***, one class used clear files for this purpose and the other two used digital software: Google classroom and Padlet. The knowledge portfolio showed evidence of ideas being shared. This resource had notes, reflections and the "digital views" from each group. Responsibility of regular updates was shared amongst the group members and this was a resource that the teacher took into consideration in terms of overall group progress. Finally, the teachers spoke fervently about the need to design a topic that had an ***open-ended*** context to it, this took time to prepare and plan for but the effort was rewarded by overall positive student engagement. It meant that some knowledge and investigations were highlighted as essential but teachers stressed the importance of encouraging diverging inquiries from the main context of the topic, where autonomy was apparent and that there was opportunity for students to pursue their own personal questions.

Conclusion

This pilot project confirmed that Knowledge Building communities could be developed in junior science classes through improved teacher understanding of the 12 principles. Integrating a Knowledge Building community into a science programme was a challenging shift in practice, however through the teacher's own exploration on classroom pedagogy using the 12 principles, this could develop and be a very practicable model to support future science learning at Year 9. Six enablers were identified by the teachers, and valid points have been made about the differences between inquiry learning and Knowledge Building; epistemic agency and collaborative contribution. The realisation this research has seen, means placing more faith and confidence in learners to help create knowledge within their class communities using carefully constructed classroom strategies and the use of a digital forum. This research also signals how classes integrating Knowledge Building can influence pedagogical teacher change. It is an area of science education that has opportunity for further investigation.

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Appendix

Scardamalia (2002) identifies twelve principles of Knowledge Building as follows:

1. Real ideas and authentic problems. In the classroom as a Knowledge Building community, learners are concerned with understanding, based on their real problems and observations in the real world.
2. Community knowledge, collective responsibility. Students' contribution to improving their collective knowledge in the classroom is the primary purpose of the Knowledge Building classroom.
3. Improvable ideas. Students' ideas are regarded as improvable objects.
4. Idea diversity. In the classroom, the diversity of ideas raised by students is necessary.
5. Rise above. Through a sustained improvement of ideas and understanding, students create higher level concepts.
6. Epistemic agency. Students themselves find their way in order to advance.
7. Democratizing knowledge. All individuals are invited to contribute to the knowledge advancement in the classroom.
8. Symmetric knowledge advancement. A goal for Knowledge building communities is to have individuals and organizations actively working to provide a reciprocal advance of their knowledge.
9. Pervasive Knowledge Building. Students contribute to collective Knowledge Building.
10. Constructive uses of authoritative sources. All members, including the teacher, sustain inquiry as a natural approach to support their understanding.
11. Knowledge Building discourse. Students are engaged in discourse to share with each other, and to improve the knowledge advancement in the classroom.
12. Concurrent, embedded, and transformative assessment. Students take a global view of their understanding, then decide how to approach their assessments. They create and engage in assessments in a variety of ways.

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GREEK SCIENCE TEACHERS' TPACK EXPRESSION FOLLOWING PROFESSIONAL DEVELOPMENT

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In the present study it was attempted to inquire science teachers' practices after being trained by Greek B' level professional development program concerning ICT integration. Class observations and respective interviews were used as research tools and were set in correspondence with TPACK model. Our goal is to present the outcomes of B' level and inquire the implementation of virtual labs and applets by trained science teachers and the context where this implementation occurs. The data analysis showed that science teachers have understood the use of these tools and actually implement them while recognizing their advantages. Moreover, they prefer that this implementation takes place in inquiry based teaching, following a teaching scenario.

Keywords: Professional development, TPACK

INTRODUCTION

Contemporary professional development programs (PDP) in ICT integration focus in the pedagogical exploitation and integration of ICT in classroom teaching since several studies have shown that effective teacher preparation is an important factor for successful ICT integration in education. (e.g. Giovannini et al 2010).

In Greece, since 2006, science teachers (among other teachers) are being trained by a multi-year and nation-wide professional development program (PDP) called B' level, concerning ICT integration in class provided by face to face or hybrid forms (B' level, 2010, Psillos & Paraskevas, 2017). Similarly to other PD programs (Voogt, Tilva & van den Akker, 2009, Shin et al, 2009, Hong & Stonier, 2014), the content and structure of B' level for science teachers is based on the well known TPACK model which provides for an integrated framework of professional knowledge which teachers have or should develop for effective ICT classroom integration. According to this model the interaction of Technology, Pedagogy and Content factors is a complex process related to synthetic forms of professional knowledge. TPACK is a powerful model used not only as a heuristic for course development but also for research aiming at investigating teachers' practices and implications of PD programs (Chai, Koh & Tsai, 2010).

Voogt, Tilya and Van den Accer (2009) in their research, intended to determine –with class observations- the extent to which trained science teachers were able to practice what they learned during their PDP about the integration of Microcomputer Based Laboratories (MBL) in inquiry based teaching. They, actually, concluded that trained teachers were able to create a classroom environment based on guided inquiry integrating MBL (ICT) which was appreciated by their students as more investigative. In another research, Shin et al (2009) aimed at examining –with class observations too- how teachers (trained by a PDP where they had to work on a range of assignments that required them to learn and use ICT in multiple pedagogical contexts) understood and showed in practice the interaction between technology, content and pedagogy. They find out that teachers gained a deeper understanding of how technology related to other aspects of teaching and they observed changes in teachers' knowledge, noting that this knowledge can have an effect on their practices. Similarly, Hong and Stonier (2014) in their study on whether TPACK understanding helps teachers –trained by a PDP which had as a goal to educate teachers on how to effectively integrate GIS technologies in their teaching by providing technological, pedagogical and content knowledge- integrate ICT, came to the conclusion that teachers integrated GIS in their teaching and this TPACK- based PDP was largely successful at helping them proceed.

In Greece, the content and structure of B' level program for science teachers which is based on TPACK, include: knowledge and applications of pedagogic approaches (mainly inquiry), familiarization and use of contemporary software (such as simulations, virtual labs and web based tools) and their added value (Psillos & Paraskevas, 2014), knowledge and skills about designing activities, worksheets and teaching scenarios integrating ICT.

This research is part of a multi level research program aiming at studying secondary science teachers' perceptions and expression in practice of their TPACK following their attention of B' Level PDP. The present study focuses on the "face to face" form which includes 96 hours of courses (for the General Pedagogical part and for the Specialization in Teaching Science ICT part), 24 hours of preparation and reflection practice and 24 hours of actual teaching (Samanta & Psillos 2015).

In our previous studies detailed elsewhere we used large scale questionnaires and in-depth interviews (Samanta & Psillos, 2015). In the present study, we report results of classroom observations and of the respective interviews, aiming at revealing the expression of teachers' TPACK in science teaching after attending the B level PDP.

METHOD

18 science teachers who had participated in B' level PDP agreed to have their teaching using ICT observed. Class observations were held in different schools during one didactic hour. Class observations were carried out using a special record tool- rubric that was designed according to TPACK model and after analyzing other similar rubrics. We decided to proceed to the linking of parameters observed to TPACK model according to Joyce, Weil & Calhoun (2011). The rubric was piloted and the feedback was taken into account. It was sent to a panel of TPACK experts (3 phd teachers and 2 school consultants) who evaluated the linking between the parameters and TPACK model. A special rubric was developed as well in order to be used during the respective semi-structured interviews. The interview questions were linked to TPACK, similarly to Jimoyiannis (2010) linking. For example, when asking if a science teacher was familiarized to virtual lab interface, the research aimed at revealing science teachers' TK but when asking why this virtual lab was used in this context in class, the research aimed at revealing the interaction between all TPACK's components. It is important to note that, following B' level's policy, the term TPACK wasn't mentioned to the participants so as not to

cause any agitation. After the completion of the observations and the interviews, the two rubrics filled for each participant were merged into one so as to gain an overall image of every teacher's practices. The 2 researchers discussed about the data, analyzed them and the linking between what teachers did (observation data) and what they think they did (interview data) and TPACK model emerged.

In order to better understand the research data and results, we must note that B' level focuses on promoting ICT integration to teachers who were taught and keep teaching in traditional way, who have limited access to equipment (usually 1 pc and projector per class and occasionally laboratories) and who have to follow a very stipulated curriculum. It is important to check and discuss the outcomes of B; level professional development program in such context and under specific limitations.

RESULTS

The observation and interview results were categorized according to TPACK's components which were merged for the sake of brevity (PK with PCK and TK with TCK).

Participants' technological and technological content knowledge (TK & TCK)

It was observed that the majority of science teachers employed virtual labs, simulations and applets which were taught to them during B' level and exist in national data bases. Few of them, in their interviews, mentioned that had searched the web for different applets and simulations suitable for their teaching and this was confirmed in our observation. They were familiar with virtual lab's and simulations' interface and certain affordances showing evidence of Technological Knowledge (TK). However, they did not fully exploit the affordances of these tools and this was confirmed in their interviews. They also admitted not being fully informed about all virtual labs potentialities and that every time they were occupied with them, they were finding new potentialities. So, they expressed the need to dedicate a lot of time, in order to get more familiarized showing evidence of evolving Technological Content Knowledge (TCK) based on B' level instruction. A trainee noted: *"I often use the virtual lab in class but for this, I spend a lot of my spare time searching for its features. I think I'm in the middle of the road and need to keep working and working…"*.

Participants' pedagogical and pedagogical content knowledge (PK & PCK)

Regarding the teaching approaches (pedagogical component- PK), almost all science teachers promoted group work to their students. We must note that teaching took place in science labs where there was only one pc and one projector. It is worth mentioning that the students participated in interactive presentations and manipulated software alternately due to equipment limitation. In their interviews, teachers expressed their preference to less traditional teaching, although they admitted keeping traditional elements. A trainee characteristically mentioned: *"It needs a lot of effort to change something so deep. I was taught traditionally and keep teaching this way but I try to reduce it. I think someday I will manage to do so."*

Most teachers, while interviewed, considered that their teaching is characterised by a high degree of freedom. Observations showed that they mainly applied guided inquiry teaching. Moreover, they stood up for inquiry based teaching, claiming that they believe it's suitable so as to reach the expected cognitive goals, expressing this way their pedagogical content knowledge (PCK) and mentioned having as a goal to find the way to apply inquiry to their teaching more often. They also expressed the need to be more trained about inquiry by PDP.

Participants' technological pedagogical content knowledge (TPACK)

The inquiry based teaching was linked by the interviewees to ICT integration. We must note that they mentioned using ICT in class in an inquiry based context in few occasions in a month due to equipment or time limitations. Except one teacher who kept his traditional habits, all the rest promoted inquiry and the majority gave their students a worksheet that was part of a teaching scenario with inquiry elements. All worksheets let their students observe, wonder, estimate and conclude. Thus, teachers found the way to express the interactions between all TPACK's components. Notably, they didn't find it necessary to depict this interaction in a written scenario as only some teachers had one, while the rest mentioned not having one by choice, even though they created a scenario data base during B' level. They noted that it makes them feel restricted and less free to change their teaching based on their students' needs.

CONCLUSIONS – SUGGESTIONS

One limitation of this study is that participants were observed only one time given the restrictions of schools' time table and comprised a convenient sample among the trained teachers due to difficulties in reaching classrooms employing ICT. Within such limitations, it seems that teachers are in a transitional phase, where B' level PDP helps them not only to increase their ICT integration but to evolve their teaching of science. Greek science teachers often use traditional teaching but prefer a well-designed "activity" idea –in an inquiry based teaching context- that encourages learning as a process linked to the curriculum context, which they employ occasionally, similarly to Voogt et al (2009). These results were relevant to the results of our previous research that showed that teachers' preference towards traditional methods has decreased and the preference towards the inquiry based has also increased (Samanta & Psillos 2015). Such a conclusion is an indication of considerable teachers' evolution since previous studies in Greece (Demetriadis et al, 2003) and in Russia (Nikolaev & Chugunov, 2012) showed that trained teachers had the tendency to adjust ICT to support traditional teaching but, in our present research, teachers made serious attempts in changing their traditional teaching. It is worth mentioning that the teachers admitted having hard time overcoming traditional methods. Besides, it is noticeable that, within external limitations, due to limited resources, the teachers of the sample employed interactive presentations in order to promote students' engagement showing flexible adaptation of pedagogical knowledge (PK).

Observation showed that the level of ICT integration via activities, worksheets and scenarios was impressively raised by the trained teachers who had planned integration of ICT in their teaching and they used activity worksheets. Yet, they preferred not to have a written scenario, although they were trained to develop them. One explanation is that written scenarios are time consuming and restrictive as mentioned in Samanta and Psillos (2018). This is something to be further searched. Such evidence show expression of aspects of TPACK but also limitations. Similarly, Drossel, Eickelmann and Gerick (2016) mentioned that more than half teachers interviewed (from Germany, Poland, Netherlands, Denmark and Australia) find that there is no time for preparing ICT infused lessons and Hong & Stonier (2014) suggested providing premade lessons due to lack of time.

Listening to the science teachers and their needs, we suggest that the upcoming B' level programs promote more clearly inquiry based teaching and give science teachers the fundamentals to apply inquiry. Moreover, teachers who have been trained need to have continuous support by the PDP because tools and pedagogical ideas are evolving and teachers' knowledge should be up to date. More class observations are in progress in order to compare the everyday practices of teachers trained in previews B' level programs and the practices of newly trained by B' level teachers.

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USING PRACTICAL WORK EFFECTIVELY IN THE SCHOOL SCIENCE LABORATORY: A TEACHER TRAINING PROGRAMME BASED ON THE LEARNING COMMUNITY APPROACH

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This study describes the design and implementation of an in-service teacher training programme for high school teachers aimed at improving their competence in the use of the laboratory for physics education. A framework for designing the programme was constructed based on PER literature, containing the following features: linking content, practice and research; action research; focus on teachers' beliefs; sufficient duration; and the learning community approach. The intervention aligns with recent international recommendations, and in particular with the need of providing teachers with meaningful, research-based professional development on inquiry teaching and opportunities to work collaboratively. Data for the evaluation of the programme were obtained using multiple instruments. The results suggest that all the identified features were effective, with action research and the learning community approach being decisive for promoting real change.

Keywords: Communities of Practice, In-service Teacher Training, Practical Work in Science

INTRODUCTION

In recent years, a renewed attention to the role of the laboratory in science education has been acknowledged not only by research (Hofstein & Lunetta, 2004; Rundgren, 2018) but also by several international reports and standards. A milestone was the document known as 'Rocard report' (Rocard et al., 2007), that called for "A reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods" (p. 2). The National Research Council clarified the meaning of inquiry teaching by identifying eight 'scientific practices' that should be developed in the classroom together with disciplinary core ideas and crosscutting concepts (National Research Council [NRC], 2012), and, more recently, the National Academies of Science, Engineering, and Medicine recommended that 'investigation should be the central approach for teaching and learning science' (National Academies of Science, Engineering, and Medicine, 2019, p. 5).

Despite the emphasis placed on inquiry education, the term 'inquiry' is often misunderstood and confused with simply proposing 'hands-on' activities (Crawford, 2014; Osborne, 2014). In contrast, effectiveness in the use of laboratory activities is only achieved if they are well-designed, their purpose is clear, and they are embedded in a carefully planned teaching-learning sequence (Abrahams & Millar, 2008; Millar, 2010; NRC, 2006). The situation is complicated by issues such as the inadequacy of laboratory facilities, classroom organisation, and the need to comply with national standards (Nivalainen, Asikainen, Sormunen, & Hirvonen, 2010).

This situation calls for a reflection about teacher training. Many teachers have had little personal experience in the lab in their education and pre-service training (Yalcin-Celik, Kadayifci, Uner, & Turan-Oluk, 2017) and, on the other hand, few in-service teacher training programmes address the problem specifically using the results of research in physics education (NRC, 2006). For these reasons, actions should be taken in order to provide teachers 'with appropriate instructional resources, opportunities to engage in sustained professional learning experiences and work collaboratively to design learning sequences, choose phenomena with contexts relevant to their students, and time to engage in and learn about inclusive pedagogies to promote equitable participation in science investigation' (National Academies of Science, Engineering, and Medicine, 2019, p.6).

In the light of these considerations, this study aims to provide insights into the following research question: *What features should an in-service teacher training programme have in order to promote an effective use of the school science laboratory, and which of these features are most effective?*

THEORETICAL BACKGROUND

A meaningful model for successful teacher training was proposed by Adey, Hewitt, Hewitt, and Landau (2004), who identified the following characteristics: theoretical justification (research-based); high quality (sufficient duration, coherent methodology, intense/engaging activities, tutoring for implementation); support by the school management; and sharing with colleagues. However, according to many accounts, teacher training courses are often short and factual in nature, which is unlikely to promote real and long-lasting change (Gilbert, 2010; NRC, 2006).

Desimone (2009) identified five 'core features' for effective teacher training, based on the results reported in previous literature: content focus; opportunities for teachers to engage in active learning; coherence between teacher learning and their knowledge and beliefs; sufficient duration; collective participation. In a comparative study, Capps, Crawford, and Constas (2012) investigated the effectiveness of the above-mentioned features in the context of professional development (PD) on inquiry, considering 17 PD programmes. Their results show a general alignment with these features, but also suggested a need of additional research into PD programmes on inquiry, in order to identify which features are more effective in this context.

In recent times, the topic of collective participation has been emphasized and expanded by focussing on teachers' collaboration. Some benefits of teacher collaboration are improved instructional practices, improved student learning, and a better breeding ground for innovation (Vangrieken, Dochy, Raes, & Kyndt, 2015). A structured, bottom-up approach to teacher collaboration are *learning communities*, or communities of practice (Wenger, 1998; Vangrieken, Meredith, Packer, & Kindt, 2017). Even in the context of science education, research suggests that learning communities can promote authentic innovation (Couso, 2008), and a number of teacher training programmes have been developed according to a learning community paradigm (Singer, Lotter, Feller, & Gates, 2011; Lotter, Yow, & Peters, 2014).

Another aspect that has received attention recently is action research (Gilbert, 2010; Laudonia, Mamlok-Naaman, Abels, & Eilks, 2017). Teachers engaging in action research identify a problem relevant to their context, formulate a research question, select the data they need to answer it, design and implement some actions, evaluate their results and draw conclusions in order to identify new research questions. Action research is particularly effective when practitioners are supported by experts who put them in contact with research results, provide coaching and feedback, and offer emotional support (Gilbert, 2010). A positive intercorrelation between action research and the learning community approach has been suggested (LINPILCARE project; Mamlok-Naaman, 2018).

RESEARCH DESIGN AND METHODOLOGY

Based on the background described above, we outlined a revised framework for our teacher training programme. Specifically, we identified five core features, the effectiveness of which was the core of our research question and was investigated using multiple methods and perspectives as described below. Based on the revised framework, we designed a programme, named 'CoLLABORA – a Community of Learners on LABORAtory work', which was implemented between May 2018 and June 2019.

Revised framework

Developing on Desimone's 'core features' we identified a revised set of five 'core features'.

Linking content, practice and research. Laboratory activities was contextualised into the topic 'waves and their applications', one of the core ideas of physics education (NRC, 2012). We proposed and discussed research-based activities and participants had the opportunity to design their own activities. We also discussed the purpose of laboratory activities into a teaching-learning sequence, the construction of effective laboratory worksheets, some issues related to assessment, and specific disciplinary and didactical issues about the topic.

Action research. Each participant designed his/her own action research project to be applied in their classroom. Two sessions at the beginning of the course were devoted to formulating an investigable research question and writing an action research plan. Opportunities from feedback and coaching were given throughout the course.

Focus on teachers' beliefs. We focussed on *self-efficacy beliefs*, i.e. context-dependent judgments about being able to perform a particular task and obtaining the desired outcomes (Bandura, 1986). Teachers who have a high sense of efficacy are more likely to teach effectively (Tschannen-Moran, Hoy & Hoy, 1998; Crawford, 2007; Lotter et al., 2018; Chicherkian, 2016). During the programme we monitored these beliefs using specific instruments.

Sufficient duration. The programme featured 45 hours of contact time over one year.

Learning community. We set up the group as a learning community, sharing expectations, goals, rules, and style. Participation of teachers from the same school was encouraged.

Methods

In order to gain information from multiple perspectives, we used a variety of instruments:

Individual questionnaires. An individual questionnaire was delivered at the beginning and at the end of the programme. The initial questionnaire investigated the participants' background, their use of the laboratory, the presence and characteristics of their school laboratory, their expectations about the programme and their knowledge of the learning community approach. The final questionnaire investigated if and how the participants' use of the laboratory had changed during the course, in which dimensions (physics content, use of practical work, etc.) they thought they had improved the most, what activities they had found more useful, the extent to which the learning community was helpful, and how much the course met their expectations.

Focussed group interview. At the end of the programme, a semi-structured focussed group interview was led, containing five questions: (1) What were the advantages of discussing laboratory practices within a specific disciplinary content? How did research results contribute to enhance the discussion about the use of the laboratory? (2) To what extent, and how, engaging in action-research was useful in order to enhance the use of the laboratory at school? (3) To what extent are self-efficacy beliefs relevant in enhancing the use of the laboratory? (4) To what extent was the course structure (duration, meeting schedule, etc.) relevant to promote enduring change in your practice? (5) What was the added value of setting up our group as a learning community and in what ways did this approach influence your practice?

Teaching Science as Inquiry test. We used the Teaching Science as Inquiry (TSI) test (Smolleck, Zembal-Saul, & Yoder, 2006) for assessing changes in the participants' self-efficacy beliefs about inquiry teaching. Consistently with Bandura's (1986) construct of self-efficacy, the TSI explores both personal self-efficacy (the belief of being capable of doing something) and outcome expectancy (the belief that teaching will have a positive outcome). Moreover, it allows assessing different dimensions and levels of inquiry (NRC, 2000).

Individual action research reports. At the beginning of the programme, each participant formulated his/her own research question and developed an action research plan. During the last meeting, each participant presented a report about their action-research project.

Participants

The programme involved 15 teachers from 11 secondary schools (grades 9-13). Most of them (9) had a degree in Mathematics, while the others had a degree in Physics (3), Engineering (3) or Astronomy (1). The participants' teaching experience ranged from 5 to >20 years.

Programme schedule

The programme, named 'CoLLABORA - A Community of Learners on LABORAtory work', was delivered between May 2018 and June 2019. Table 1 summarises the schedule and content of the meetings. In-between the meetings, collaborative online activities were proposed via the Moodle platform, which also contained all the course resources and a 'course journal'.

Table 1. Programme schedule and content.

Date	Topic/activities
May 11th, 2018	Learning community setup. Pre-course administration of the TSI test. Analysis of a research-based laboratory activity.
May 18th, 2018	Laboratory activity on ray optics + discussion.
September 7th, 2018	Laboratory activity on mechanical waves. Formulation of personal research questions + feedback from peers and researchers.
September 14th, 2018	Didactical issues about 'waves and their applications'. Design of personal action research plan + feedback from peers and researchers.
October 12th, 2018	Disciplinary and didactical issues about 'mechanical waves'. Reflection on scientific practices. Laboratory activity on standing waves + discussion.
November 9th, 2018	Disciplinary and didactical issues about 'sound waves'. Laboratory activity on sound waves + discussion; focus on the use of technology.
December 14th, 2018	Visit to the Museum of the History of Physics and discussion/reflection on learning in out-of-school contexts. Group work on the different purposes of laboratory activities into a teaching-learning sequence.
January 11th, 2019	Reflection+discussion on the assessment of practical work. Co-design of a laboratory activity on ray optics.
February 15th, 2019	Laboratory activities on wave optics according to the three types of experiments + discussion.
March 8th, 2019	Laboratory activity on light sources and their spectra + discussion.
April 12th, 2019	Laboratory activity on atomic spectra + reflection/discussion on the didactical issues of modern physics.
May 10th, 2019	Final workshop: each participant presented the outcomes of his/her own action research project.
June 7th, 2019	Final focussed group interview.

RESULTS

General outputs of the programme

According to the individual questionnaires, 70% of the teachers changed their use of practical work at school since they had started the course. Self-reported changes include using different kinds of activities, adopting a more open inquiry, and developing improved didactic and assessment tools. Besides gaining a better understanding of the role of practical work in physics education, participants also think they became more capable of designing a laboratory activity. The most appreciated activities during the programme were experimenting and constructing research-based experiences. Participants also valued the active engagement, the connection between physics content and scientific practices, and the collaborative approach.

Effectiveness of the five features

Below we report our results with respect to the five features of our framework.

Linking content, practice, and research. The participants considered useful to include the reflection on the laboratory into a content strand that is central throughout the curriculum. The use of research-based materials was relevant 'in order to qualify [their] didactic choices' (Lucia). In particular, discussing the purpose of the different laboratory activities in a teaching-learning sequence provided 'new ways of thinking about practical work […]' and it 'left room to the participants' creativity about how to use them in the classroom' (Sara).

Action research. According to the participants, engaging in action research was effective in fostering a more scientific attitude towards teaching: 'Even when I don't do planned action research, now I look at my everyday practice with a research attitude' (Alberto); 'I have learnt that there are many aspects of my practice I can experiment on' (Giorgio). Action research also fostered the development of positive self-efficacy beliefs, as it is discussed below. The time spent in formulating an investigable research question and developing an action research plan was considered particularly relevant: 'The best part of it was stopping to think about my practice in order to pose the right question' (Maria Rosa).

Focus on teachers' beliefs. The TSI scores at the beginning and at the end of the programme suggest that there was a slight overall improvement for self-efficacy (+0.14 on average for self-efficacy, +0.08 for outcome expectancy), but a large variability among participants was observed. A deeper analysis into the personal path of each teacher would be required in order to identify the factors that contributed to the evolution of their beliefs. However, a connection was suggested between high TSI gains and the completion of action research projects: 'Beliefs change if you try for yourself and you see that you like what you are doing' (Giorgio). The case study described below also supports this hypothesis. Concerning the five dimensions and levels of inquiry (NRC, 2000), the largest average improvement was observed for 'learner gives priority to evidence in responding to questions' (+0.28) and 'learner formulates explanations from evidence' (+0.20), and an overall increase towards a higher students' autonomy was observed (+0.28).

Sufficient duration. Consistently with the literature, the duration of the course was judged 'necessary for letting things settle' (Maria Rosa) and even 'not enough' (Alberto). Participants agreed that real change is a long-term process and that even more opportunities for meeting and working together would be needed.

Learning community. Working collaboratively with colleagues and establishing a relationship environment where ideas and difficulties could be shared 'without the fear of judgement' (Lucia) was decisive: 'I see the foundations for building a community of teachers who share materials and ideas' (Francesco). Participants particularly appreciated the possibility of interacting with colleagues from different backgrounds and contexts, which gave them the possibility to 'experience a wider network of relationships beyond the one in our schools' (Alberto). When two teachers from the same school were present, this was recognised as 'a seed to start a learning community in each school' (Francesco). The learning community was also identified as ‘a powerful strategy for reinforcing the relationship between schools and university’ (Giorgio). Collaborating online was however a critical aspect: according to the participants, part of the problem lay in the specific platform (Moodle, judged ‘not very user-friendly’, but they also acknowledged that working collaboratively is not automatic and requires training.

A case study: Lucia

We describe the experience of one of the participants, Lucia, more in detail, in order to describe how the course influenced a teacher’s practice in her specific case.

Background. Lucia got her degree in Mathematics in 2008; during her degree she followed no laboratory courses. At the beginning of the programme, Lucia had been teaching physics for 8 years and she was teaching in grades 9-10 in a technical high school. According to her initial interview, before the course she ‘occasionally’ proposed laboratory experiences. Lucia’s initial score in the TSI was 2.80 for self-efficacy and 2.90 for outcome expectancy.

Action research plan. Lucia’s action research plan was implemented in her 10th grade classrooms in January 2019. Her research employed a quasi-experimental design involving an experimental and a control classroom. Specifically, she wanted to test the effectiveness of a research-based observational experiment in the context of a teaching-learning sequence on mechanical waves, compared with a traditional laboratory. She evaluated her research using two different rubrics (an observation rubric filled in by herself and by an external observer, and the students’ self-evaluation), the analysis of students’ lab reports, and a test administered three months after the lab. Her results supported the effectiveness of the research-based laboratory and, as the start of a new action research cycle, she refined her research question as how to re-design the lab in order to engage all of the students, including the weakest ones.

Impact of the programme and effectiveness of the five features. In her final questionnaire, Lucia listed some of the new habits she implemented in her classroom: ‘Now I provide the students with the rubrics I use for assessment; I use a larger variety of laboratory activities; I have modified the structure of my lab worksheets in order to give the students more room for inquiry; and I encourage my students formulate their own questions’. Lucia particularly appreciated the research-based proposals, which she ‘thirsted for’: ‘It was like a pat on the back. It is good to know that someone is thinking about it’. She judged the experience of action research a crucial point of the programme: ‘During our pre-service teacher training, we were asked to design imaginary plans for imaginary classrooms; on the contrary, in everyday practice we just do the same things year after year. Engaging in action research gave me the opportunity to design and carry on a real project on a real classroom’. Lucia reported large gains in the TSI test (+0.93 for self-efficacy and +0.58 for outcome expectancy). She connected this improvement to her action research experience: ‘I felt a need for change, but, in my school, there is a traditional approach to lab activities… I used to think, “maybe I am a mathematician and I cannot do practical work, probably I am the wrong one”. This year I have worked on myself and now I believe that I can be comfortable in the lab and that I can promote change in my school’. For Lucia, improving her beliefs meant not only promoting personal change, but also making her think of herself as a change agent in her school. Lucia also appreciated the course organization and the learning community approach: 'The monthly schedule allowed us to set our goals on a timeline pattern, then meet to build the community and step forward. The yearly duration allowed us to make small changes, with the opportunity discuss them soon after'. According to Lucia, 'The strength of the programme was to offer stimuli while at the same time bringing out the very best from each participant. In most programmes, we listen to an expert and then we do some group work… here I found room for personal reflection and adequate input based on research, that motivated me to change; I found helpful colleagues and researchers who gave me precious feedback. This year I did not feel alone.'

DISCUSSION AND CONCLUSIONS

From the data collected with multiple instruments, we can conclude that all the features considered in our programme were effective, with action research and the learning community approach being decisive. In fact, engaging in action research impacted the teachers' attitude towards their teaching (fostering a more evidence-based approach). Moreover, a successful action research project boosted the improvement of self-efficacy beliefs and promoted a sense of agency. Concerning the learning community approach, the participants highlighted the need of a 'non-threatening, inspiring, trustful and collaborative' context in which to grow as teachers and persons. These comments reinforce our choice of adopting this approach as out working model and supports us in envisaging actions to further improve it.

The focus on teachers' beliefs seems relevant as a means to effectively impact teachers' practice, though personal stories and paths should be taken into account to interpret the results. Qualitative, in depth instruments are needed in order to gain further insights on development of the participants' beliefs. In the light of the results about action research and programme duration, we argue that even more time and opportunities for action research would be needed as sources of self-efficacy. This will be a priority for the continuation of the programme.

Based on the results of this study, we plan to continue the programme for another year, focussing on action research and experimentation in the classroom. We also plan to introduce more collaborative practices such as co-planning, engaging in micro-teaching sessions, observing and being observed by peers, giving and receiving feedback, with the aim of reinforcing the community and foster collaborative approaches to the teaching of physics. Secondly, we plan to design a revised version of the programme to be implemented with a new group, with the aim of enlarging the community and promote the establishment of local teachers' networks. We hope that, in the long term, this effort will contribute to the formation of productive links between research and practice, the schools and the university, and foster change and innovation as well as personal and professional development.

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DEVELOPMENT AND EVALUATION OF A TEACHER TRAINING ADDRESSING THE USE OF EXPERIMENTS IN CHEMISTRY EDUCATION

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Research on the quality of instruction in chemistry education provides quality characteristics which correlate positively with students' measured cognitive and affective variables. A content-specific individual teacher training using video analysis and focusing on these characteristics has shown efficacy down to student level. In the project at hand we develop and evaluate a comparable teacher training which is independent from the content. The one-day teacher training uses video data from the participating teachers' chemistry lessons. For an extensive evaluation on different levels (e.g. teachers' cognition and practical performance) several instruments have to be developed or adapted. Therefore, the project consists of two studies. In the first study, the instruments are developed and evaluated. The intervention itself is evaluated in a second study using a pre-post-follow up design.

Keywords: In-service Teacher Training, Training and Development, Video Analysis

THEORETICAL BACKGROUND

Research on the quality of instruction provides general or more precisely non subject-specific criteria which correlate positively with students' performance, interest and attitudes (Schulz, 2011; Seidel et al., 2006). From studies in science education, especially chemistry and physics, one can conclude a distinct relation between

a) criteria concerning structuring (e. g. clear separation of the experimentation process into planning, execution and evaluation)

b) target-orientation (e.g. transparency of learning goals and procedure; summary of results) and

c) students' learning outcomes (Schulz, 2011; Seidel et al., 2006).

Tesch & Duit (2004) showed a positive correlation between total duration of the experimentation process and students' learning gains, but no correlation between these gains and the duration of the execution of the experiment. This suggests that a structured embedding with appropriate planning and evaluation of the experiment is necessary for an increase in learning. From the aforementioned video studies (Schulz, 2011; Seidel et al., 2006; Tesch & Duit, 2004), which were conducted in regular lessons at German schools, it can be deduced that structuring plays a central role. This structuring, related to a learning objective according to factual content and functional learning-process-oriented aspects, can also be called sequencing.

Unfortunately, studies assessing science lessons reveal shortcomings in Germany (Schulz, 2011; Seidel et al., 2006) in comparison with other European countries (e.g. Finland and

Switzerland (Börlin & Labudde, 2014) regarding structuring as well as sequencing and target-orientation.

The development of teaching with regard to quality characteristics does not take place on its own. Therefore, learning opportunities for this topic must be created within the framework of pre-service teacher education and also in-service teacher training. According to Radtke (1996), in order to achieve a continuous professionalisation of teachers at this point, teachers' action must be linked and further developed with pedagogical content knowledge. A one-day teacher training to foster hands-on inquiry learning (Schmitt, 2016) was able to show short and medium-term changes in the attitude of teachers towards the content of the training as well as in the pedagogical content knowledge regarding experiments. Coaching with video material from the teachers' own lessons has also proven its worth in several studies (Schulz, 2011; Seidel et al., 2006; Wackermann, 2008). Schulz (2011) showed that a lesson-specific, individual coaching using videos from the teachers' lessons positively influences lesson quality, resulting in a higher learning gain for students. Thus, the learning effectiveness of a topic-specific coaching on quality characteristics of experimental phases at the action level of teachers and at the cognitive and affective level of students is proven.

Nevertheless, for an economic and generalisable teacher training the question has to be answered, if a training in groups independent from the topic of the lesson shows similar results.

RESEARCH QUESTION

The aim of this project is to evaluate an in-service teacher training which mainly focuses on the transfer of research results of Schulz (2011) addressing the optimisation of quality characteristics especially in experimental phases. In order to economise the educational intervention the project evaluates the effects of a non-content-specific training for groups of teachers. In this study, the following research question is addressed:

Does the intervention lead to changes in teachers' epistemological beliefs and in pedagogical content knowledge (PCK) concerning quality characteristics and practical performance in class?

In order to answer this question, appropriate instruments have to be developed and their psychometric criteria have to be determined. This leads to the following research question:

Are the developed test instruments objective, reliable and valid for measuring teachers' epistemic beliefs and pedagogical content knowledge (PCK)?

METHODS AND DESIGN OF THE PILOT STUDY

For measuring teachers' epistemic beliefs and pedagogical content knowledge (PCK) about experiments and their methodical implementation, two instruments were used. Hence, items assessing teachers' beliefs as a part of professional competence Baumert & Kunter (2011) and the PCK test items were constructed or adapted.

Concerning the instrument for measuring PCK, 26 items with four statements each were constructed on the basis of Tepner & Dollny (2014). Each of these statements had to be rated on a four-level Likert scale. In addition, the PCK-items were validated by an expert rating in which educational researchers of chemistry education were asked for their rating.

For the instrument on epistemic beliefs, 17 items with one statement each were selected and adapted from the instrument of Lamprecht (2011). The items that he used to assign teachers to one of the three types of teaching-learning convictions (training, discursive, mediation) were selected (Lamprecht, 2011). Each statement had to be evaluated on a five-level Likert scale.

The teachers of the sample (N = 23) were tested online with LimeSurvey. All items were rated in the same order. After the demographic part, the survey continued with the PCK-items and is completed with the items to measure epistemic beliefs. To continue the survey, the teachers were forced to make a choice.

PRELIMINARY RESULTS OF THE PILOT STUDY

In the PCK-test, the expert rating (N = 3) using a four-level Likert scale shows only moderate agreement (κ_{Fleiss} = .45), measured at the statement level for all 104 statements. For a dichotomous coding, summarising (slightly) agreeing and (slightly) disagreeing, the inter-rater reliability improves regarding all statements (κ_{Fleiss} = .67). Eliminating statements with a broad range in the expert rating left 72 statements. For those, the four-level coding shows an improved inter-rater reliability (κ_{Fleiss} = .67) and the dichotomous coding leads to a good reliability (κ_{Fleiss} = .91) without substantially reducing validity. Unfortunately, Rasch analysis of the results of the PCK-test (N = 23) leads to insufficient EAP reliability (rel_{EAP} < .60), independent from the number of statement and type of coding.

Data analysis of the test for the teachers' epistemic beliefs results in a two-dimensional model (see table 1). The first dimension consists of ten items regarding chemistry education. The second dimension consists of seven items regarding teaching chemistry.

table 1. comparison of unidimensional and two-dimensional model

model	deviance	AIC	chisq	df	p
unidimensional	936.62	1199.99	33.96	2	0
two-dimensional	902.66	1172.31			

For the two dimensions there are moderate to good EAP reliabilities and acceptable infit values. It is noticeable that the variance in the two dimensions is different (see table 2).

table 2. EAP reliability, variance and infit for both dimensions

dim1: chemistry education			dim2: teaching chemistry		
rel_{EAP}	variance	infit	rel_{EAP}	variance	Infit
.862	2.325	0.58 – 1.24	.602	0.162	0.86 – 1.50

Consequences for Main Study

Leading up to the main study, an increase in the sample size is necessary for both the experts and the teachers, since sporadic (poor) statistic parameters may also be related to the small sample size. In addition, it is checked whether the construct which the test instrument for PCK is based on is multidimensional. In any case, a revision of the instrument for PCK is absolutely necessary and at least recommended for the instrument on epistemic beliefs. Possibly, the performance tests for planning and reflecting lessons from the project ProfileP+ (Kulgemeyer et al., 2019) offer an alternative to the PCK test presented here.

OUTLOOK ON MAIN STUDY

First, the intervention materials for the group coaching were developed building upon the individual coaching used by Schulz (2011). The intervention will be evaluated following Lipowsky (2010), levels of evaluation. On the first level the participating teachers' reactions and ratings on the program content are evaluated. The second level assesses changes in teachers' cognition, especially beliefs and knowledge. On the third level practical changes in class are evaluated. Influences on students' knowledge, interests or beliefs are assessed on level four.

For the intervention study, we aim at a sample of 50 in-service chemistry teachers, who are not identical to the sample of the pilot study. Prior to and after the intervention, data for the levels 1 to 4 is collected and one chemistry lesson including an experiment of each participating teacher is videotaped and rated.

The teachers take part in a single day training of six hours intervention time (see figure 1). It starts with a presentation of research results of quality characteristics of chemistry lessons with experimental phases and methods of structuring teaching (Oser & Baeriswyl, 2001), followed by an instruction how to use video data for teaching improvement using a video of a scripted lesson. The remaining time the participating teachers work in groups of two teachers analysing scenes of their own video data, which were preselected by the researchers in order to identify quality characteristics, that are worth improving. Subsequently, they plan a new lesson regarding those identified characteristics.

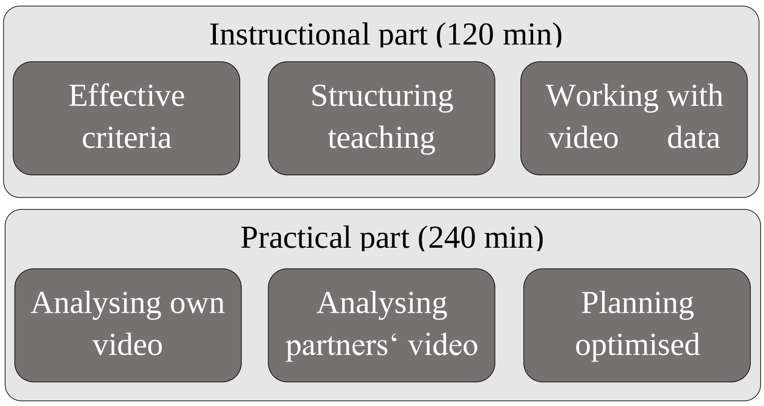

figure 1. Content of teacher training

This new lesson is videotaped a few weeks after the intervention, when post-data for evaluation level 1 and 2 is collected. In a follow-up-test three months after the intervention, medium-term effects of the intervention are assessed (see figure 2).

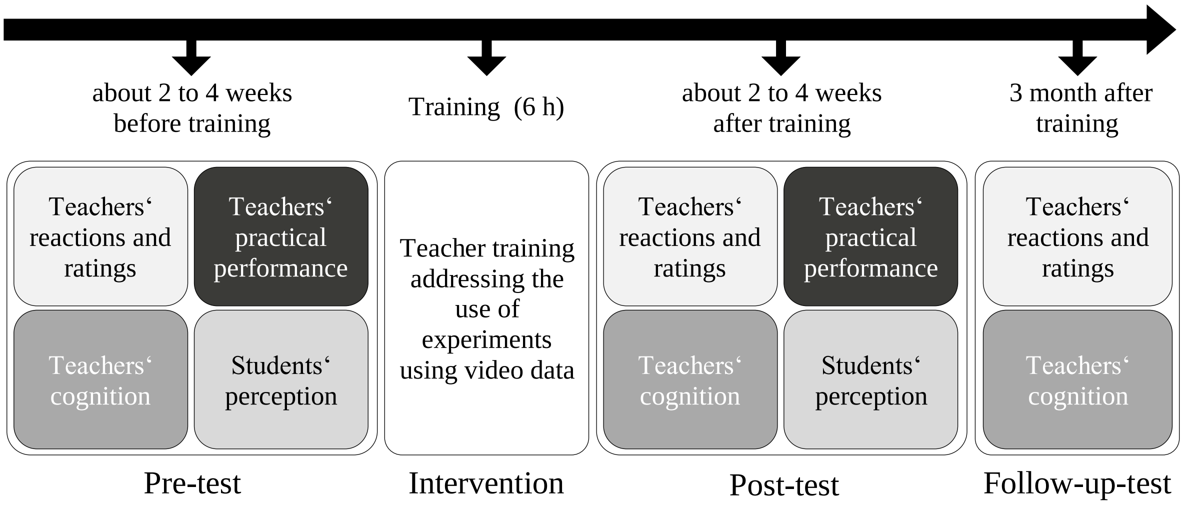

figure 2. Design of the intervention considering four levels of evaluation according to Lipowsky (2010)

Instruments

The success of the teacher training program is operationalised by the following variables considering four levels of evaluation (Lipowsky, 2010) (see figure 3):

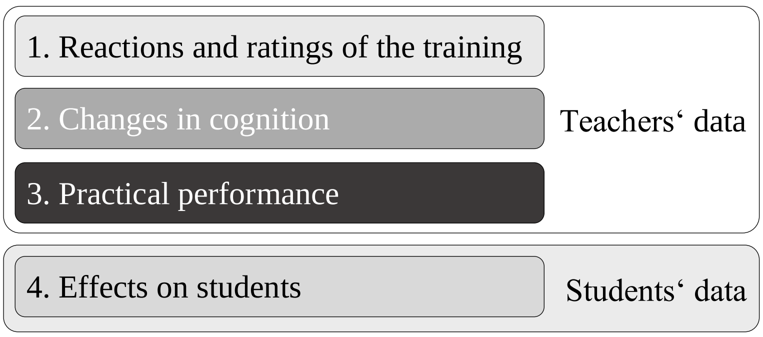

figure 3. Levels of evaluation according to Lipowsky (2010)

Level 1: The teachers' reactions and ratings of the training and its content are assessed by a questionnaire modified from Schmitt (2016).

Level 2: Teachers' changes in cognition are measured by two different instruments. On the one hand, data about their epistemological beliefs is collected by a survey adapted from Lamprecht (2011). On the other hand, teachers' PCK of experiments and their methodical implementation is collected by a self-developed test following Tepner & Dollny (2014).

Level 3: The teachers' practical performance is rated by video analysis applying the video coding system developed, validated and used by Schulz (2011).

Level 4: Data from the students' perception of quality of instruction is collected by a questionnaire also used by Schulz (2011).

EXPECTATIONS AND RESTRICTIONS

Because of the expected heterogeneity of topics and grade levels in the main study, no data of student's knowledge is assessed on evaluation level 4. Consequently, the effects of the intervention on student's knowledge cannot be proved. However, increased learning outcomes as a consequence of enhanced appearance of quality characteristics are already proven (Schulz, 2011).

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TEACHER KNOWLEDGE IN A PROFESSIONAL DEVELOPMENT COURSE IN A CURRICULAR REFORM IN BRAZIL

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In this paper we investigate early stages in the processes of implementation of a new curriculum centred on scientific literacy and inquiry-based science teaching for 1st through 9th grades in schools in Southeast Brazil. We have analysed discursive interactions during lessons of a six week long in-service Science Teacher Education course in which primary and secondary teachers developed an instrument to analyse and evaluate teachers' and students' instructional materials elaborated based on the new curriculum and used this instrument to propose changes before its final implementation in schools. Our aim is to understand what knowledge teachers mobilize when evaluating and proposing modifications in science curricular reform materials for teachers and for students. Our analysis shows the tensions between content and demands of the prescribed curriculum, as well as possibilities of practice in science classrooms, especially in relation to how teachers deal with changes in: (i) science educational goals and (ii) the role of teachers and students in knowledge construction in the classroom.

Keywords: Curriculum; Teacher professional development; Inquiry-based teaching

INTRODUCTION

For decades it has been acknowledged that teachers' learning is a long and complex process and that teachers' knowledge is multifaceted and intertwined with social context, experiences and beliefs (e.g. Ellis, Eduards & Samorinsky, 2010; Kincheloe, 1998; Putman & Borko, 1997; Schön, 1983; Shulman, 1986; Tardif, 2014; Zeichner; 1999). However, there are still concerns with hierarchical relationships between teachers' knowledge and academic/expert knowledge, perpetuated throughout the history of teacher education. In particular, curricular reforms – and professional development related to them – too often are oriented by a rationale of implementing "experts" views that can be more effective if they can "resist" to teachers' challenges and practices (i.e. teachers' proof curricula). Thus, they tend to ignore multiple actors involved in the process (e.g. Wallace, 2012) and/or to adopt perspectives of "standards setting" in classrooms that are centered in demanding/informing/teaching teachers and students, not in negotiating and/or arising (Kordalewski, 2000). Science education is no exception to this pattern. There is a consensus that science learning goes beyond subject matter, incorporating dimensions of scientific literacy (SL) like "doing science", "learning about science", and "addressing socio scientific issues" (Hodson, 2014, p. 2537). One of the approaches to promote scientific literacy in the classroom is inquiry-based science teaching (IBST) (National Research Concil, 2012), in which scientific practices and student engagement play a central role. In many countries, these ideas have influenced curriculum development (e.g. Next Generation Science Standards Lead States, 2013).

In this paper we investigate early stages in the processes of implementation of a new curriculum centred on SL and IBST in Southeast Brazil (São Paulo City Secretary of Education, 2017, 2018), as part of a national curricular reform (Franco & Munford, 2018; Marcondes, 2019; Brazilian Ministry of Education, 2017; Sasseron, 2018). The implementation process is still underway and has included several actions of teacher in-service education and elaboration of instructional science materials based on the inquiry cycle (Pedaste et al., 2015).

We have analysed discursive interactions during lessons of an in-service science teacher education course in which primary and secondary teachers developed an instrument to analyse and evaluate teachers' and students' instructional materials and used this instrument to propose changes before its final implementation in schools. Our aim is to better understand how teachers construct knowledge about science curricular change that is informed by key ideas in science education research. In particular we investigate: how do teachers use their knowledge when evaluating and proposing changes in science curricular reform materials?

Various studies have been conducted in the context of science curriculum implementation (e.g. Brown & Sadler, 2018). Frequently, teachers' learning is examined considering how they learn and/or adopt science curriculum/teaching approaches aspects (Wallace, 2012). In this paper teachers' knowledge is examined considering their actions when having some agency to propose changes, and act upon public policy initiatives.

METHOD

São Paulo is a city with more than twelve million habitants, located in Southeast Brazil. It has 555 schools, 12.000 primary teacher and 2.300 science teachers. The implementation of curriculum involved different instances of teacher development, as represented in Figure 1: courses for tutors (in orange), courses that these tutors teach to teachers (in green), and a course to evaluate instrutional material that was offered for both teachers and tutors (in purple). In blue, teachers in science classroom are represented and in red is the prescribed curriculum.

The study was conducted in a six-week long course (total of 24 hours) for 34 teachers from different schools in São Paulo (Brazil). Some of the participants were experienced and others were novice, and some teach at the primary school/elementary level (1^{st} – 5^{th} grades) whereas others at secondary level/middle school (6^{th}-9^{th} grades), and some acted as teacher educators. In the course, teachers: i) discussed and defined criteria for analysing the instructional material based on a preliminary analyses of 5^{th} grade materials; ii) developed one instrument (a form) to analyse and evaluate teachers' and students' instructional materials of the curricular reform; iii) were grouped in accordance to grades they had chosen and used this instrument to analyse curricular materials (each group analysed eight learning sequence); iv) presented their proposals and evaluation to peers.

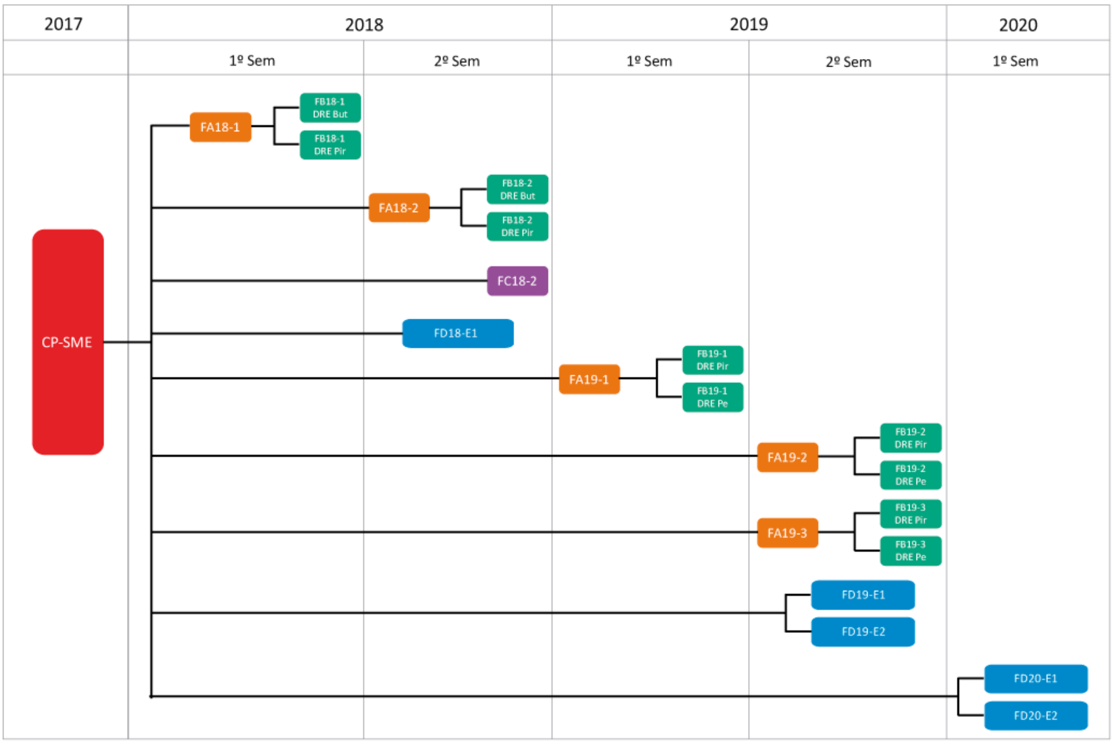

Figure 2. Professional Development Courses involved in Curricular Reform in São Paulo City. (Source: Authors).

The major data sources for this study were participant observation (Spradley, 1980) in science lessons with video/audio recording and field notes. Moreover, the instrument (the form) that teachers filled in during the lessons were analysed to better characterize what were the proposed changes. Our analyses focused on discussions in the groups of 2nd-3rd grade teachers and of 6th grade teachers. We selected events, considered telling cases (Mitchell, 1984), that made visible aspects of the process of evaluating and constructing knowledge about curriculum, in particular those related to inquiry-based teaching, scientific literacy and classroom practices. The discourse was transcribed word-by-word adopting the microethnography approach (Bloome, Carter, Christian, Otto & Shuart-Faris, 2005). Initially, the transcripts were analysed considering the content of discourse with focus on the types of knowledge teachers had been talking about (e.g. characteristics of students, prior experiences, readings about inquiry-based approaches). The categories were constructed during the analyses process.

In a second phase, informed by a social cultural perspective on teacher learning (Putnan & Borko, 1997; Ellis, Edwards, & Smagorinsky, 2010), we took Amanda Berry's (2007, 2008) notion of "tension" that she uses to describe teacher educator's practice and we adapted it to analyse discursive interactions in the context of the professional development course. In accordance with this author, the notion of "tension" has the potential to:

> capture the feelings of internal turmoil that many teacher educators experience in their teaching about teaching as they found themselves pulled in different directions by competing

> concerns, and the difficulties for teacher educators in learning to recognize and manage these opposing forces. (Berry, 2008, p. 32).

Figure 2 represents different types of tensions that are present in the experience of science teacher educators as proposed by Berry (2008, 2007).

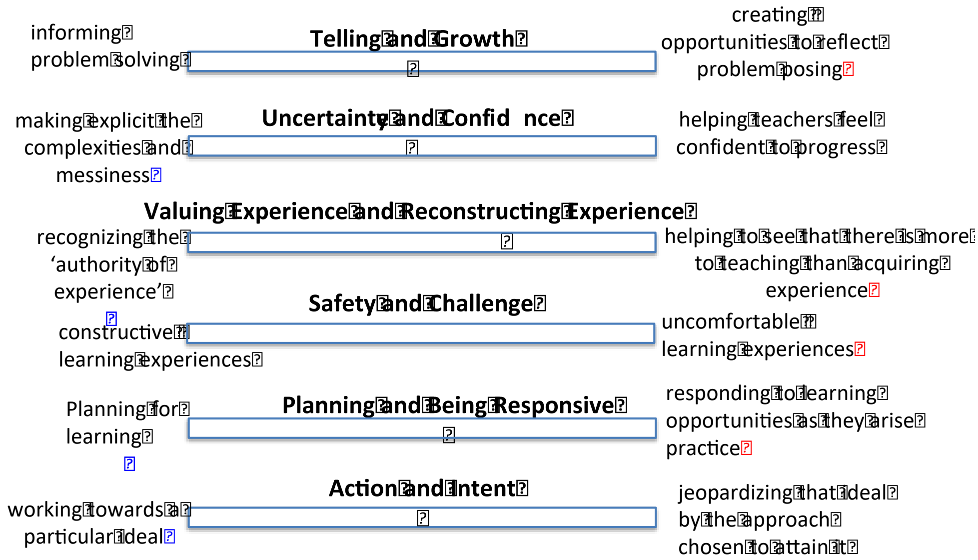

Figure 2: Representation of different categories of tensions in accordance with Berry (2007, 2008) (Source: Authors).

We reframed our initial research question about teachers' knowledge to the following analytical question: "What is the nature of the opportunities for learning to teach science that are constructed during a professional development course for curricular implementation?"

RESULTS AND DISCUSSION

To evaluate and propose changes in inquiry-based learning sequences (IBLS), teachers defined and used the following criteria: valorisation of the students' previous knowledge, adequacy and quality of the language, relevance of practical activities, adequacy of content and skills for the school grade, appropriateness duration, structure of the inquiry cycle, possibilities of student engagement, possibility of working with a diversity of students, adequacy of the orientations to the teacher, consistency between assessments and curriculum elements.

Some of these aspects may be considered as cultural myths (Tobin & McRobin, 1996), that is, they are references to enact science classes in a certain way, in accordance to certain beliefs about how a science class or a science curriculum must look like. The professional development space allowed these myths to surface and interactions between teachers, who had already applied the IBLS, brought up the difficulties, limitations and conceptions of scientific literacy and inquiry-based approach in classroom practices. Therefore, we considered that the aspects that teachers rose revealed tensions (Berry, 2007) between subject matter knowledge, theoretical knowledge demands of prescribed curriculum, and possibilities of science classroom practices.

Our analyses indicate that various types of knowledge were used to construct proposals for revising curricular materials. Frequently teachers' interpretations of the materials and suggestions were supported by their own experience at school, including knowledge about their students' knowledge or abilities (e.g. conceptual knowledge and teaching experiences teaching the lessons from the curricular materials).

Both when working in small groups or in whole class discussions, elementary school teachers often were more attentive to aspects of the written text in curricular materials. Proposals involving changes in written texts were very common in the group. For instance, when they analysed the 2nd grade materials for students, they engaged in a long discussion about the tittle of an activity in a sequence about the water cycle: "The water that was gone"[2]. One of the teachers argued that the title was telling the answer of the inquiry question and a tittle in the format of a question would be more appropriate. She also pointed that the very idea of "water going away" would be "the way kids would talk about it" and "you can imagine drops of water with little legs walking". Thus, this was an inappropriate tittle also to promote conceptual accuracy. They examined the activity and pictures that compose the activity, and pointed out that "the title should help them to see the drops", and proposed titles like "What changed in the mirror?" Moreover, they established relationships with knowledge from the discipline Portuguese/Reading and Writing. For instance, in the same sequence mentioned above, a teacher noticed that a practical activity were similar to a "the genre" food recipe. Later, a colleague noted that the way the text was presented it looked like a list, a genre that they usually did not work with students as much as they should.

The group of teachers working with students in transition to secondary/middle school (i.e. 6th grade) had one teacher who had developed almost all the activities they were discussing. In this case, discussions were often structured around asking him how he did it at his school and how things went. In one occasion he stated "I just know it because I worked with students this", and a colleague agreed. Sometimes details like the use of the materials would receive his attention, and often how students participated and reacted received attention. For instance, when discussing an astronomy activity, he advised colleagues that "You should use play dough" and, enacting what was supposed to be done, he commented that "When you actually do it, they [students] get curious. I found it a good practice. Easy and simple to visualize. They proposed a bunch of theories. They got very excited about it." In various occasions teachers talked about students or school characteristics.

The modifications in the material that received more emphasis in whole classroom discussions involved changes in the sequencing of activities or concepts that should be worked throughout the year.

[2] A Portuguese version of this inquiry-based learning sequence is available at https://curriculo.sme.prefeitura.sp.gov.br/sequencia/as-gotas-de-agua

Two of these aspects called our attention due both to the big discussion in the two groups that were analysed, and their relationship with SL and IBST. First, there were tensions around science educational goals. The new prescribed curriculum places a greater emphasis on socio-scientific issues and on the social and cultural aspects of the production of scientific knowledge. For example, when talking about the place the theme "water" had in the curriculum and in 3rd grade instructional materials, teachers considered that science should address the concepts involved in the water cycle as social issues like water pollution should be addressed in geography lessons. Another example involved teachers analysing a practical activity in the 6th grade material on the role of indirect evidence, imagination and prior knowledge of scientists in the construction of scientific knowledge. Their interpretation was that the activity played just a motivating role, but does not contribute to "learning about science". Although this perspective did not represent a hindrance to perform the activity, it had a different function from a perspective that broadens goals of science teaching. These two examples illustrate challenges for teachers in incorporating dimensions of scientific literacy.

The second aspect to be highlighted is related to teachers' and students' roles in this new curriculum. When they reported the application of practical activities proposed in the instructional material, teachers point out that the room had become more tumultuous when students take a more active role. This required more effort and another way of acting of the teachers themselves. Also regarding students' role of, teachers reported that students didn't feel confortable participating in activities that required interactions and collaboration between students to construct knowledge. In one of the events analysed, teachers in 3rd grade regretted that while some students were arguing, others copied the assignment.

Further analysis of the events, using Berry's notion of tension, evidenced the complexity of the learning opportunities that emerge in the context of professional development courses – an aspect that was not evidenced in the other analysis. As an example we will present aspects of the analysis of an event that took place with 6th grade teachers. One of the teachers, Lúcia, shares her experience of developing the mystery box activity[3] to teach about earth's internal layers as proposed in the instructional material[4].

In this event the interactions among teachers made visible multiple tensions. For instance, the tensions between *value and reconstructing* are presented as we contrast two dialogues that occurred. At the beginning of interactions, teachers discuss impressions about the activity:

> Pedro: It is only ludic, right?
> Lúcia: Yes.
> Júlio: Yes, yes.
> Pedro: It is a comparison.
> Júlio: It is not very scientific, is it?
> Pedro: No.

[3] This is a tradicional activity to explore inquiry-based science teaching approach. An example can be seen here https://media.bscs.org/mss/se/chapter_pdfs/science_as_inquiry_introductory_chapter_for_any_unit/sai_ch1.pdf

[4] A Portuguese version of this inquiry-based learning sequence is available at https://curriculo.sme.prefeitura.sp.gov.br/sequencia/a-terra-viva-formacoes-e-transformacoes-do-solo

These interactions evidenced how participants relied in what happens in their classes and their views to construct a comprehension of the activity without using SL and IBST to frame their understanding of the activity. However, later in the event Lúcia will take another direction:

> Lúcia: So, I... I understood that ... look, for example... here, you have to infer what is inside [the box] in [the same way//(...).
> Júlio: //as what is inside the Earth.
> Lúcia: In the same way that you have to infer, because there is no way to get inside [the Earth], so you have to imagine.

In this case, her understanding of the activity aggregates aspects of the notion of model and modelling related to IBST, practices that are introduced and discussed in the curriculum. Another learning opportunity emerges in another interaction, also involving Lúcia:

> Lúcia: (...) I said [to a student]: "Ok, you said that you thought that it was, let's suppose, a coin. But why did you think that?" Then, he had to argue why. Establish a relationship. So it is nothing like (...).
> Lúcia: Say something like "I think it is a glass, just because I think". Do you get it? (...).
> Lúcia: It had to have some support; otherwise it is not enough just to put it out there.
> Pedro: Yes. "Just because", anything, you cannot [do it].

Again, Lúcia supports his colleagues in understanding the activity by connecting her experience to aspects of IBST.

Another tension that we identified in the same event was related to *uncertainty and confidence*. On one hand Lúcia bring into the conversation "the complexities and messiness" of teaching:

> Lúcia: Now, look at this one, Mystery Box, (...) Did you do it?
> Júlio: no, no, no.
> Lúcia: You have to do it, but in one of these days that you are feeling very well.
> Pedro: but what did you put inside?
> Lúcia: Because they through the box in the air. I put a bunch of coins rapped in paper balls, got it?
> Pedro: aham
> Lucia: Then, they shake it. Thus, I did this activity in homeopathic doses.... One day in two classes... the other day in other two classes... because I wouldn't be able to do it in all my classes.
> Pedro: It's because it becomes too messy.

On the other hand, she helps her peers to feel confident about teaching the activity, and, consequently adopting a different approach that they are used to:

> Lúcia: The other day, there is this class… that is a class with excellent students in terms of behaviour… they do what I ask them. I said: "let's go downstairs". In the school we have three sports courts.
> Pedro: In the sports court?
> Lúcia: Yes. We have three sports courts, and one indoor court, and between them there's a courtyard.

Pedro: Great... Then you can seat there?
Lúcia: We made a circle.
Pedro: It's good because it's different from what we usually do.
Lúcia: So, it's good. This was the last class that I did it with. Maybe I would do it with the first one, if I had the courage to take the others outside. It would be less messy if they were in the courtyard.

These interactions and the tensions that emerge evidenced the role that peer interactions can have in learning to teach in the context of Professional Development Courses.

CONCLUSIONS

When teachers are in a situation where they take a more active role in proposing and analysing instructional materials, they have opportunities to make sense of their practices, bringing up tensions between subject matter knowledge, theoretical knowledge demands of prescribed curriculum, and possibilities of enacting in the science classroom. In the course analysed here, these tensions became explicit, and teachers had pointed out the relevance of training and a demand for an instructional material specifically produced for theoretical deepening, which shows the consciousness about these tensions and the need to discuss and problematize them, bring up the possibility to effectively support changes recommended by political reforms.

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EXPLORING TEACHER'S BELIEFS AND ATTITUDES TOWARDS TEACHING PHYSICS DURING A LESSON STUDY INTERVENTION

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ABSTRACT

This study explored how the beliefs and attitudes of teachers towards the teaching and learning of physics were influenced by participation in a lesson study intervention. Data for this study was collected through semi-structured interviews, and lesson observations conducted with four teachers from three South African schools. Analysis of the data following teacher's participation in the lesson study intervention indicated that teachers became more confident, determined and prepared to teach difficult concepts regardless of the learning situation; openly acknowledged that classroom collaboration could benefit learners' learning, changed their expressed beliefs about learners' difficulties. These findings suggest that creating opportunities for teachers to take ownership of learning activities during professional development programs may positively influence their beliefs and attitudes, as they become more practical, confident and enthusiastic about teaching physics.

Keywords: Attitudes and Beliefs, Lesson study, Physics

INTRODUCTION

The poor performance and low enrolment of learners in physics-oriented courses could be attributed to teachers' beliefs and attitudes developed towards physics (Bhargava & Pathy, 2014; Masood, 2014; Osborne, Simon, & Collins, 2003). Attitude is an essential disposition that directs the nature of human behavior and relates to how individuals manage emotions that occur during the learning process. There has been a global concern on the effect of teachers' beliefs and attitudes on learners' performance. However, less has been written on how teachers change their beliefs and attitude toward teaching. Teachers' attitudes being a component of teachers' emotional dispositions could include constructs like conceptions and awkward behaviors of teachers towards teaching physical science as a subject. Physics is a science subject perceived by some teachers and learners to be too mathematically oriented, too extensive and mostly dependent on textbooks (Bhargava & Pathy, 2014; Masood, 2014). Research indicates that learners' performance and enrolment in physics have been reflecting a decline over many years probably due to the abstract nature of the subject (American Association of Physics Teachers (AAPT, 2013). Teachers' emotional dispositions towards the teaching of science have been well documented (Ualesi & Ward, 2018). Thus, it is an important component required for improving learner's performance, as well as empowering physics teachers' quality and effectiveness. For instance, research has shown that some science teachers lack the educational background in science and consequently, fail to engage learners in hands-on practical activities that are physics-oriented (George, 2017; University of Vermont, 2018).

More so, Hannula, Di Martino, Pantziara, Zhang, Morselli, Heyd-Metzuyanim, Lutovac, Kaasila, Middleton, Jansen, and Goldin (2016) claims that there is a dialectical relationship between teachers' attitudes, beliefs and their classroom practice, as well as how their beliefs changes. Hence, the attitude of science teachers which could be formed by their belief about how learners learn, value teachers hold, classroom management practice, the nature of their scientific knowledge and instruction plays a significant role in improving the quality of physics teaching. Thus, the aim of this paper is to report on how teachers' participation in a lesson study intervention influenced teachers' beliefs and attitudes to teaching the physics part of the FET physical science curriculum within the South African context.

This paper report results from a larger study that focused on improving the teaching of electricity and magnetism in South Africa (Author, 2018). This study is informed by the notion that attitude is a structure of an individual's belief system (Jones & Carter, 2013). Research indicates that teacher's belief system has a direct implication on their classroom actions, which may improve or discourage learners' learning and academic performance (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2009). For this reason, it is important to identify and clarify teachers' beliefs influencing their attitudes towards teaching physics (Haney & Lumpe, 1995). Research question: How do teachers' beliefs and attitudes towards teaching Electricity and Magnetism develop during participation in a Lesson Study intervention?

METHOD

A qualitative inquiry using an exploratory case study design was adopted in this study (Yin, 2014). A purposive and convenient sampling was employed in this study to capture specific attributes of four teachers from city and rural schools, knowing that it does not represent the whole population of physical sciences teachers in South Africa (Cohen, Manion & Morrison, 2007; Maxwell, 2013). Teachers participated in a five weeks intervention program designed to improve their teaching of electricity and magnetism. The various phases of the intervention program gave teachers the opportunity to collectively reflect, analyze, plan and discuss difficult physics topics within a community of practice. Teachers engaged in lesson study activities aimed at equipping them with a responsive classroom approach (Lewis& Hurd, 2011). Data were collected using interviews, and lesson observations, and analyzed by content analysis.

THEORETICAL FRAMEWORK

This study is underpinned by the theoretical construct of the adult learning theory (Knowles, 1980). The adult learning theory provides guiding principles that helps to understand how Lesson study as a professional development program was used to introspectively gain insight into teachers' personal beliefs and attitudes towards physics teaching (Peltz & Clemons, 2018). These guiding principles includes teachers' understanding of what learners needs to know, the role of learners' experience, learners' self-concept, learners' orientation to learning, readiness and motivation to learn (Knowles, 1980; Palis & Quiros, 2014). Within the context of this study, Lesson study was chosen and adapted as an In-school training approach to support the development of teachers' scientific skills and abilities in teaching physics.

Lesson study is a research-oriented practice that has successfully contributed to the high-quality teaching and learning practice in the Japanese educational system (Huang, Takahashi, & da Ponte, 2019). Doig and Groves (2011) indicated that the jointly organized classroom lessons conducted during lesson study often tend to develop attitudes, beliefs and understanding among participants. Thus, the various activities implemented during the collaborative phase of the lesson study intervention provided new experiences that created a unique learning opportunity for the teachers. However, the application of teachers' learning during the lesson study intervention was more evident in their ability to solve problems related to learners' difficulties and misconceptions in electricity and magnetism. However, the basis of adult learning theory in this study lies on teachers' motivation, interest, and capacity to work collaboratively; and this collaborative effort proved instrumental to the voluntary change that was observed in teachers' competencies in terms of their individual attitude and opinion about teaching and addressing learners' difficulties in physics.

RESULTS AND DISCUSSION

Data for the study presented in this paper were gathered from the analysis of teachers' interviews, lesson observations and reflective writing. Teachers in this study were observed during the adapted Lesson Study intervention. Prior to the commencement of this study, teachers expressed feelings of unpreparedness which was associated with teachers' lack of interest on specific topics they don't understand, thus affecting their attitude when teaching these topics to learners. For example, Mbali mentioned that she usually avoids answering questions from learners whenever she was teaching the concepts related to electromagnetism. However, the planning and reflection phase of the lesson study intervention helped her to become more prepared and confident, thereby increasing teachers' competency and positive attitude towards teaching physics concepts that appear difficult and confusing.

> *Participating in this program has helped me to a greater extent in bringing down this wall I have built around me when teaching electromagnetism which I initially don't answer some questions that learners tend to ask. I just teach and leave* (Mbali interview).

During the initial interview, Lenox indicated little concern about learners' problems in electromagnetism since learners are not assessed in the final Grade 12 examinations.

> *When we moderate for marking, we hardly consider electromagnetism as a difficult topic because learners are not assessed on that topic at the matric level* (Lenox interview).

This remark revealed a low level of enthusiasm and competence in teaching electromagnetism, caused by his belief. However, during the lesson observations, Lenox did show enthusiasm when teaching the collaboratively planned lesson. Prior to the lesson study, teachers rarely reflect on the effectiveness of their classroom instruction and learners' response to activities. For instance, the initial reply of teachers when reflecting on the difficulties of learners showed that all teachers demonstrated an undesirable attitude towards reflective practice. Nonetheless, two of the teachers mentioned that their rate of reflection shifted during participation in the study. During the initial consultation session with teachers, Martha mentioned that she only reflects and certainly explains a lesson again if she noticed that learners seem not to grasp the fundamental concepts relating to the topic that was taught.

> *I do my reflection whenever I have this feeling that I had a bad lesson and I just go back to re-explain the lesson again but during our first meeting, Mr. Alex's suggestion on the idea of allowing learners to observe, draw and discuss the magnetic field lines around the magnet made me realize that I could develop new methods of teaching the same lesson if I take my time to critically reflect on the previous method used. (Martha, interview)* .

However, participating in the Lesson Study intervention created an experience that helped teachers to reflect on their existing beliefs about learners' difficulties and their teaching methods, as they became open to alternative approaches, thereby improving their willingness to learn and adjust their instructional practices. For example, analysis of Martha's response shows that she often participates in compassion-based reflective actions, but taking part in this lesson study intervention improved her attitude and level of reflective practice. This was observed during the first phase of the intervention program, where she engaged in a relational analysis that accompanied a dialogue during the lesson study consultation meeting. It appears from the preceding findings that lesson study could, however, help teachers to critically examine their values and teaching attitudes, and thus improve their reflective practice. This finding supports Rock and Wilson's (2005) view that Lesson Study improves reflexivity in teachers.

The opportunity to reflect on their attitude towards teaching physical sciences impacted their perception and views about teaching physics concepts that are critical and more challenging to individual teachers.

CONCLUSIONS

In summary, findings of this study indicate that teachers' attitudes towards their classroom teaching was improved through their increased confidence level, increased level of reflection, improved pedagogical knowledge and skills. However, teachers informed attitudes did not always lead to improving their classroom effectiveness.

The result obtained with respect to this should not be generalized due to the small sample used. Nevertheless, results indicate that engaging teachers in research-based activities and giving teachers the opportunity to take ownership of learning opportunities during professional development is a promising way of fostering positive attitudes towards teaching physics within the South African context.

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IN-SERVICE CHEMISTRY TEACHERS' PCK OF ELECTROCHEMISTRY: A CASE IN SÃO PAULO, BRAZIL

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The aim of this study is to investigate chemistry teachers' PCK of galvanic cells through a mixed-method case study. The sample consisted of 128 in-service chemistry teachers from São Paulo, Brazil, and the data were collected using an adapted version of the PCK of Electrochemistry Test. Teachers' responses to each question were analysed in a five-point scale reflecting the PCK quality. Then, raw scores were analysed by Rasch Partial Credit Model and the teachers were stratified in five levels using the Scale Characteristic Curves methodology. The outcomes of this study revealed that teachers had a good or medium score in questions about learner prior knowledge, curricular salience and difficult aspects to teach; and low score in questions about representations use and conceptual teaching strategies. Concerning the teachers stratification, most of the teachers are in the low levels (3 in the 'no shown', 28 in the 'limited' and 82 in the 'basic'). Thus, in general, teachers presented low scores on the PCK of Electrochemistry Test and, consequently, it is necessary, in the Brazilian context, the production and teaching of continuous professional development courses that covered this topic.

Keywords: pedagogical content knowledge, teaching of electrochemistry, Rasch analysis

INTRODUCTION

In the literature, there have been emerging studies to better understanding the complexity in electrochemistry teaching. In the Brazilian context, Nogueira, Goes, and Fernandez (2017) claim chemistry teachers, students, and textbooks show difficulties in understanding the redox reactions simultaneity and the difference between galvanic and electrolyte cells. In addition, Marcondes, Souza, and Akahoshi (2017) emphasize that although chemistry teachers focus on teaching galvanic cells, this teaching is superficial as these teachers do not prioritize concepts such as salt bridge and half-cell reactions. Therefore, to teach electrochemistry, teachers should improve their knowledge of students' alternative conceptions about electrochemical phenomena, their knowledge about curricular saliency, and their own difficulties in understanding electrochemistry subject matter.

The aspects aforementioned can be studied from the perspective of Pedagogical Content Knowledge (PCK). This knowledge was proposed by Shulman (1986) and is "the ways of representing and formulating the subject that make it comprehensible to others" (p. 9) and also "an understanding of what makes the learning of specific topics easy or difficult" (p.9).

From Shulman's PCK definition, some researchers proposed PCK models (e.g Magnusson, Krajcik & Borko, 1999, Rollnick et al., 2008). Between these models, we decided to use the

Topic Specific PCK model (Mavhunga, 2012) as this one focuses on the subject matter knowledge in a topic-specific level. According to this model, PCK has the following components: a) leaner prior knowledge (LPK); b) curricular saliency (CSL); c) what is difficult to teach (DFT); d) representations (REP); e) conceptual teaching strategies (CTS).

To better know PCK quality of in-service chemistry teachers from São Paulo state, Brazil, in teaching galvanic cells, a central idea of Electrochemistry, this study has the aim to investigate chemistry teachers' PCK of galvanic cells.

METHODOLOGY

The research design to investigate chemistry teachers' PCK of galvanic cells was based on a mixed-methods case study (Creswell & Clark, 2017). In this paper, we will focus on the quantitative part.

Sample

The sample consisted of 128 in-service high school chemistry teachers from São Paulo State, Brazil. The teachers selection was conducted through convenience sampling (Creswell, 2012): almost all of them were personally asked to answer the test when they attended professional development courses offered by the authors; the other teachers were asked by email to answer the test.

Chemistry teachers' characteristics as major degree, gender, and professional experience can be seen in Table 1.

Table 1. Chemistry teachers' characteristics.

Major degree					Gender	
Chemistry	Biology	Science	Physics	Others	Male	Female
96	14	06	02	10	56	72

School kind				Experience teaching Electrochemistry		
Public	Private	Both	NA	Yes	No	NA
108	02	17	01	90	36	02

Experience time				
Mean	S.E.	Range	Minimum	Maximum
15	7.1	35	1	36

Instrument

We collected the data using an adapted version of the PCK of Electrochemistry Test (A-PCKET; Ndlovu, 2014). The adapted version has 07 open-ended questions addressing the TSPCK categories proposed by Mavhunga (2012), namely: Curricular Saliency, What is difficult to teach, Representations, Students Prior Knowledge, and Conceptual Teaching Strategies.

The main modifications we did in the test were: (i) removing Electrolytic Cells questions to focus only in Galvanic Cells, since the latter is more emphasized by Brazilian chemistry teachers (Marcondes, Souza, & Akahoshi 2017) and; (ii) reducing the number of questions to shorten the test accomplishment time. An overview of the A-PCKET can be seen in Table 2.

Table 2. Description of the A-PCKET questions.

Nº	PCK component	Purpose	Source
1	CSL	Identifying and sequencing central ideas in electrochemistry teaching	Adapted of Ndlovu (2014)
2	CSL	Identifying the main chemistry topics necessary for teaching electrochemistry	Adapted of Ndlovu (2014)
3	DFT	Identifying the main difficulties in electrochemistry teaching	Adapted of Ndlovu (2014)
4	REP	Identifying good and bad aspects of representations and how to use them in teaching	Adapted of Ndlovu (2014)
5	LPK	Identifying students' alternative conceptions about oxidation, reduction, cathode, and anode.	Elaborated by authors
6	LPK	Identifying students' alternative conceptions about electrons flow and salt bridge.	Adapted of Ndlovu (2014)
7	CTS	Elaborating a class to confront students' alternative conceptions about galvanic cells	Elaborated by authors

Data analysis

We scored the teachers' responses to the PCKET items using a rubric corresponding to each question. This rubric have a five-point scale reflecting the PCK quality: 0 to 'not manifested' PCK; 1 to 'limited'; 2 to 'basic'; 3 to 'developed' and; 4 to 'exemplary'. The raw score was analysed thought Rasch Partial Credit Model (Boone, Staver & Yale, 2014) using the Winsteps© Rasch Measurement 4.4.1 (Linacre, 2019) software.

Two parameters were used to verify if the test fit the Rasch Model and, consequently, if it is valid to assess the high school chemistry teachers from São Paulo: the mean-square (MnSq) and z-standardized (ZStd) outfit statistics. Moreover, the reliability of the persons and of the questions was calculated.

At last, the teachers were stratified in five strata (the same of the rubric) according to their PCK score. To do that, we used the Scale Characteristic Curve (SCC) methodology (Dogan, 2018). In this methodology, all items characteristic curves are summed to obtain a scale characteristic curve.

RESULTS AND DISCUSSION

Instrument quality

The MnSq and ZStd outfit values asses if the empirical data agree with the expected values given by the Rasch Model. The recommended values are: 0,5 < MnSq < 1,5 or -2,0 < ZStd < 2,0 (Kirschner, et al. 2016). As we can see in Table 3, all questions were between the expected values. Concerning the test reliability, question and person reliability were both calculated. According to Linacre (2018), it is recommended values, respectively, greater than 0.9 and 0.8. The test also achieves the recommended values in this aspect.

Table 3. Questions fit, questions reliability and persons reliability.

Question	MNSQ outfit	ZSTD outfit	Questions reliability
1 (CSL)	1.07	0.55	0.93
2 (CSL)	1.00	0.05	
3 (DFT)	1.15	1.13	**Persons reliability**
4 (REP)	0.93	-0.39	0.81
5 (LPK)	0.96	-0.1	
6 (LPK)	0.83	-1.19	
7 (CTS)	0.83	-0.90	

To increase the test validity, the predictive validity was analysed as well. In this analyse, the theoretical score ordering of teachers is compared with the empirical one (Linacre, 2018). Since the A-PCKET is about Electrochemistry teaching, we expected teachers without a chemistry degree to have low scores. As can be seen in the Item-person map shown in Figure 1, most of the teachers without a chemistry degree are below the teachers' mean (teachers in the square). Moreover, the teachers with the lowest scores are those without a chemistry degree. Thus, the order of theoretical scores, based on the PCK theory, is equal to the empirical one and, therefore, the test validity is increased.

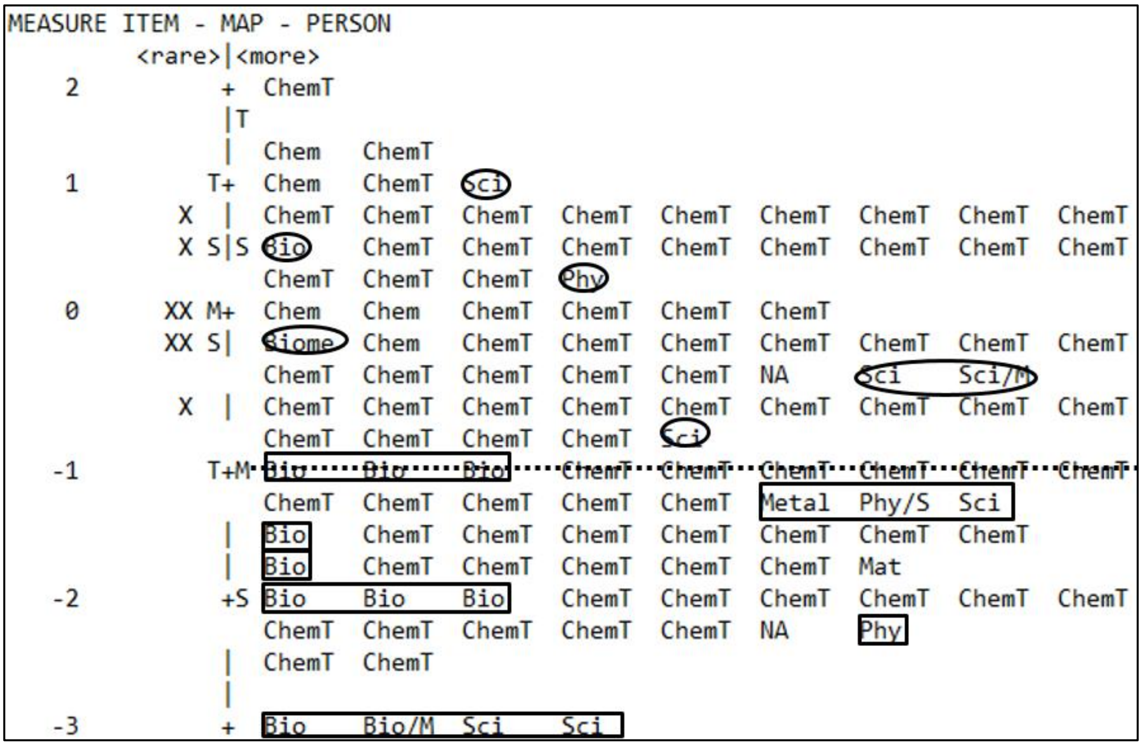

Figure 1. Item-person map emphasizing the scores of teachers without major in Chemistry.
Note: The dashed line represents the teachers' mean. Teachers in the square have a score below the mean. Teachers in the circle have a score above the mean. "Chem" is chemistry, "Sci" is science in elementary classes, "Phy" is physics, "Bio" is biology, "Metal" is metallurgical engineer, and "Biome" is biomedicine science.

Since the test showed fit values (MnSq and ZStd outfits), reliabilities and score ordering (predictive validity) into the expected, we claim the A-PCKET produced validity results and can be used in the São Paulo context.

Items difficulties

Regarding teachers' performance, they had medium scores in DFT, CSL and LPK questions (consequently, these questions had a smaller measure of difficulty), as shown in Table 4. REP and CTS questions proved to be very hard questions and had the highest difficult measure. Since the ability to use representations and conceptual teaching strategies requires the integration of the other components (e.g. using some representations to confront some student difficult) (Rollnick & Mavhunga, 2014), it is expected that those questions to be the most difficult.

Table 4. The measure of questions difficulties and teachers' knowledge.

	1 (CSL)	6 (LPK)	3 (DFT)	5 (LPK)	2 (CSL)	7 (CTS)	4 (REP)	Questions mean	Teachers mean
Measure	-0.65	-0.25	-0.25	-0.09	0.05	0.40	0.79	0.00	-0.99

About the difficulty of the test in general, when the test is easy for teachers, the teachers mean is higher than questions mean; otherwise, if the test is difficult, the teachers mean is lower. Comparing in our case, in Table 3 it is possible to see that PCKET is very difficult for teachers. These results agree with research reports: electrochemistry is, despite teachers' experience, a very difficult topic to teach (Ndlovu, 2014, Rollnick & Mavhunga, 2014).

Teachers stratification

The resulting SCC originated by teachers' answers to A-PCKET is shown in Figure 2. In the Scale Characteristic Curve (Dogan, 2018), the x-axis is the teachers' score in the test, the y-axis shows the expected number of items teachers scored on each curve, and the points where one curve intersects other are the cut-off criteria. For example, a teacher with a measure of 1.6 (the last cut-off point) is more likely to score "exemplary" and "developed" in three questions and "basic" in one.

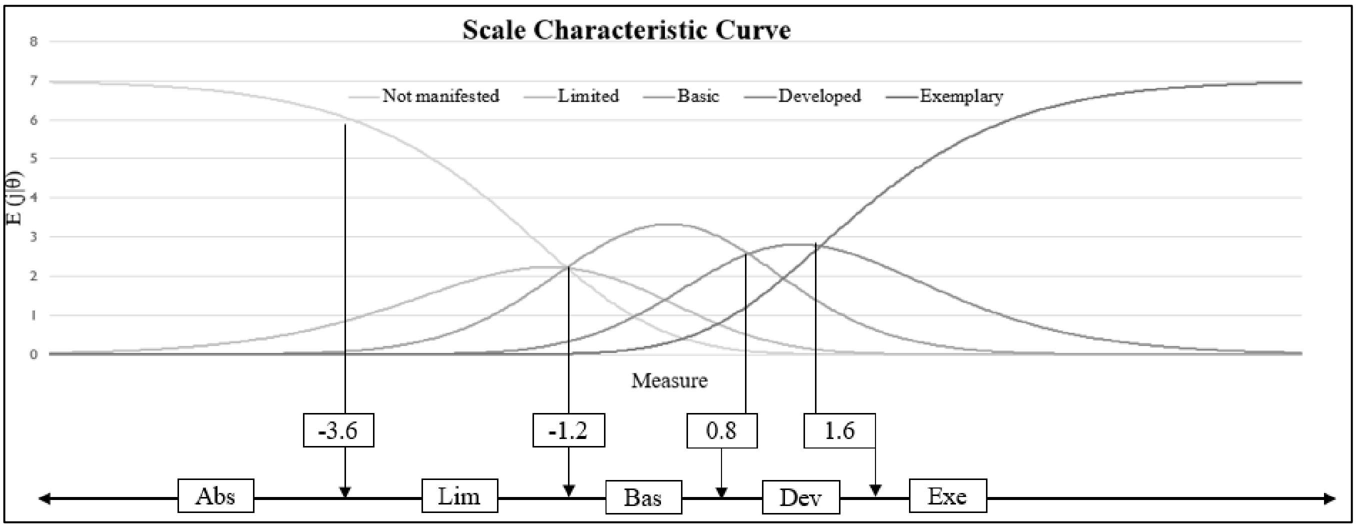

Figure 2. Scale characteristic curve originated by teachers' answers to A-PCKET.

As can be seen in Figure 2, the SCC has three cut-off points related to the intersection of the curves (-1.2, 0.8, and 1.6). However, in addition to these points, we also added one more: -3.6.

We did that because we consider that to manifest a PCK in the test, teachers must get at least one question with a “limited” score. If teachers score all questions with ‘not manifested’, we consider that teachers did not manifest PCK in the test situation.

Thus, with these four cut-off points, we have five PCK levels. In the first one, ‘not manifested’, teachers get a ‘not manifested’ score in all questions. In the second one, ‘limited’, teachers get at least one item with a ‘limited’ score, but could have some items with ‘basic’. In the third one, ‘basic’, teachers get mainly ‘basic’ score and have chances to get ‘limited’ and ‘developed’ scores. In the fourth level, ‘developed’, teachers get mainly developed score and could get ‘basic’ and ‘exemplary’. In the last level, ‘exemplary’, teachers get more ‘exemplary’ and ‘developed’ scores.

The teachers distribution in those five levels can be seen in Figure 3. It is perceived the teachers’ low scores on A-PCKET also is reflected in PCK levels: most of the teachers have limited or basic PCK level.

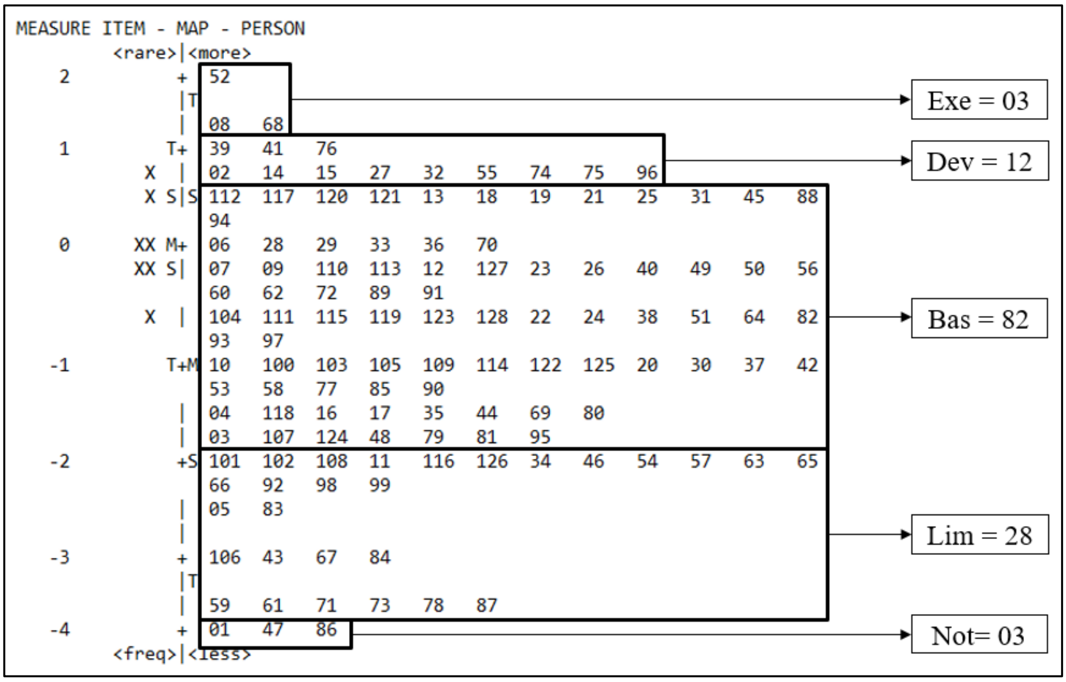

Figure 3. Teachers stratification in four levels: limited, basic, developed, and exemplary.

CONCLUSION

From the outfit, reliability and predictive validity results, it is possible to see that the adapted version of PCKET (Ndlovu, 2014) was able to be used in the São Paulo context and allows us to investigate in-service chemistry teachers’ PCK of galvanic cells. The score of teachers was medium in five questions: identifying central ideas and previous content to teach electrochemistry (questions 1 and 2); identifying difficulties aspects to teach electrochemistry (question 3), and recognizing learner prior knowledge about electrons flow/salt bridge and oxidation/reduction (question 5 and 6). Moreover, teachers present great difficulty in two questions: assessment and use of representations (question 4); proposed a conceptual teaching strategy (question 7). Therefore, in general, teachers presented low scores on PCKET, and most of them have limited or basic level on PCK of electrochemistry.

There are two possible explanations for the teachers' low score on PCKET: lack in subject matter knowledge (SMK), which does not allow the PCK development (Rollnick et al., 2008) and; lack in the integration of PCK components, which results in an isolated and, consequently, undeveloped PCK. In this sense, the investigation of the teachers' SMK and integration between PCK components is necessary and is the next step in our research.

Besides that, we will conduct a qualitative multiple case study to investigate the differences between teachers' PCK level. In this sense, we will choose some teachers from each strata and each group of teachers will be a case. From this, we expected to get a better understanding of how PCK of Electrochemistry can be developed though the different levels and then propose continuous professional development courses covering this topic, mainly in use of representations and conceptual teaching strategies.

ACKNOWLEDGEMENT

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ORIENTATION TO TEACHING INTRODUCTORY ELECTRICITY – AIMS AND MOTIVES OF TEACHERS

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This study investigates the aims and motives regarding the teaching of introductory electricity of 34 physics teachers from parts of Austria and Germany. According to the model of teacher professional knowledge and skill, teacher's beliefs and orientations act as amplifiers and filters when it comes to personalising professional knowledge during their actual teaching practice. The construct of Orientation to Teaching Science (OTS) as one type of such filters serves as a theoretical basis for this study. According to Magnusson, Krajcik, & Borko (1999), an orientation presents a "general way of viewing and conceptualising science teaching". However, recent research suggests that OTS can differ from topic to topic. Hence, the goal of this study is to search for first hints of topic-specific teaching orientations among the teachers participating in a design-based research project on introductory electricity. As a first step we administered an open-ended questionnaire to 34 teachers in parts of Austria and Germany to identify their aims and motives regarding teaching introductory electricity at middle school. The results of the subsequent qualitative content analysis and their relation to Orientation to Teaching Science are reported in this article.

Keywords: Teacher Professionalism, Teacher Thinking, Teaching Practices

INTRODUCTION

The resources teachers draw upon in their daily teaching routine have been one focus in science education research in the past decades. Nearly each study regarding teachers' resources that influence teaching mentions (Shulman, 1987) initial conceptualization of pedagogical content knowledge (PCK). Nevertheless, there was little consensus among science education researchers how PCK should be conceptualised (Loughran, Mulhall, & Berry, 2004; Magnusson, Krajcik, & Borko, 1999). One approach to specifying PCK was developed during the first PCK-Summit held in 2013, which resulted in the formulation of "the model of teacher professional knowledge and skill (TPK&S)" (Berry, Friedrichsen, & Loughran, 2015). The innovations resulting from this frequently-called "consensus model" is a differentiation between personal PCK and skills on the one hand and topic-specific professional knowledge (TSPK) on the other hand as well as a distinction between teachers' PCK and their beliefs and orientations. In this model, beliefs and orientations act as amplifiers and filters that personalise knowledge, which teachers have acquired during their studies and years of teaching practice. As Gess-Newsome (2015) puts it, this knowledge must pass through the lens of teachers. This idea of amplifiers and filters may also account for findings that show that for example professional development does not have a direct effect on teachers' classroom practice (Gess-Newsome, 2015).

THEORETICAL FRAMWORK AND RESEARCH QUESTIONS

In recent years, many studies regarding teachers' beliefs, especially epistemological beliefs, have been conducted. However, the concept of Orientation to Teaching Science (OTS) and its role as an amplifier or filter is underrepresented in research. According to Magnusson, Krajcik and Borko (1999), an "orientation presents a general way of viewing science teaching" and "serves as a conceptual map that guides instructional decisions". However, in an extensive review of literature, Friedrichsen et al. (2011) identified four major problems concerning OTS: "Using OTS in different or unclear ways", "Unclear or absent relationship between orientations and other PCK model components", "Assigning science teachers to one of the nine orientations proposed by Magnusson et al. (1999)" and "Ignoring the overarching orientation component". However, they identify a consensus about three dimensions of OTS. These are (1) beliefs about the goals and purposes of science teaching, (2) beliefs about the nature of science and (3) beliefs about science teaching and learning. Furthermore, Campbell, Melville and Goodwin (2017) found first hints that OTS is, like TSPK, topic specific. Subsequently, the conceptualisation of Orientation to Teaching Science only as an overarching, topic-independent set of beliefs is not satisfactory. We think of OTS as an overarching concept, similar to the description given by Magnusson et al. (1999), but there might be further subcategories of OTS that especially influence the teaching-style of various topics within a subject. Hence, we propose a topic-specific orientation to teaching science, in the case of introductory electricity "orientation to teaching introductory electricity (OTIE)".

The main aim of our study, which is part of a DBR project on teaching introductory electricity in middle schools (Haagen-Schützenhöfer, Burde, Hopf, Spatz, & Wilhelm, 2019) is to investigate whether this conceptualisation is meaningful and if this topic-specific orientation can be captured. To do so, in a first step we administered an open-ended questionnaire to 34 teachers in parts of Austria and Germany to identify their aims and motives regarding the instruction of introductory electricity. Doing so, we want to gain first insights about the topic-specificity of the participants' beliefs about the goals and purposes of teaching introductory electricity and their beliefs about teaching and learning introductory electricity on a superficial level. We interpret the answers to the questions in the questionnaire as hints regarding the teachers' beliefs. Furthermore, these insights form the basis for in-depth interviews, which are not reported in this article. Hence, the analysis was guided by the following research questions:

RQ1: What are the most important key ideas/aspects teachers want to convey in their introductory electricity lessons?

RQ2: How do the participating teachers rate the importance of the use of models, experiments and calculations for their teaching and students' learning of introductory electricity and what are the reasons for their rating?

DESIGN & METHODS

This study is embedded in a large DBR project on introductory electricity carried out in parts of Austria and Germany. In the first year of this project, participating teachers followed their usual approach to introductory electricity in 7th and 8th grade middle school. Different types of data were collected for this study during this period, the results presented in this article are a small part of the overall project. After teaching introductory electricity, participating teachers were asked to fill in an online-questionnaire. In total, 34 physics teachers (M_{age} = 40.4 years, SD_{age} = 9.9 years, N_{female} = 15, N_{male} = 19, $M_{teachexp}$ = 13, $SD_{teachexp}$ = 7.48) filled in the online-questionnaire. Among other questions, which are not reported in this article, the teachers were asked about certain aspects of their introductory electricity lessons which correspond with the research questions of this article. These questions were:

1. What are the three most important key ideas you want to convey in your introductory electricity lessons?
2. a) How important are models for teaching introductory electricity?
   b) What are the reasons for your rating in 2a)?
3. a) How important are experiments for teaching introductory electricity?
   b) What are the reasons for your rating in 3a)?
4. a) How important are calculations for teaching introductory electricity?
   b) What are the reasons for your rating in 4a)?

The first question was formulated as an open-ended question, whereas questions two to four were two-tiered questions. In the first tier, the teachers were asked to rate the importance of models/experiments/calculations in general on a likert scale ranging from one (not important) to four (very important). In the second tier, the teachers were asked for the reasoning behind their rating. All open-ended questions were analysed by means of qualitative content analysis (Mayring, 2010).

FINDINGS & RESULTS

In this section, the results of the ratings from the likert scale items as well as the resulting categories from the qualitative content analysis are reported.

Important key ideas when teaching introductory electricity

In order to answer research question one, the answers regarding the question "What are the three most important key ideas you want to convey in your introductory electricity lessons?" were analysed inductively, some answers were assigned to two categories. The resulting categories are shown in Figure 1. The colour coding represents the priority of the answers from the teachers, the percentages refer to all 34 teachers.

The distribution of the categories shows that the participating teachers follow quite different key ideas in their introductory electricity lessons, since there is no predominant category. Electricity in everyday life is the most frequently mentioned category (53% of all teachers), followed by introducing a model representation of electric current (42%) and thematising the basic quantities voltage, current and resistance (38%). In addition to categories which are specific to introductory electricity, some teachers also mentioned more general key ideas like conducting experiments (24%), enjoying physics (12%) and performing measurements (9%). Only one teacher (3%) mentioned understanding the Nature of Science as one of the three most important key ideas.

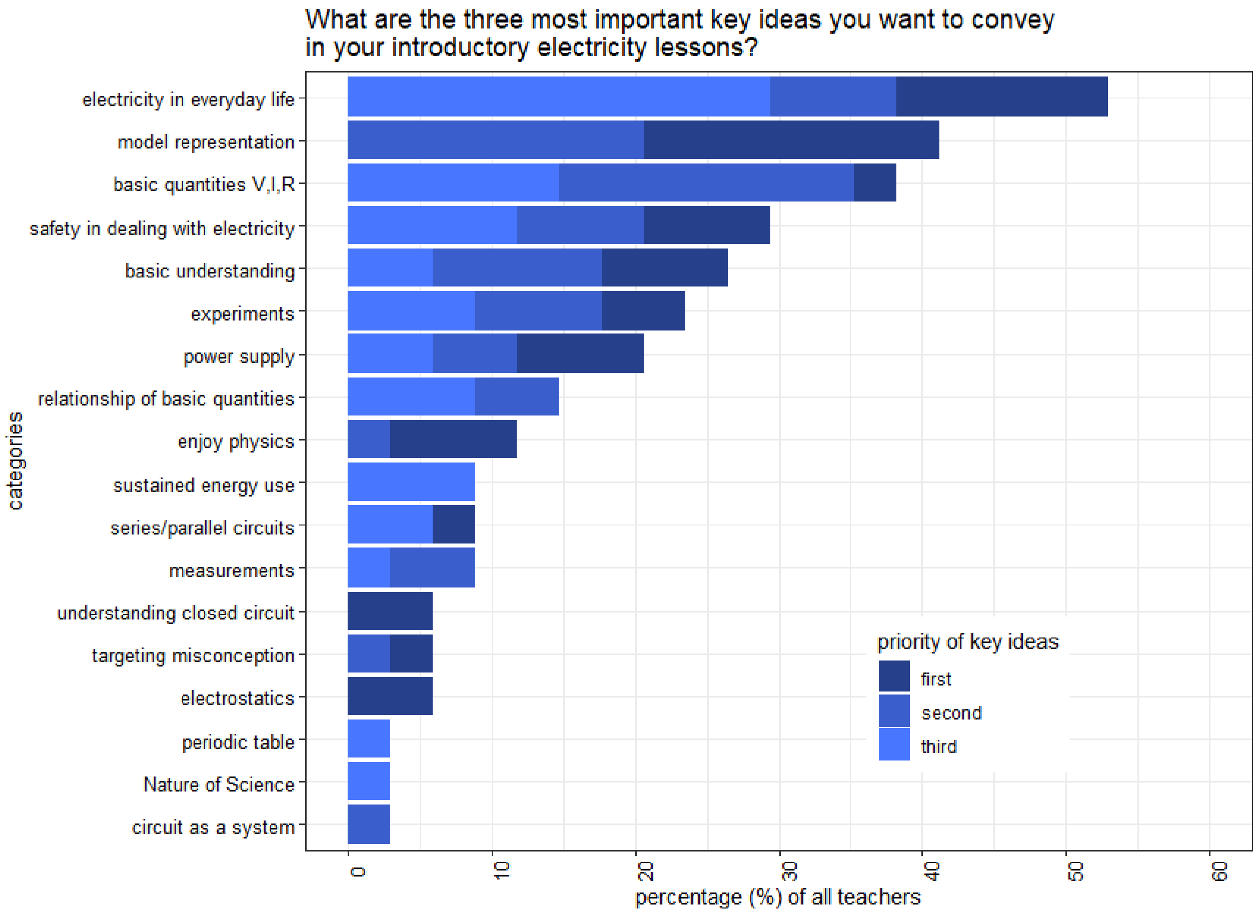

Figure 1. Teachers' answers regarding the question "What are the three most important key ideas you want to convey in your introductory electricity lessons?"

Perceived importance of calculations, experiments and models for teaching introductory electricity

In this section, the distribution of the ratings regarding the questions “How important are models/experiments/calculations for teaching introductory electricity?” are presented. In the subsequent sections, the teachers’ reasonings behind their rating are discussed. The distribution of the ratings is shown in Figure 2.

Regarding the perceived importance of models, almost all of the participating teachers rate the use of models as very (56%) or rather important (38%). A similar result is reported for the perceived importance of experiments, where 59% of all teachers rate experiments as very important for teaching introductory electricity and 35% rate it as rather important.

The results concerning the question “How important are calculations for teaching introductory electricity?” are rather heterogeneous. About half of the teachers rate calculations as rather (47%) or very (6%) important, whereas the other half of the teachers rate calculations as rather not (41%) or not (6%) important.

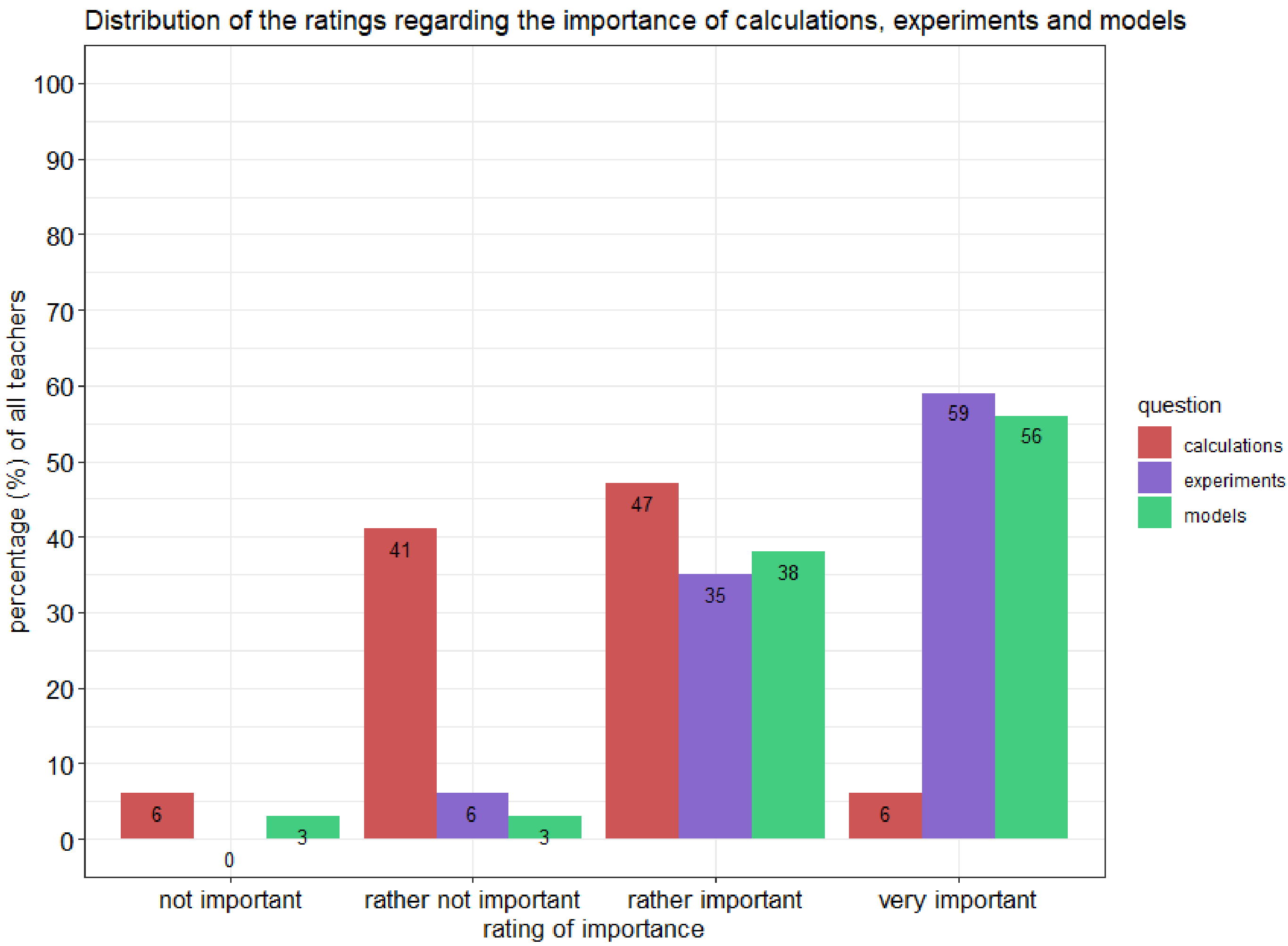

Figure 2. Distribution of the teachers' ratings regarding the importance of calculations, experiments and models for teaching introductory electricity

Perceived importance of models for teaching introductory electricity

Figure 3 shows the resulting categories of the reasoning behind the rating regarding the importance of models. Answers from three teachers were assigned to two categories, resulting in a total amount of 37 codes. However, the percentages reported in Figure 3 refer to the 34 teachers. 65% of the teachers report “models illustrate the abstract” as their reasoning behind their rating, all of them rated models as rather or very important. Answers attributed to this category also frequently mention that electric current is invisible and hence needs to be represented using a model. Hence, this category can be seen as topic-specific for electricity.

In contrast, the categories “models as an important part of physics” (26%) and “models facilitate learning” (18%) are rather general, topic-independent categories. Additionally, one teacher argues that models are not important for introductory electricity because they are too complicated for children at this age (grade 7 and 8). Another teacher argues that models are not central for his or her teaching without any further explanation.

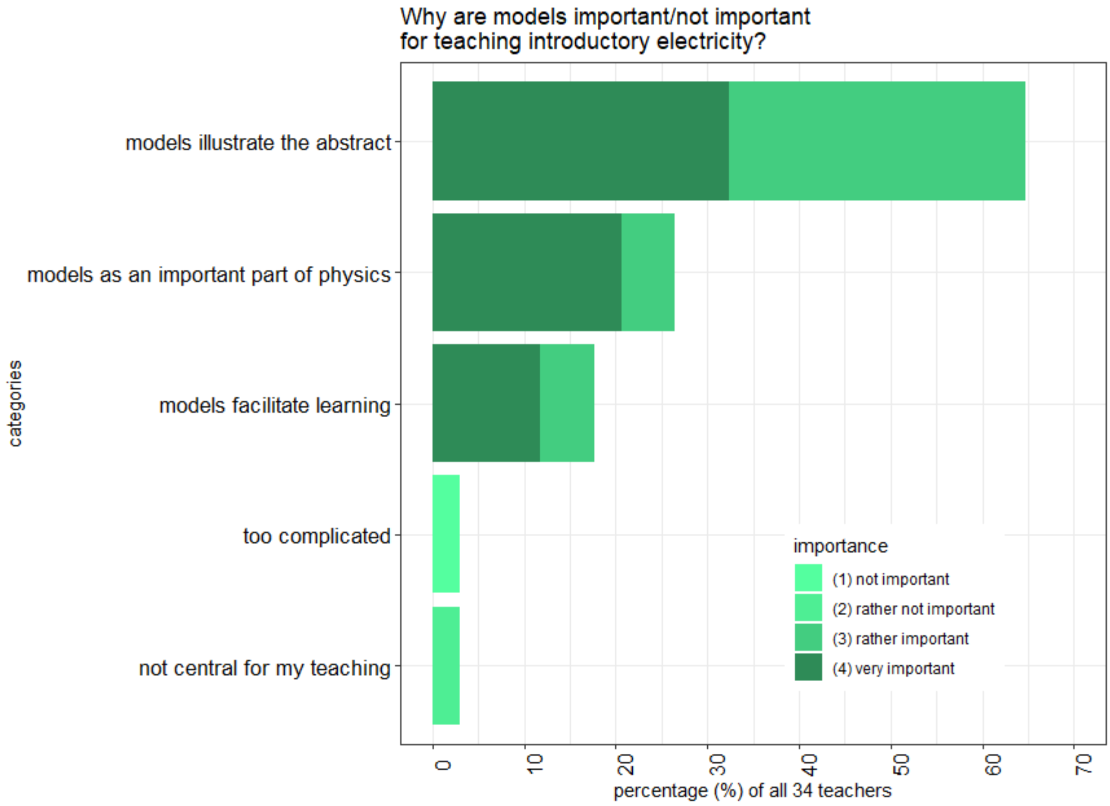

Figure 3. Teachers' reasonings regarding the question "Why are models important/not important for teaching introductory electricity?" The rating refers to the general importance of models for teaching introductory electricity, while the categories represent the different reasonings behind the rating of the importance

Perceived importance of experiments for teaching introductory electricity

Almost all of the teachers rate experiments as rather (35%) or very (59%) important for teaching electricity, whereas only two teachers (6%) rate them as rather not important. The latter group argues that experiments are overestimated for learning content knowledge, as shown in Figure 4. Again, the answers from some teachers were assigned to multiple categories, however the percentages in the figure refer to the 34 teachers. Although there is consensus among the teachers that experiments are important, the reasons for their opinion are quite diverse.

Similar to the findings concerning the use of models, some reasonings for the use of experiments are of a topic-specific nature whereas others are more general and topic-independent. For example, the most dominant category “experiments facilitate learning” (32%) is a general category and reasonings that were assigned to this category do not refer to any topic-specific aspects. This also applies to the category “interest/motivation” (24%). Reasonings assigned to this category explain that experiments spark interest or improve the motivation of students. However, the categories “electric current is invisible” (32%) or “experience electricity phenomena” (9%) are clearly topic-specific for (introductory) electricity. An additional, interesting, finding is that while teachers perceive models as important for teaching introductory electricity because models are an important part of physics, experiments are important due to other reasons. Only one teacher emphasises that experiments are important because they are a crucial part of physics.

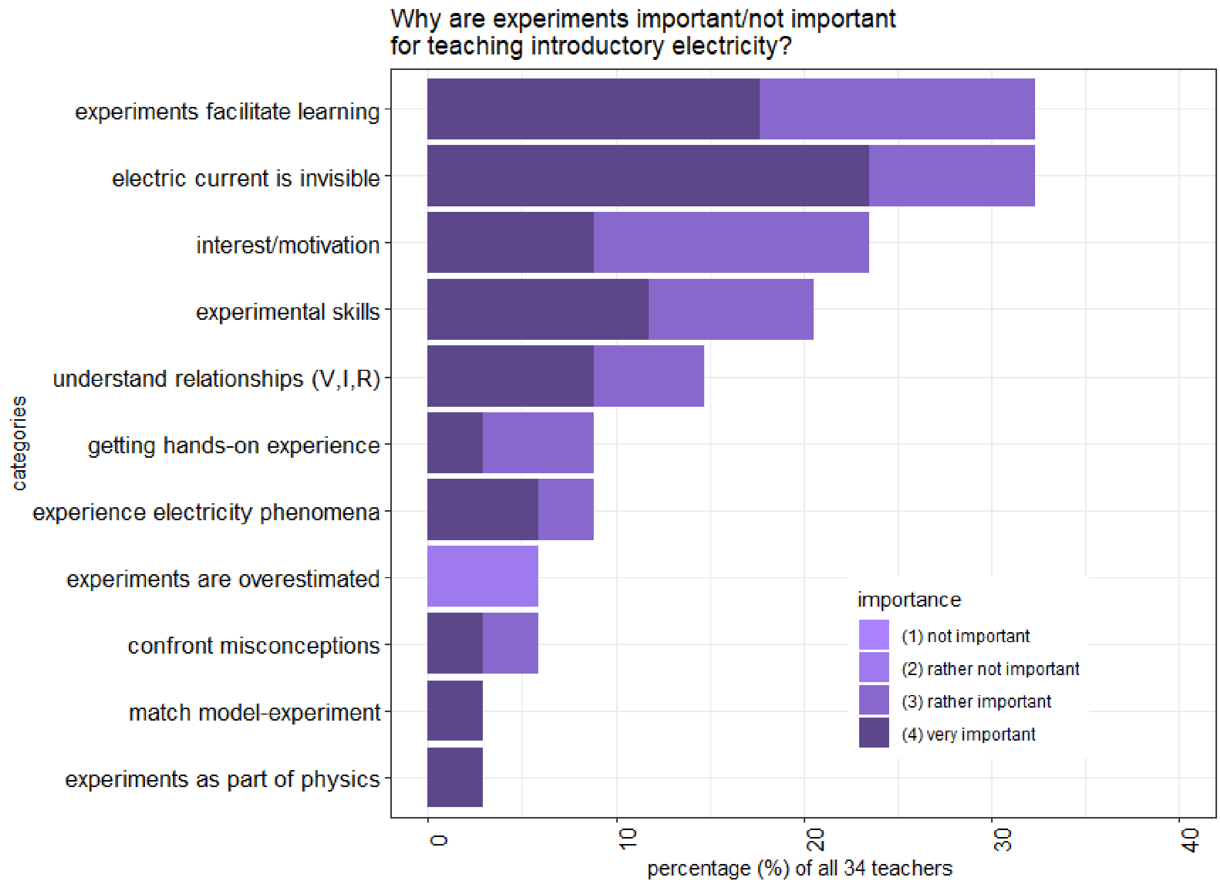

Figure 4. Teachers' reasonings regarding the question "Why are experiments important/not important for teaching introductory electricity?" The rating refers to the general importance of experiments for teaching introductory electricity, while the categories represent the different reasonings behind the rating of the importance

In total, the resulting categories concerning the use of experiments can be attributed to three overarching themes:

1. Experiments facilitate learning, interest and motivation
2. Experiments make electric current “visible” or “perceptible”
3. Experiments are important for hands-on experience and experimental skills of students

Perceived importance of calculations for teaching introductory electricity

Since the results regarding the reasoning behind the rating of the importance of calculations for teaching introductory electricity are diverse, the resulting categories are presented in two separate figures. Figure 5 shows the resulting categories for teachers who rated calculations as rather or very important. Figure 6 shows the results for teachers who rated calculations as rather not or not important. The percentages displayed again refer to the total amount of 34 teachers.

These resulting categories presented in Figure 5 and Figure 6 indicate that a conceptual or qualitative understanding of introductory electricity is more important for many teachers (38% in total) than performing quantitative calculations. Interestingly, these reasonings can be found for teachers who have rated calculations as rather important (15%) but also rather not or not important (23%). None of the teachers explains his or her rating of the importance with topic-specific reasons.

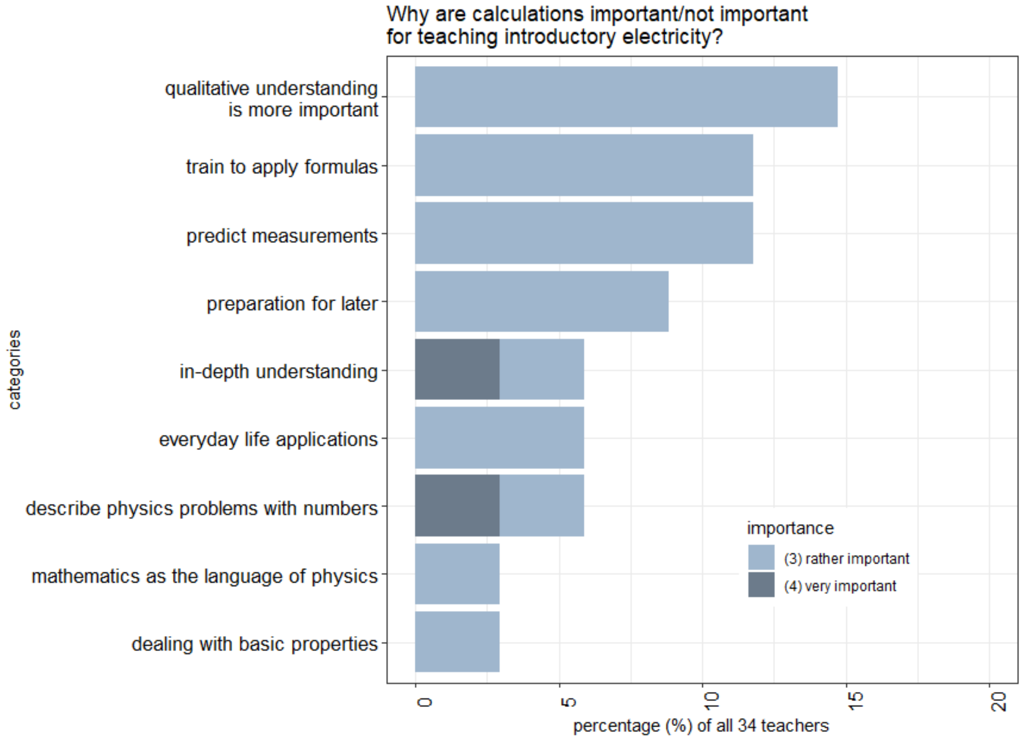

Figure 5. Teachers' reasonings regarding the question "Why are calculations important/not important for teaching introductory electricity?" The figure shows reasonings behind the ratings “rather important” and “very important”. The rating refers to the general importance of calculations for teaching introductory electricity, while the categories represent the different reasonings behind the rating of the importance

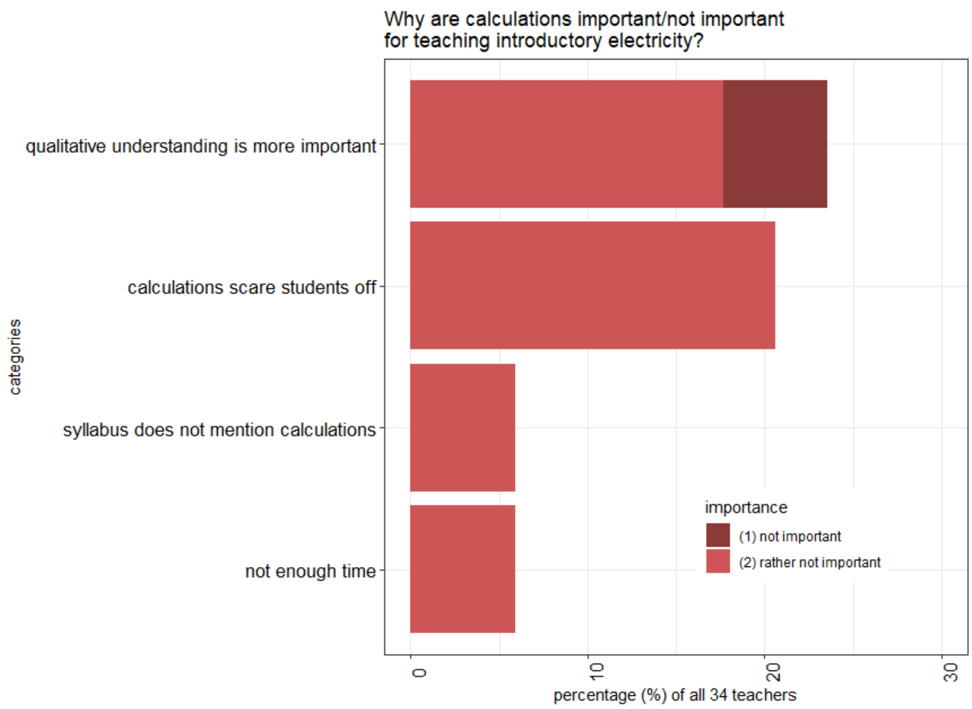

Figure 6. Teachers' reasonings regarding the question "Why are calculations important/not important for teaching introductory electricity?" The figure

shows reasonings behind the ratings of "rather not" and "not important". The rating refers to the general importance of calculations for teaching introductory electricity, while the categories represent the different reasonings behind the rating of the importance

DISCUSSION UND CONCLUSION

The findings presented in the previous section will be discussed now with respect to their topic-specificity and in relation to two dimensions of the conceptualisation of Orientation to Teaching Science proposed by Friedrichsen et al. (2011). The two dimensions we focus on are beliefs about the goals and purposes of science teaching and beliefs about teaching and learning science. Although the reasonings and answers to the open-ended questions of questionnaire can neither represent nor describe the teachers' beliefs thoroughly, the presented results can act as first hints whether there are certain topic-specific elements to the afore mentioned beliefs.

We interpret the answers to the question "What are the three most important key ideas which you want to convey in your introductory electricity lesson?" as indicators for the participants' beliefs about their most important goals and purposes of introductory electricity teaching. The results presented in the previous section indicate that there are some general goals or aims teachers follow, for example to "enjoy physics" or to understand the "Nature of Science". However, there are also goals or key ideas which are topic-specific. For example, reasonings that were assigned to the category "safety in dealing with electricity" are topic-specific reasonings which do not refer to a specific concept (e.g. voltage) but rather represent why it is important to teach introductory electricity in general.

This can only be seen as a first hint that teachers' individual beliefs about the goals and purposes of teaching science vary for different topics in some aspects. Still this leaves room for the idea that the teaching style of a single teacher, for example how they approach experimental work, might differ between two topics. This idea can be illustrated with a concrete example: A teacher may have a different approach to experiments when teaching electricity and mechanics because he/she believes that experimental work is more important when teaching electricity since the students need to learn how to handle electricity safely. We think that this idea should be addressed in future research.

While we certainly cannot provide a detailed picture about the teachers' beliefs about science teaching and learning, the perceived importance of models/experiments/calculations for teaching introductory electricity is certainly related to the participating teachers' beliefs about science teaching and learning. The results regarding the perceived importance of both experiments and models indicate that teachers' beliefs about science teaching and learning may have topic-specific elements. For example, some teachers highlight that experiments are important when teaching introductory electricity because electric current is "invisible" or models are important because they illustrate the abstract (like electric current).

Overall, this implies that studies that intend to capture Orientation to Teaching Science need to consider a potential topic-specificity. Future studies should further explore whether teachers' orientations to teaching science differ for different topics.

The findings reported in this article are furthermore interesting for researchers focusing on curriculum innovation. While it is broadly known and accepted that general beliefs about teaching and learning science influence the implementation of curricula and/or teaching materials, this might also be true for beliefs about teaching and learning a specific topic. Imagine developing a curriculum for introductory electricity which heavily focuses on electricity in everyday life but neglects experiments and models of electric current. It might very well be possible that the fidelity of implementation (O'Donnell, 2008; Stains & Vickrey,

2017) of this curriculum might subsequently be non-satisfactory since most of the teachers think that models and experiments are important for teaching and learning introductory electricity and hence divert from the proposed curriculum.

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TEACHER-LEADERS' LEARNING WHILE LEADING A PLC OF PHYSICS TEACHERS – THE CASE OF THE INQUIRY-BASED LABORATORY

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Teacher-leaders (TLs) play a major role in teachers' Professional Development (PD) and in building effective Professional Learning Communities (PLCs). However, the PD of the TLs themselves is rarely discussed in the literature. This study examined the learning of high-school physics TLs in a program involving PLCs. The program has been operating since 2012, using a "Fan Model": the TLs participate in a PLC led by a team from the Weizmann Institute of Science (TL-PLC), while they simultaneously teach in high school and lead regional PLCs of physics teachers all over Israel. We extended the Interconnected Model of Professional Growth (Clarke and Hollingsworth, 2002), adjusted it to the professional world of physics TLs, and used it to study the learning of three TLs that were chosen as case studies. We studied for four years (2014-2017) the changes in their knowledge, attitudes, and practice, in the context of the inquiry-based laboratory. For each case study we created a chronological map based on our Extended Interconnected Model of Professional Growth. The results show significant changes in the three TLs' knowledge, attitudes, and practice, and their ongoing professional growth. The TLs' learning was promoted by the mechanisms of "Enactment" and "Reflection", which were implemented in the program in a specific rational order and at appropriate times, in all the aspects of the TLs' practice. The alternating meetings, every other week, of the TL-PLC and the regional PLCs, helped to integrate the TLs' learning into their practice, both as teachers and as PLC leaders. The TLs successfully implemented the inquiry-based activities in their teaching routine for a long period. Our results enhance our understanding of the TLs' learning, as well as features in the program that promoted it, and can contribute to the design of effective PD programs for both teachers and TLs.

Keywords: Continuing professional development; Learning Communities; Laboratory Work in Science.

INTRODUCTION

It is widely agreed that effective teachers' Professional Development (PD) programs should be ongoing, challenging, focused on student learning, and situated in teachers' practice (Borko, 2004; Darling-Hammond & Richardson, 2009; Desimone, 2009). Professional Learning Communities (PLCs) are an essential component of high-quality PD (Grossman, Wineburg & Woolworth, 2001; Shulman, 1997; Vescio & Adams, 2015). Teacher-Leaders (TLs) play a major role in teachers' PD and in building effective PLCs (Klentschy, 2008; National Academies of Sciences, 2015; York-Barr & Duke, 2004). However, the PD of the TLs themselves is rarely discussed in the literature (Criswell, Rushton, McDonald & Gul, 2017; Even, 2008). This study is part of a larger research (Levy, Bagno, Berger & Eylon, 2018) aimed at bridging this gap.

We examined the PD of high-school physics TLs that participated in a program involving PLCs. The program has been operating since 2012, by using a "Fan Model" (described in Fig. 1): the TLs participate in a PLC led by a team from the Weizmann Institute of Science (TL-PLC), while they simultaneously teach high-school physics and lead regional PLCs of physics teachers.

Figure 1. The "Fan Model" used in the PLCs program

The TLs' learning is "evidence-based": They enact each new instructional activity in their classes and in the regional PLCs, collect and analyze data about students' and teachers' learning, as well as reflect collaboratively on the evidence from classes and from the regional PLCs. Each PLC operates by face-to-face meetings lasting 4 hours each, twice a month during the school year. In the 2019 school year there were 24 TLs in the program, and 12 regional PLCs with about 250 high-school physics teachers.

The context of the current study is inquiry-based laboratory, aimed at moving away from the widespread contrived instructional laboratory (Abrahams, 2015) towards inquiry-oriented activities that represent aspects of authentic research, and give students more responsibility for their work (American Association of Physics Teachers, 2015; Etkina et al., 2010). Each inquiry-based activity lasts two lab-lessons, in which the students work collaboratively in small groups, and experience a variety of inquiry practices, such as asking questions, formulating hypotheses, planning and carrying out experiments, analyzing data, constructing explanations, and finally sharing their results with the whole class. The inquiry-based activities were new to all TLs and fundamentally differed from their traditional teaching methods, pushing them beyond their "comfort zone".

Theoretical frameworks for research on TLs' PD should take into consideration the multiple contexts of their practice, both as teachers and as PLC leaders. Situative perspectives serve as a powerful research tool, taking into account both the individual teacher-learners and the social systems in which they participate, including PLCs (Borko, 2004; Putnam & Borko, 2000). Our theoretical framework is based on the Interconnected Model of Professional Growth (Clarke & Hollingsworth, 2002), shown in Fig. 2. This model recognizes the complexity of teachers' learning and suggests the perspective of teachers as active learners who shape their professional growth through reflective participation in PD programs and in practice.

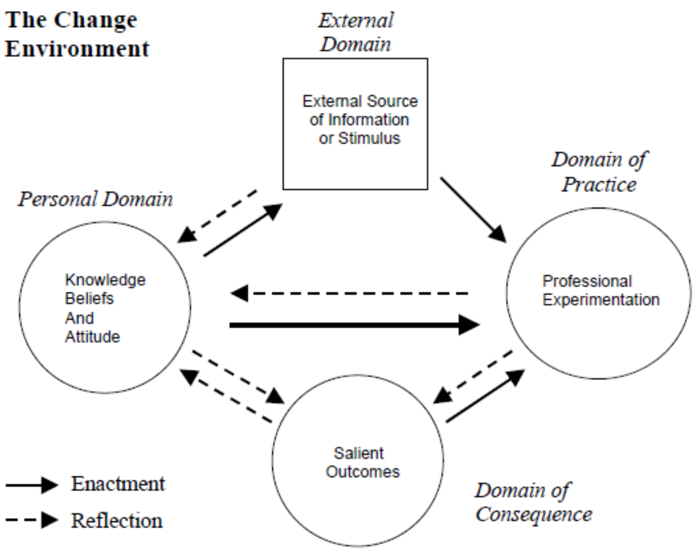

Figure 2. The Interconnected Model of Professional Growth (Clarke & Hollingsworth, 2002)

According to the model, four distinct domains encompass the teacher's world: the Personal Domain, referring to teacher's knowledge, beliefs and attitudes; the Domain of Practice, referring to professional experimentation; the Domain of Consequence, referring to salient outcomes, such as student learning or student motivation, and changes at the school level; and the External Domain, referring to sources of information, stimulus or support. A change in one domain is translated into another domain through the mediating processes of "Reflection" and "Enactment", which are represented in the model as arrows linking the domains.

We extended Clarke & Hollingsworth's model to an Extended Interconnected Model of Professional Growth (EIMPG), adjusted it to the professional world of physics TLs, and used it to study the TLs' professional growth, focusing on changes in their knowledge, attitudes and practice in the context of the inquiry-based laboratory.

Our main research questions are as follows: 1) what changes occurred in the TLs' knowledge, attitudes, and practice, in the context of inquiry-based laboratory; 2) how were these changes related to features of the PLCs’ program?

METHODS

This longitudinal study lasted four years (2014-2017). We used a case-study methodology that provided us with a prolonged and in-depth exploration of processes in the TLs' learning within the different aspects of their practice: their classrooms, their school, and the regional PLC that they led. Three TLs: Roy, Dana, and Sofia, were chosen for the case studies. All three are high-school physics teachers, who joined the program in different years, and differed from each other regarding their background as teachers and as TLs. Dana joined the TL-PLC in 2014, after 19 years as a teacher, and had no former experience as a TL. Sofia and Roy joined the TL-PLC in 2012. Sofia has been a teacher for 25 years, has been a district teachers' facilitator for 15 years, and has participated in many former PD programs. Roy has been a teacher for 18 years, graduated from a special M.Sc. program designed for excellent physics teachers, and had no former experience as a TL. Thus, Sofia was a senior teacher and had leadership experience, whereas the other two did not; Roy had research experience, whereas the other two did not.

Data were collected from a variety of sources, e.g., video records of TL meetings, reflection papers, interviews, and annual portfolios. The data related to Roy, Dana, and Sofia in the context of the inquiry-based laboratory were sorted and categorized (using Atlas.ti software) according to the different domains of the EIMPG, focusing on the different aspects of the TLs' practice. The mediating processes of "Enactment" and "Reflection" were identified, numbered in chronological order, and presented in a map that was created for each case study. The categorization, as well as the EIMPG maps, were validated by four researchers. Our results were discussed with Roy, Dana, and Sofia.

RESULTS

Roy, Dana, and Sofia's professional growth over the four years, both as teachers and as PLC leaders, was a complex, ongoing process. We will first examine the changes in the knowledge, attitudes, and practice of each case study in the context of the inquiry-based laboratory, using the EIMPG maps. Then we will consider features of the PLCs' program that promoted these changes.

Changes in Roy's knowledge, attitudes, and practice

The EIMPG map for Roy, in the context of the inquiry-based laboratory, is shown in Fig. 3. The mediating processes of "Enactment" and "Reflection" are represented, respectively, as solid and dashed arrows linking the different domains of the EIMPG. The colors denote different aspects of Roy's professional experimentation: as a teacher in class, as a TL in school, as a TL in the regional PLC, and as a member of the TL-PLC.

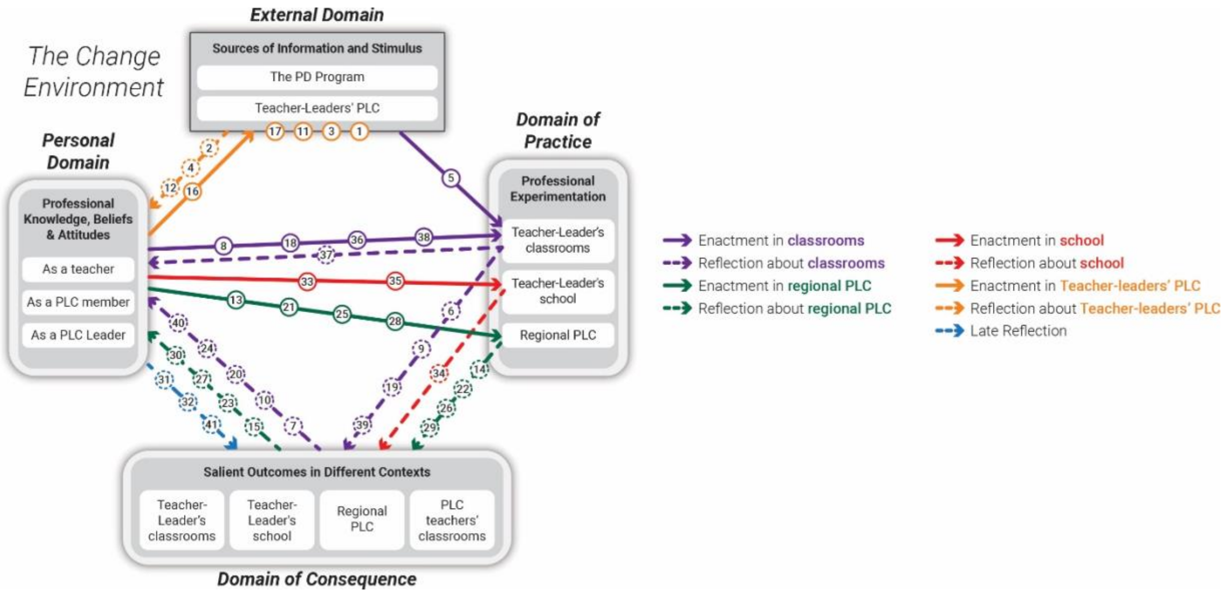

Figure 3. Roy's EIMPG Map

Roy's initial experience with an inquiry-based lab activity was as a learner in the TL-PLC (1). His reflection was (2):

I had the notion that an inquiry-based lab is a long and grandiose process, and requires expensive instruments. I really liked the experience today of inquiry with such simple equipment. (Roy's reflection paper 1, September 2014).

At the following TL meeting, Roy experienced another inquiry-based lab activity (3) and reflected on that experience (4):

Our group had a frustrating half an hour because it took us a long time to figure out how to take measurements. It made me feel like my students when they face difficulties in the lab… It was an important experience for me. (Roy's reflection paper 2, September 2014).

A few days later, Roy enacted his first inquiry-based activity in a 12th grade lab-lesson (5), described the outcomes (6), and referred to the challenges that he faced (7):

I wasn't sure what to emphasize in the class discussion: the needed lab-skills? The theoretical aspects? I'm afraid my students remained confused". (Interview, September 2014).

Roy enacted the same activity in another 12th grade class (8) and reflected on it (9 and 10):

The students focused on the challenge of taking measurements and getting results. This second experience in class made me ask myself what are the main goals of this activity and when is the best time to enact it. (Interview, October 2014).

After his third experience at the TL meeting (11), Roy reflected (12):

It was the first time I really understood the whole process of inquiry and now I feel much more confidence with it. (Roy's reflection paper 3, November 2014).

Then Roy enacted an inquiry-based lab activity in his PLC for the first time (13) and reflected on it (14-15):

The teachers really liked this activity. They enjoyed the team work and said that the challenges that they faced were frustrating. (TL meeting, November 2014).

Roy also advised other TLs how to enact the activity in their regional PLCs (16), and the challenges were discussed with the leading team (17). Roy's map presents many more sequences of "Enactment" and "Reflection" (18-32; 36-41), both in his classes and in the regional PLC. He helped other teachers in his school to enact inquiry-based activities as well (33-35), and was pleased with the outcomes.

The repeating enactments, following changes in Roy's knowledge and attitudes, were more mature, and included personal adaptations of the activities. Roy reflected on the changes in his attitudes towards the inquiry-based laboratory:

At the beginning of the year I thought that inquiry activities require a lot of time and expensive equipment. However, after all my experimentations this year, I definitely changed my opinion – we can do inquiry activities even with the limited time we have and also with cheap and simple equipment. I even managed to persuade the teachers at my school and at my PLC to use inquiry activities. (Roy's portfolio, July 2015)

In addition, Roy gained more confidence as a TL:

I feel much more confident now. Here I am leading teachers, they try the new activities in their classes and they come back with positive feedback. It makes me feel that I can influence both teachers and students. (Interview, April 2016).

Roy, attributed great importance to his experiences in class before the enactment in the regional PLC:

We must try everything in class before introducing it in the PLC. It helps us find the best way to enact each activity. For example, how much time is needed for the inquiry activity, what difficulties are expected? When I tell the teachers that I tried it with my students and it worked well, it motivates them to try it in their classes too. (Interview, July 2016)

Roy successfully implemented the inquiry-based activities in his teaching routine, developed new inquiry-based activities for his students, and shared these activities with the other TLs.

Changes in Sofia's knowledge, attitudes, and practice

Sofia's EIMPG map is shown in Fig. 4. Sofia participated in a former summer PD and had some experiences with inquiry-based activities, which are not presented in the map. Her first experience in that context within the PLCs' program was at the TL meeting (1), and she reflected on that experience (2):

It was very challenging because our results were different from our predictions, and we struggled to understand our mistake. I really enjoyed the activity, but I don't think I will use it with my students. It is too complicated. (Sofia's reflection paper 1, September 2014).

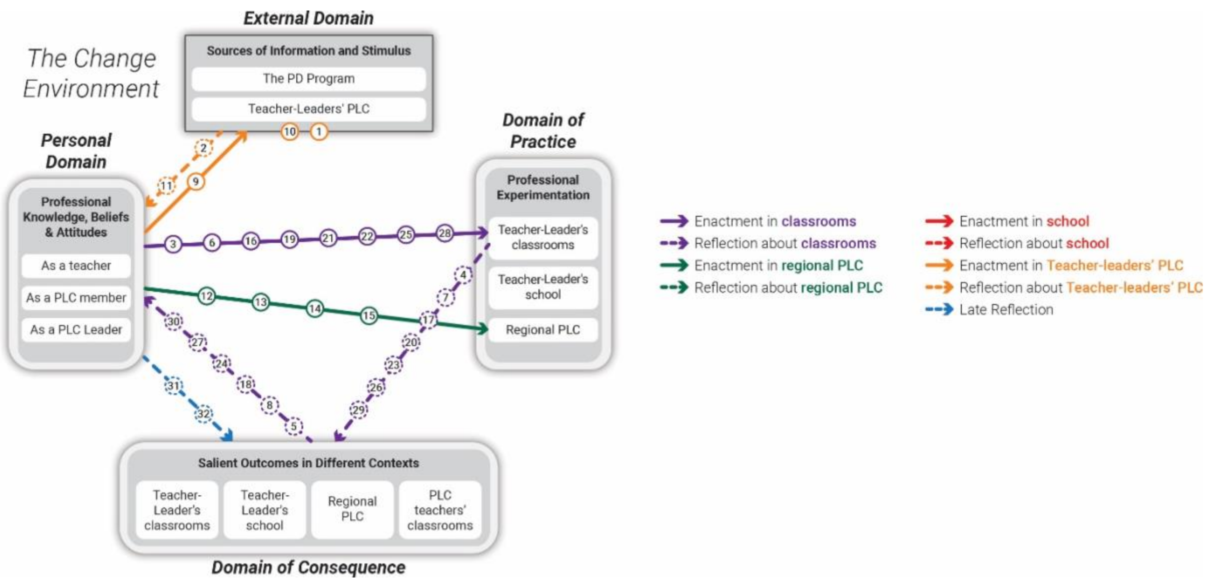

Figure 4. Sofia's EIMPG Map

Sofia made some changes in a traditional activity that she used before, designed it as an inquiry-based activity, and enacted it in her 9th grade class (3). Her reflection was (4 and 5):

Each group decided on its own inquiry question… It was interesting for me to realize that some of them understood the experimental system and some of them didn't…We had a rich discussion regarding measuring skills, and it was amazing. (TL meeting, October 2014).

Sofia enacted another inquiry-based activity in another class (6) and reflected (7 and 8):

> *It was so good! I am enthusiastic about this way of working in the lab*. (Interview, October 2014).

At the TL meeting, Sofia suggested how to design another familiar experiment as an inquiry-based activity (9). In the following TL meeting, she experienced another new activity (10) and reflected on it (11):

> *I really like it; I intend to use it with my students next week*. (TL meeting, November 2014).

Sofia enacted some inquiry-based activities in her regional PLC (12-15), but did not reflect on these experiences. She kept using inquiry-based activities in class for a long period, and her EIMPG map presents multiple enactments and reflections (16 - 32).

Changes in Dana's knowledge, attitudes, and practice

Dana's EIMPG map is shown in Fig. 5. Dana's initial experiences with inquiry-based activities were as a learner in the TL-PLC (1 and 2). She reflected on these experiences (3):

> *We felt like students. It was very frustrating that we didn't manage to take measurements at first*. (Dana's reflection paper 2, September 2014).

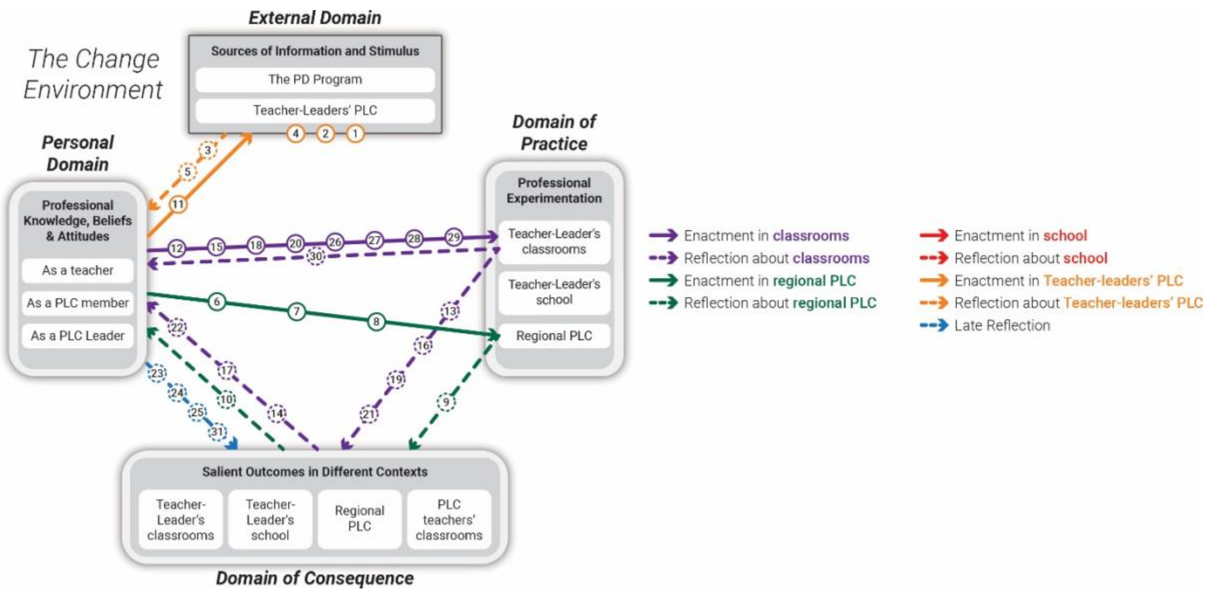

Figure 5. Dana's EIMPG Map

Dana experienced a third inquiry-based activity in the TL-PLC (4), and her reflection this time was (5):

> *I think that this activity is easier for students.* (Dana's reflection paper 3, November 2014).

She enacted two of these activities in the regional PLC and reflected on them (6-10):

> *The teachers were enthusiastic about this new approach of inquiry-based lab activities*. (TL meeting, January 2015).

Unlike Roy and Sofia, who immediately implemented the inquiry-based activities in their classes, Dana needed to undergo several experiences, both in the TL-PLC and in the regional

PLC, in order to enact an inquiry-based activity for her class for the first time. She shared her plans with all the TLs (11), enacted the activity in her 11th grade class (12-13), and reflected about what motivated her to do so (14):

> *I heard the other TLs and the teachers in my regional PLC reflecting on their experiences after they had begun to use inquiry-based activities with their students, and I told myself that I can't stay behind.* (Interview, January 2015).

After many sequences of "Enactment" and "Reflection" (15-31, January 2015 – July 2017), in different classes, Dana learned how to implement the inquiry-based activities successfully and continued to do so, in many variations, even after three years.

Features of the PLCs' program that promoted changes in the TLs' knowledge, attitudes, and practice

Roy, Dana, and Sofia implemented the inquiry-based laboratory in their teaching routine, in spite of the many challenges, and the changes in their practice lasted for more than three years. Examination of their EIMPG maps reveals that individual pathways exist for Dana, Sofia, and Roy's professional growth, as well as several similar patterns in all three EIMPG maps. For example, (1) repeating sequences of "Enactment" and "Reflection", in a certain order, which promoted changes in the Personal Domain, in the Domain of Practice, and in the Domain of Consequence; (2) experiences in the TL-PLC, accompanied by personal and collaborative reflection, and a change in the Personal Domain; (3) interactions between the Personal Domain and the External Domain, indicating the important role of the TL-PLC as a meaningful learning environment. We suggest that these similar patterns are related to features of the PLCs' program.

The TLs' learning, and the changes in their knowledge, attitudes, and practice, were promoted by the mechanisms of "Enactment" and "Reflection". The implementation of "Enactment" and "Reflection" in the program in a specific rational order and at appropriate times, in all aspects of the TLs' activity, enhanced their long-term professional growth.

The engaging experiences of the TLs in all aspects: as learners at TL meetings, as high-school physics teachers, and as regional PLCs' leaders, encouraged them to try the new activities in their classes, and to acquire the confidence needed for their successful implementation in class as well as in the PLCs.

The alternating meetings, every other week, of the TL-PLC and the regional PLCs helped to integrate the TLs' learning into their practice, both as teachers and as TLs. The evidence from the TLs' own classes, from the classes of other TLs, and from the PLC teachers' classes, provided the TLs with a wide perspective about the new activities. The collaborative reflection enabled the TLs to share insights, successes, and difficulties, and to get support, both moral and practical, from their peers and from the leading team.

The "Fan Model", as well as the features of the PLCs program, provided the TLs with opportunities to actively investigate their teaching and leading, consistently reflect on their practice and its consequences, and learn from one another in a supportive and non-judgmental environment.

DISCUSSION AND CONCLUSIONS

Roy, Dana, and Sofia's professional growth demonstrate professional "growth networks", as defined by Clarke and Hollingsworth (2002), who distinguished between local or short-term changes and lasting, long-term, teacher growth. Our results contribute an important aspect: the professional growth of TLs. In all three case studies the mediating processes of "Enactment" and "Reflection" were, as in the Clark & Hollingsworth's model, mechanisms that promoted changes in the knowledge, attitudes, and practice of the TLs. Roy, Dana, and Sofia's learning was based on their enactments and multiple reflections as learners at TLs' meetings, as high-school physics teachers, and as regional PLCs leaders.

The interactions we found between changes in the TLs' knowledge and changes in their practice demonstrate the significance of the construct "Knowtice" (a combination of Knowledge and Practice), introduced by Even (2008), which applies to the learning and development of physics TLs who lead regional PLCs.

Our results indicate the challenges of developing physics TLs as reflective practitioners, as described by Criswell et al., 2017, highlight the special needs of physics TLs, and emphasize the importance of responding to their needs and challenging their habits and views (Etkina, Gregorcic & Vokos, 2017; Timperley, Wilson, Barrar & Fung, 2008), particularly in the context of inquiry-based activities (Holmes & Wieman, 2018; Luft, 2001).

The TL-PLC turned out to be a meaningful and enriching learning environment. The supportive and non-judgmental environment helped the TLs to dare to try new things and cope with the challenges they were facing. These results support PLCs as a sustained, practice-based, and collaborative setting for effective teachers' PD (Vescio & Adams, 2015), in particular a TL-PLC.

Can the cases of Roy, Dana, and Sofia be generalized to other TLs in the program? Case studies always raise this question. However, the results of this study are in line with our research regarding the TLs in our program (e.g., Levy, Bagno, Berger & Eylon, 2018).

Having a better understanding of the learning processes and professional growth of physics TLs can contribute to the design of effective PD programs for both teachers and TLs.

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A NANOSCALE SCIENCE AND TECHNOLOGY TRAINING COURSE: PRIMARY TEACHERS' LEARNING ON THE LOTUS AND GECKO EFFECTS

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Lotus and gecko effects are considered as appropriate for introducing Nanoscale Science and Technology (NST) topics in compulsory education. Under this lens, we investigate primary teachers' (PTs) learning on the two effects after their participation in a NST training course. PTs completed a written questionnaire before and after the implementation. The analysis of the responses revealed that PTs' explanations shifted from a sensory perception-based to a more scientific view level. The common explanations involved the structural aspects of the two effects. Other abstract concepts such as forces were less internalized.

Keywords: primary school, in-service teacher training, teacher thinking

INTRODUCTION

Nanoscale Science and Technology (NST) consist of a modern field that focuses on the understanding of the behavior of materials having length scale in the range of 1-100nm, often denoted as the nanoscale. Due to the progress in the nanoscale materials domain, a plethora of applications in several sectors (materials science, electronics, medicine, etc) can be witnessed (Kumar & Koumbhat, 2016). A significant number of these advancements come from the field of biomimetics. Self-cleaning windows, superhydrophobic textiles have been driven by the inspiration from the superhydrophobic property of the lotus leaf (lotus effect). Efficient adhesive tapes, robots that can climb vertically, super adhesive gloves that may be used by firemen replicate the strong adhesion of the gecko lizards on to ceilings (gecko effect) (Bhushan, 2010).

Figure 1 and 2 represent aspects of the two effects. The lotus leaves present structural multi-scale roughness, having micro-bumps and nano-bumps which are covered with epicuticular wax, resulting in a high repellence between water droplets and the surface (Figure 1). Superhydrophobic lotus leaf exhibits self-cleaning properties showing high static water contact angle and low contact angle hysteresis (Kim et al 2018). The gecko lizard possesses one of the most effective adhesion mechanisms in nature regarding to its body mass. One single toe of the gecko consists of microscale hair-like structures (called setae). Each seta ends to even smaller structures, the spatulae, whose width lies at the nanoscale dimension (Figure 2). When they come into contact with the ceiling a large number of van der Waals forces are sufficient enough for the gecko to defy gravity and adhere on the ceiling (Bhushan, 2010).

Introducing nanophenomena of the natural world and their related applications such as those described above are considered suitable for introducing salient NST concepts (e.g. size dependent properties, forces & interactions) to school students ("easy to digest" approach, Lin et al., 2015, p. 25). This approach has a positive impact to students' interest and it has the potential to excite and inspire schoolchildren about modern and future innovations. Both the effects have been included under the umbrella of the NST concept "Nanophenomena in the natural world", which has been acknowledged as a core concept for primary nano-education (Lin et al., 2015; Blonder & Sakhnini, 2016).

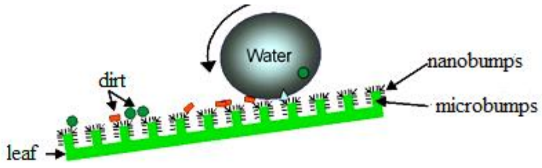

Figure 1. Representation of the lotus effect.[5]

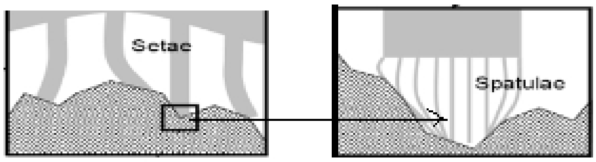

Figure 2. Representation of the gecko effect.[6]

However, in practice introducing NST at the primary level can turn out to be challenging. A major cognitive barrier for learning NST is the lack of intuition. The problem is conceptual & practical; objects –concepts are hard to visualize, difficult to describe, their relationships to the observable world can be counterintuitive (Sabelli et al., 2005, p.3). There is a consensus amongst scientists and educators in the field of NST that education of NST concepts relies on models and modeling. To be specific using, creating and understanding aspects of the nature and role of models are considered as a means for the construction of knowledge in nanoscale science education (Daly & Bryan, 2010).

Apart from the cognitive barriers, teacher preparation has been recognized as salient research topic. Undeniably, teachers play a pivotal role in the integration of NST in education. However, research findings indicate that teacher acknowledge their insufficient content knowledge about NST whereas several studies address that NST content learning is a critical aspect of teachers' learning. Research findings indicate that In order to help teachers to increase their understanding of fundamental NST concepts, they have to engage in appropriate learning environments (Healy 2009; Bryan et al., 2015).

Taking into account the above considerations we have designed and implemented a NST training course in order to educate primary teachers (PTs) about concepts and phenomena at the nanoscale, among them the lotus and the gecko effect. In this paper, we examine whether the course changed PTs' knowledge concerning the two effects. The research question that guided this study was: Did PTs' explanations about the lotus and gecko effects get improved after their participation in the NST training course?

RESEARCH METHODOLOGY

The training course consisted of nine lessons. The first five lessons were structured in a way to scaffold PTs to approach the nanoscale via macro- and micro- scale. During the sixth, seventh and eighth lesson lotus and gecko effects were introduced. The content of the two effects was transformed so that it could be approached by the primary teachers. Specifically, we introduced concepts that were related to their structural and physical properties (Kim et al., 2018). The former included micro- and nano-bumps/ setae-spatulae for the lotus and gecko effect respectively. The latter (physical properties) included concepts such as superhydrophobicity, self cleaning, contact angle, surface contact area for the lotus effect and electrical force and

[5] http://bioimicryreport.blogspot.com/2014/02/lotus-leaves-inspire-self-cleaning.html
[6] https://www.powershow.com/viewfl/ff23b-ZDc1Z/Gecko_Adhesion_powerpoint_ppt_presentation

surface contact area as well for the gecko effect. In addition for both of the effects, relevant applications that had clear connections to the everyday life were introduced. For example, the lotus effect was connected to superhydrophobic and self cleaning fabrics and the gecko effect to gecko pads and sticky gloves (table 1).

The lotus effect lesson can be divided into two phases. During the first phase, primary teachers collected data by studying animations, drawings and electron micrographs and by conducting experimental activities as well in order develop understanding about the salient concepts that relate to the phenomenon. During the second phase, they created and presented to the class their own models, that represented certain aspects such as, the structure of the surface leaf in the micro- and nano- scale, the superhydrophobicity, the self cleaning property, the contact angle etc (table 1). In figure 3, a group of teachers using a protractor measures on a printed image the contact angle between the water droplet and a wooden surface in order to clarify whether the surface is hydrophobic or hydrophilic. Figure 4 associates with the second phase of the lotus effect lesson. A group of teachers builds a concrete model using everyday materials, such as wooden sticks, egg cartons etc.

Table 1: The content and the activities that were conducted by the PTs during the lotus and gecko effect lessons.

The lotus effect lesson		
Lessons	Content	Activites
Lesson 6 -7	● Structure of the surface leaf in the micro- and nano- scale ● Superhydrophobicity ● Self cleaning property ● Contact angle ●Surface contact area ● Applications in everyday life	● Collecting data studying animations, drawings, electron micrographs & experimental activities ● Discussion ● Models Creation & Presentation: Suggest their own models in order to represent aspects of the lotus effect
The gecko effect lssson		
Lesson 8	● Structure of the gecko feet in the micro- and nano-scale ● How the gecko can adhere to a ceiling ● Applications in everyday life ● Surface contact area between surfaces	● Collecting data studying animations, drawings & electron micrographs ● Discussion ● Demonstration to the PTs of a model (Figure 7)

The gecko effect lesson consisted of two phases also. In the first phase, teachers collected information about the effect studying animations, drawings and electron micrographs (Figure 5). Then the whole discussed about the structure of the gecko feet in the micro- and the nano-scale, the mechanism that the gecko lizard exploits in order to adhere to the ceiling and about related applications in everyday life. In the second phase, the educator demonstrated a concrete model in order to represent the importance of the gecko foot structure in the maximization of the surface contact area between the foot and the ceiling (Figure 6).

Figure 3. A teacher measures the contact angle of the surface and the droplet.

Figure 4. A group of PTs create a model to represent the lotus effect.

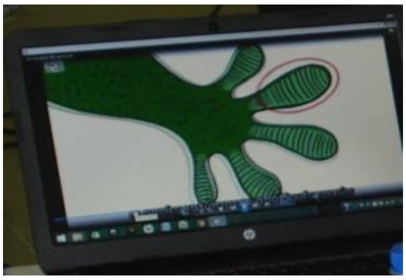

Figure 5. A snapshot of a video that PTs studied in order to collect data about the gecko effect.

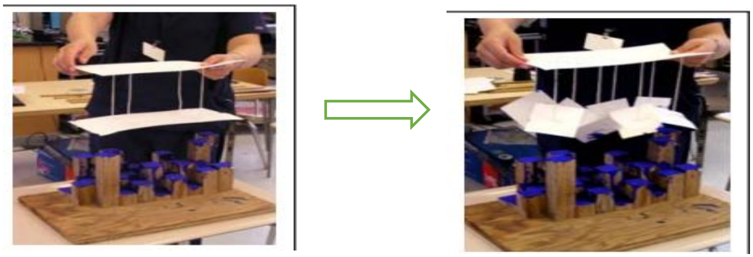

Figure 6. The model that was demonstrated in order PTs to develop understanding about the importance of the surface contact area to the adhesion of the gecko lizard to ceilings.

A total of 13 PTs (9 female) of several primary schools of Northern Greece participated in the training course. The years of teaching experience ranged from 6 to 21 years with a mean of 15 years.

A pre-post written questionnaire consisting of 7 items was created in order to assess primary teachers' NST knowledge. In this study, we present the first results from the two items that corresponded to the lotus and gecko and effect respectively. (i) Explain by using your own words and/or by a drawing *the spherical shape of a water droplet that rests on the leaf surface,* (ii) Explain by using your own words and/or by a drawing *the ability of the lizard to "stick" to surfaces even if upside down.* We consider that these two items can serve as a means for examining PTs' learning about key learning goals of the lotus and gecko effects' units: PTs to understand the superhydrophobic and strong adhesion property of the lotus and the gecko effects respectively and to appreciate the importance of the micro- and nano-scale in the determination of the two properties.

PTs' written responses were analyzed using the content analysis method. Specifically, within the participants' responses, significant words or phrases that provided a coherent explanation about the two effects were highlighted (Flick, 2009).

RESULTS

The table below depicts the words or phrases that were included in PTs' explanations concerning the lotus effect before and after the implementation.

Table 2. Terms that PTs expressed before and after the implementation in order to explain the lotus effect.

Explanation	PRE (terms)		POST (terms)	
Surface	Smooth, soft surface	7	Terms associated with the structure of the surface leaf in the micro- and nano- scale (micro- & nano-bumps)	6
	Hair-like structure	1		
Phenomena			Terms related with hydrophobicity	6
			Surface contact area	3
			Contact angle	1
Forces	Forces	3	Terms related with Forces	1
	No explanation	2	Vague terms about the structure	1

It is evident that PTs at the beginning of the training, expressed mostly perception-based explanations, such as the leaf has a soft or a smooth surface, while 4 of them attributed the spherical shape of the droplet to hair-like structure or to forces between the droplet and the leaf, without specifying the nature or the origin of these forces. After the training, PTs expressed their interpretation in much richer form, including several notions of the scientific knowledge, referring (for example) to the structure of the leaf in the micro- and the nano-scale and the superhydrophobic wetting state. As far as the drawings that PTs provided, either they did not draw any aspect of their explanation, either they provided vague drawings (Figure 7 left part). After the implementation, PTs draw exclusively the structural characteristics of the leaf at the micro- and nano-scale, fact that demonstrates explanations that are far from the sensory perception (Figure 7 right part).

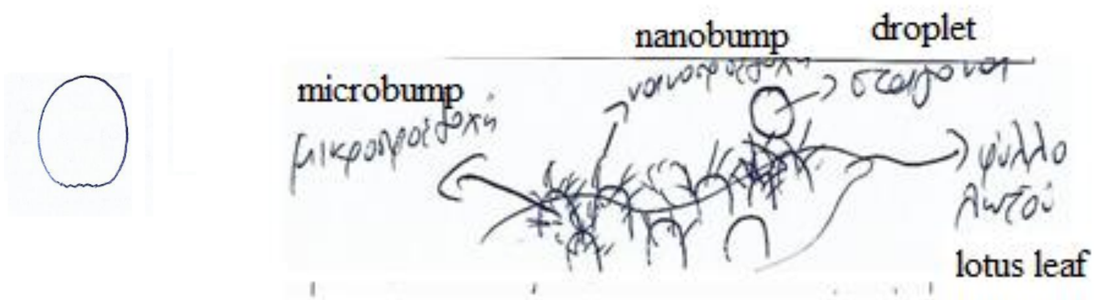

Figure 7: Representative drawings PTs provided in order to represent the lotus effect before (left) and after (right) the implementation.

Concerning the gecko effect at the beginning the highest concentration of PTs' explanations included adhesion mechanisms influenced by systems that are used in our daily life to hang objects, such as suction cups, claws and glue (Table 3 left part). After the training, PTs departed from intuitive-type of reasoning, and similar to the "lotus-effect" case, they expressed interpretations in much richer form, including several elements of scientific knowledge. For example, they referred explicitly to the structure of the toe at the micro- and the nano- scale and to the surface contact area (Table 3, right part). Furthermore, 4 PTs attributed the gecko adhesion to electrical forces, whereas 3 PTs characterized them as “attractive”.

Table 3. Terms that PTs expressed before and after the implementation in order to explain the gecko effect.

Interpretation	PRE (terms)		POST (terms)	
Intuitive	Claws, suction cups, glue	16		
Surface	Rough wall surface	3	Terms regarding the structure in the micro- and nano- scale (seate-spatulae)	11
			Surface contact area	8
Forces	Forces	1	Electrical forces	4
			Attractive forces	3
	No explanation	2		

In Figure 8, a representative drawing that was created by a PT in order to explain the adhesion property of the gecko lizard is presented. The drawing in the left part depicts suction cups on the gecko toe. In the left part, the same PT drew the structure in the micro- and the nano- scale.

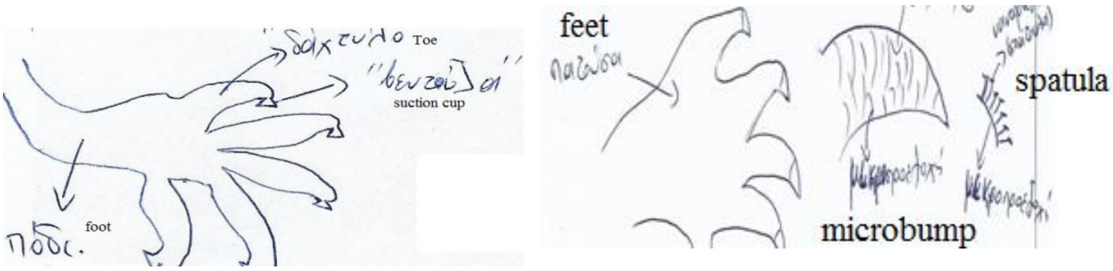

Figure 8. Representative drawing PTs provided in order to represent the gecko effect before (left) and after (right) the implementation.

DISCUSSION

Concluding, the focus of this study was to investigate primary teachers’ learning on lotus and gecko effects after their participation in a NST training course. It consists of a preliminary analysis, which aims to highlight the terms that PTs used in order to explain the two effects before and after their participation in a NST training course. Until now, little has yet been published about teachers’ learning on NST concepts and phenomena, and we anticipate that this research to contribute to this missing.

Our findings indicate that for both of the effects there was a shift from perception- or daily experience – based explanations to more informed ones, relevant with nano-related vocabulary. We consider this as an encouraging finding that shows that PTs’ explanations actually got improved after the instruction.

For both of the effects, primary teachers seem to meet no difficulties to acknowledge the structural aspects, since they used relevant terms. However, concepts related to physical properties (surface contact area, contact area, electrical forces) aspect were more underestimated. This finding indicates that PTs met some difficulties to explain how the structural properties affect the behavior of the effects. Similar results are obtained from the related literature (e.g. Bryan et al.2012; Sockman et al. 2012)..

In particular, the difficulties regarding the role of the structure to minimize/maximize the surface contact area (lotus and gecko effect respectively) were less for the case of the gecko effect explanation (table 2 and 3 right part). This finding suggest that appropriate model-based inquiry activities, such as the demonstration via a concrete model regarding the increase of the surface contact area that occurs in the gecko effect may foster effective understanding (figure 6). Of course, a further research is needed to support this view.

In addition, for the gecko effect case, aspects regarding the type of forces that act upon the gecko lizard were less reported. This finding suggests the need to support PTs to develop understanding specifically about this aspect of the effect.

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PRIMARY SCHOOL TEACHERS EXPERIENCE OF THE DIGITALIZATION OF TEACHING

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The aim of this study is to understand primary school teachers' experience of the ongoing process of digitalization of teaching. The study is done in a Swedish context and includes eight interviews with teachers from six different municipal schools. The results showed that the teachers were positive toward integration of technology and that some of the teachers experienced an increased use of digital teaching, which is in line with the recently revised school curriculum. However, they reveal a lack of prerequisites for digital teaching that can hinder the goals to be fully achieved; these are of both internal and external character and emphasizing, among others, the need to increase the elements of digital teaching in the teacher education programs, as well as offer competence development courses for active teachers.

Keywords: ICT enhanced teaching and learning, Primary school, Educational reform

INTRODUCTION

Discussions about digitalization and the school system have been on the agenda in the Swedish context for a while now. As a result of these discussions the government presented a national digitalization strategy which included an update of the school curriculum, taking effect from July 1, 2018 (The Swedish ministry of education and research, 2018). The overarching goal with the strategy is to position Swedish schools in the lead when it comes to capitalizing on opportunities for digitization. This means to use "the possibilities of digitization in the best way to achieve a high digital competence among children and pupils and to promote knowledge development and equivalence." (The Swedish ministry of education and research, 2017, p. 4). The introduction of digital teaching in the curriculum presents new challenges for the schools. Above all, using digital technology has gone from being a voluntary teaching method to be a compulsory component in all activities. For example, it means that all schools have to acquire materials to meet the requirements and that all the staff at Swedish primary schools have been commissioned to implement digital tools in their teaching. It also states that it is the principal's responsibility to follow up the school's results and to ensure that teachers receive the skills training required to reach the national goals, including learning from each other and conducting a discussion to develop the education. As the revised regulation of the curriculum was only recently presented, the process of change and adaptation is in its initial phase.

By turning our attention to teachers at six different municipal schools in Sweden, we wanted to understand more where in the digitalization process the schools are, as well as how teachers initially relate to digitalized teaching.

THEORETICAL FRAMEWORK

The main purpose with the introduction of digital tools in schools is to raise students' performance. But in order for this to happen, the technology needs to be used in a way that makes learning more efficient. According to Blackwell et al (2013), researchers disagree on the positive effect of digital education and this in turn affects teachers' use in their teaching. Hylén (2013) explains that the disagreement may be due to the fact that technology use in the school has been too scarce for studies to prove positive results. Furthermore, Hylén says that since many schools introduced one computer per student, the positive results have increased. The introduction of digital education will not provide improved results immediately and Hylén emphasizes that when new technology is presented, it may take years before the positive development begins to take shape. This is affected by other issues such as, for example, the technology, service agreements, licenses, competence development and more. According to this author, studies indicate that the importance of school management taking an active role in the transformation is great and therefore it is important that teachers and school leaders discuss together how the new working methods should be adapted to the new situation.

Drivers and barriers for ICT implementation

Several important factors for how the teachers implement and use technology in education have been discovered in earlier research. Drossel et al. (2017) emphasize factors such as the degree of collaboration between colleagues, the teachers' self-confidence in the use of digital tools, and the teachers' attitudes towards the use of technologies in education. They further suggest that understanding the teachers' attitudes towards information and communications technology (ICT) is important for a successful implementation of digital tools aimed at improving student results. In other words, the teachers are key figures in the implementation process. This view is also reported by Hylén (2013) who argues for competence development among teachers as necessary to impact their attitudes, and by Tallvid (2014) who emphasizes that teachers are the ones that need to realize the objective, even when the initiatives most often come from school leaders or policymakers. Perrotta (2013) argues that there is a clear connection between teachers' perception of school management's support in technology education and their perception of usability. Also, the school culture affects teachers' experiences and expectations of the use of technology, perhaps even more than what the teacher's personal qualities, such as age, gender and teacher experience, do. The same finding was done by Li et al. (2018), showing that teachers' professional competency and perception of benefits on use of ICT are significant factors affecting the actual use in student-centered education; teacher cooperation is affecting teachers' perceptions on use of digital contents for student-centered education; and endogenous teacher level factors such as teacher's job satisfaction and self-confidence are affecting teachers' perception on the use of ICT for student-centered education.

Just as research has demonstrated several important factors for successful implementation, a number of barriers that teachers encountered when integrating technology in the curricula have also been found. Ertmer (1999) sorted these barriers into first-order barriers and second-order barriers. First-order barriers refer to the barriers which are external to teachers such as lack of access to hardware and lack of support. Second-order barriers are internal to teachers, such as the teacher competence and willingness. Ertmer highlighted that if teachers were to become "effective users of technology, they will need practical strategies for dealing with the different types of barriers they will face."

METHOD

This study was conducted during the winter of 2018 at six different municipal schools in Stockholm County, Sweden. Our initial step to reach out to the schools were to contact the principal at each school with a request for primary school teachers whom to talk with. All together eight semi-structured interviews were conducted, respectively with five female, and three male teachers. Each interview lasted for approximately 30 minutes and were recorded and annotated. The interview consisted of seven main questions, each of them followed by sub-questions and asked the teachers, among other things, to answer questions that related to their view on digital competence, the introduction of digitalization in the curriculum at their specific school, and to give examples of perceived challenges with the implementation of digitalization. The recording was approved by the respondents by signing an interview agreement. In the case teachers could not be available for a face-to-face interview, we also prepared to conduct telephone interviews. This happened for half of the interviews.

The teachers' work experience ranged between 6 months and 32 years, and all were involved in teaching several different subjects (such as English, Swedish, social science, mathematics, and science). Teacher 7 (T7) had only six months experience and could thus not reflect about the time preceding the curriculum revision. For further information see Table 1.

Table 1. Participants in the study. Last column shows the tools the teachers have access to and the school's strategy of for instance a 1:1 relationship between number of computers and students.

Teacher	Gender	Age (years)	Teaching experience (years)	Interview	Digital tools and profile
T1	Female	30	7	Telephone	iPad, 1:1
T2	Female	55	18	Telephone	Desktop computer, 1:1
T3	Female	54	32	Face-to-face	iPad, 1:2
T4	Female	38	6	Face-to-face	iPad, Bee bots
T5	Male	39	7	Face-to-face	Desktop computer, 1:1
T6	Male	30	2	Face-to-face	iPad
T7	Male	25	<1	Telephone	iPad
T8	Female	31	7	Telephone	iPad

FINDINGS

In the following section the teacher's views are presented. First, we account for the teacher´s attitudes, then how they relate to the term digital competence. This is followed by their view of their own opportunities for educational development. Then we identify their experienced barriers towards digital teaching. The section ends with a summary of the teachers' reflections on their own digital teaching.

Teachers´ attitudes

All the teachers in this study showed an interest in digitalization of teaching. However, this result might have been affected by the selection process. One might expect that the teachers who showed interest in participating in a study about digitalization in teaching, also have a higher interest in general of the subject.

Digital competence

The way digital competence was understood among respondents could be described as multifaceted given the various perspectives presented during the interviews. While some teachers explained digital competence as knowledge of handling digital tools, other participants formulated themselves using words to describe the ability of understanding how digitalization affect students´ everyday life. For example, T5 explained digital competence to be "that students can deal with a computer, be able to communicate, use a computer when writing, use a search engine, be source critical.".

The most common way to motivate the presence of digital tools was by arguing that schools need to keep up with the society. An example is T4 who explained that the reason for it to be important is that the schools need to keep up with the surrounding society and that digitalization is part of this work. In addition, T8 also expressed digitalization as a way of "following reality".

Background in digital teaching

The teachers generally lacked formal education in how digital tools can be used. They viewed the lack of training as negative, pointing towards that they are expected to keep up with the technological developments but are not offered strategies to handle this. However, the fact that six out of eight teachers responded that their teacher education did not include any course on digital competence was excepted as several of them had worked as teachers for many years. Only two of the teachers had worked less than six years, and in both these cases ICT had been included in their training. However, both these teachers regarded this insufficient as they did not consider the courses to be adequate as they were only introduced to digital tools and were not taught in what and how digital tools should be used in practice. One of the teachers had only used digital tools it in connection with science subjects, thus lacking knowledge on how to use digital tools in other subjects.

All, except for one teacher, had been offered voluntary courses on digital tools by their employer. The courses have been given in various forms, from courses lead by a colleague at the school to courses outside the workplace during afternoons. Despite this, seven of the teachers brought up that the courses only go on for a limited time and then they experience a lack of continuity.

Only one teacher, T1, had a work situation that differed considerably. T1 was part of an IT group at the school, which works actively with digitalization issues. However, there is no reduction in time or compensation for the extra work, resulting in that T1 was not entirely satisfied with the support from the management side.

Perceived barriers – access and time

Even though most of the teachers in this study were employed at schools where digital tools such as smartboards, bee-bots, computers and tablets have been around for a long time, they all agreed that the implementation of teaching using such tools was still problematic. Two main reasons, were mentioned, namely access and time, and both of these were beyond their influence and control.

Regarding access to technology, teachers from two of the six schools stated that they do lack digital tools that facilitate digital teaching. To solve the lack of technology, in a school task where students were to make stop-motion movies, T4, who only had one iPad to share among 30 pupils, confessed that she lets the students borrow her own mobile phone. The reason was that she felt she had no other option. Another implication mentioned by T6 was the access to educational software. As the school had a business agreement and rented tablet computers all teachers had to go through the external company in order to install and download applications.

Regarding time allocated to teaching with technology, all eight teachers said that there is a widespread interest among colleagues and themselves to use technologies, however the time to develop their competence does not exist. And so far, none of the participants had been given time to develop their digital skills. Rather, it has been introduced as an addition to the tasks that teachers already have. This can, according to the respondents, in turn inhibit the teachers who need support in their planning of digital teaching.

Reflections on their own digital teaching

The teachers were asked to estimate the amount of their own use of digital tools along a 10 graded scale and to compare their use today with their use the previous school year (T7 had only been employed for six months and could therefore not make the comparison). Four of the teachers estimated their use to be higher today, one had not changed, and two estimated their use to be lower today than last year. In total, only a small increase in use of digital tools can be seen after the point where the new requirements took effect.

When the teachers were asked about the positive side of the use of digital tools, six of them mentioned that digital tools increase the motivation of students and makes it easier to obtain commitment in the classroom. One specific example mentioned by T7 was how they in geography class used the three-dimensional map provided by Google. The map, which makes it possible to rotate and view a point of interest from different angles had resulted in less confusion among the students and that he as a teacher spends less time on explanations. T5 provided an example from math class and emphasized how the use of digital tools had improved the students understanding of math. T1 highlighted that the use of digital tools had made it easier for teachers to work with different subjects simultaneously. Both T1 and T4 mentioned the possibility for students to create their own material, and T2 and T5 emphasized increased collaboration in the classroom as students helped each other. Digital tools were also described in positive terms by T2 who explained that students engaged themselves with digital tools in anticipation of help from the teacher. Similar situations were described by T1 and T3, as both stated that students used the tools to look for information while waiting for the teacher to arrive. Furthermore, the teachers reported on advantages with digitalization of teaching in terms of easier administration tasks such as that student assessment had become smoother (T5), it was easier for the teachers to take contact with students after school hours via e-mail (T4, T5), and it was easier to share documents (T4, T5).

Although much of what was mentioned during the individual interviews were similar opinions, there were also things that differed. One such difference was whether the use of digital tools affects students' written language: T6 emphasized that digital tools helped students in their writing development by providing the opportunity for the student to concentrate on the content of the story, such as developing the action of the story. T5 experienced that the students´ written language had approached the speech language when they write. The reason to this, as understood by T5, was that the students read shorter texts online than they would do on paper.

DISCUSSIONS AND CONCLUSIONS

The results showed that the teachers were positive towards the integration of digital teaching in the curriculum, and they also showed a positive attitude towards using it in their own teacher practice. However, the teachers experienced both external and internal barriers to the integration, such as lack of time (external), lack of technology (external) and lack of knowledge (internal).

Since digital education now is a requirement in Swedish primary schools, teachers must be given the opportunity to work towards more digitized education. This emphasizes the need to implement courses or increase the elements of digital teaching in the teacher education programs, as well as offer competence development courses for active teachers. Another suggestion, based on the results from this study, is to find means for having continuous meetings with colleagues, which has been pointed out as an important factor for personal development. This is also in line with the changes in the school curriculum pointing towards the principal's responsibility to ensure that teachers receive the skills training required (The Swedish ministry of education and research, 2017). Having access to further education should also be seen as an opportunity for the teachers to develop their own strategies to deal with the different types of barriers they will come across (Ertmer, 1999)

This study has contributed to understanding the factors affecting Swedish primary school teachers' perception on digital teaching after the implementation in the school curriculum. Although untried, the authors expect that the findings may have a wider validity as many countries now face similar challenges.

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BRINGING BIOINFORMATICS TO SECONDARY EDUCATION: A WORKSHOP FOR SCIENCE TEACHERS

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Having in mind the technological world we live in, scaffolding teachers to integrate computer-based resources in their classes is an important endeavour when it comes to teacher professional development. In this context, a workshop on bioinformatics to address gene regulation, molecular biology and genomics in high school gathered a group of 18 high-school science teachers. Following the workshop, the participants answered a questionnaire aiming to diagnose teachers' perceptions about bioinformatics; to identify the main constrains that are preventing teachers from successfully implementing bioinformatics in their classes; and to evaluate the potential to integrate basic bioinformatics exercises in their educational practices. Data were subjected to descriptive statistics and to content analysis. The results showed that the teachers attending the workshop were highly motivated and interested in learning more about bioinformatics and about strategies to integrate bioinformatics in their classes. Despite teachers highlighted the adequacy of bioinformatics to the educational context, most of them mentioned that their academic background was not sufficient to confidently implement bioinformatics-based exercises in their classes. Teachers claimed for more training courses in this area and approximately half of the participants admitted that schools are equipped with the necessary resources to integrate bioinformatics. Overall, this study emphasizes the importance to foster more initiatives to integrate bioinformatics in secondary education curriculum and highlights the need to increase the offer of teachers' training on bioinformatics.

Keywords: Computer Based Learning, Teacher Professional Development, Technology in Education and Training

INTRODUCTION

Despite technology is now acknowledged as a helpful tool for teaching and learning science, many science teachers got their academic qualifications for teaching at a time in which technology, namely computers, were rarely used or inaccessible for most of the people. It is therefore with no surprise that in-service teachers feel uncomfortable or not motivated to use computers in their classrooms, being urgent to scaffold teachers to develop their Technological Pedagogical Content Knowledge (TPACK) (Koehler & Mishra, 2009; Mumtaz, 2000).

Having this need in mind, professional development programs for science teachers should focus on helping them to integrate the use of the technology in the teaching practices. An opportunity to integrate computers and digital resources as a didactic tool based on real research procedures is to approach genomics and molecular biology based-on bioinformatics tools (Chiovitti et al., 2019; Gelbart & Yarden, 2006; Martins, Fonseca, & Tavares, 2018; Nunes, Júnior, Menezes, & Malafaia, 2015). Despite genomics being one of the most important revolutions of late 20th century and at the beginning of this century, the lack of literacy on genomics and molecular biology in the general population is reported in several studies (Eklund, Rogat, Alozie, & Krajcik, 2007; Kirkpatrick, Orvis, & Pittendrigh, 2002; Kolarova, 2011; Lock, 1996; Tarver, 2010). While an effort is being made to integrate bioinformatics in high-school science curricula in different countries, it is unquestionable that more teacher's training opportunities in bioinformatics is needed (Attwood, Blackford, Brazas, Davies, & Schneider, 2017; Kovarik et al., 2013; Machluf, Gelbart, Ben-Dor, & Yarden, 2017; Marques et al., 2014).

In this context, the workshop "*From DNA to Genes and to Comparative Genomics: Bioinformatics in the classroom*" was aimed to instruct science teachers about the suitability of bioinformatics activities to their teaching practices. Teachers were challenged to explore bioinformatics-based exercises particularly chosen to teach basic molecular biology concepts, to address gene regulation and to discover the usefulness of comparative genomics (Martins, Fonseca, & Tavares, 2018). This training workshop on bioinformatics allowed to boost teachers' TPACK, since teachers developed their technological knowledge by learning how to use bioinformatics tools and, concomitantly, they enlarged their pedagogical and content knowledge, by discussing new strategies to teach curricular contents and additionally introduce key concepts in genomics such as Open Reading Frame (ORF) or Basic Local Alignment Tool (BLAST) (Martins & Tavares, 2018). The workshop was promoted in the context of an international meeting for teachers (Casa das Ciências, 2018) that occurred in Portugal in 2018.

OBJECTIVES

The main objectives of this study were to diagnose teachers' perceptions about bioinformatics; to infer the potential of its integration in educational practices; and to identify the main constrains that are preventing teachers to successfully implement bioinformatics in their classes.

RESEARCH QUESTIONS

This study was driven by two main research questions: "*Which are the teachers' perceptions about bioinformatics and its integration in science teaching practices*?" and "*Which are the main constrains that are preventing teachers from integrating bioinformatics in their teaching practices*?"

METHODS

Participants

The sample included 18 science teachers (14 female and 4 male) from 14 different schools that voluntarily enrolled at the workshop. Seven of the 18 teachers hold a master's degree. Participants have an average of 26.61± 7.48 years of teaching experience. Between 2016 and 2018, 4 teachers taught at elementary school level (students between 12-15-year-old), 6 taught at secondary school level (students between 16-18 years old) and 8 taught both elementary and secondary school levels.

Materials

Framed within the curriculum for biology in secondary education (Council, 2013), the four hours workshop "*From DNA to Genes and to Comparative Genomics: Bioinformatics in the classroom*" drives teachers to explore the potential of bioinformatics as a didactic tool to approach contents, such as the organization and regulation of genetic material, and to carry out evolutionary inferences. From an *in silico* analysis of a DNA sequence it is proposed to identify genes and to determine the putative functions of their products. Additionally, using comparative genomics platforms such as *MaGe – Magnifying Genomes* (MicroScope), the participants were challenged to evaluate the presence of certain genes in different taxonomic groups aiming to infer evolutionary relations. This activity contributes to a holistic approach to genomics, genes and proteins, as well as to propose evolutionary hypotheses (Martins, Fonseca & Tavares, 2018). Each teacher was asked to bring their personal computers to carry out the exercises.

To diagnose teachers' perceptions about bioinformatics and its integration in science teaching practices as well as to identify the main constrains that are preventing teachers from integrating bioinformatics in their classes, a specifically designed questionnaire, adapted from the survey previously described by Martins, Lencastre and Tavares (2018), was implemented. The questionnaire, including 35 questions in various formats, namely dichotomous, Likert-type (ranged from 1 to 5) and open-ended questions, and is divided into three parts: *Part A*: socio demographic data; *Part B*: assessment of teachers' training and academic background on bioinformatics, and appraisal of teachers' attitudes towards bioinformatics integration and of their perceptions regarding workshop attendance; *Part C*: teacher's opinions about the questionnaire: objectivity, comprehension of the items, and suggestions.

In Part B, questions were designed according to the objectives defined for this study. Questions 1 and 5 (Q1; Q5) were aimed to diagnose teachers' definition of bioinformatics as well as to characterize the importance of bioinformatics to the current research. The assessment of teachers' interest and perceived knowledge about bioinformatics were addressed through questions Q3, Q12.1., Q12.2. Another dimension evaluated was teachers' perspectives on the importance of integrating bioinformatics in their teaching practices as well as to identify the main obstacles to this integration. In this regard, questions Q2, Q6, Q7, Q9, Q9.1., Q9.1.1., Q10, Q11, Q12.3., Q12.4. were included in the questionnaire. Question Q8 was intended to characterize the use of technology in the classroom by teachers. Lastly, and having in mind the main findings of previous studies highlighting the importance of promoting teachers training actions in the area of bioinformatics (Machluf et al., 2017; Machluf & Yarden, 2013; Martins, Lencastre, & Tavares, 2017, 2018), questions Q4.1., Q4.2., Q12.5., Q13, Q14, Q15, Q16 and Q17 were introduced to characterize the impact of the workshop on teachers perceived knowledge about bioinformatics as well as to evaluate the workshop, identifying the potential of the action but also having feedback on possible improvements.

Teachers rated the questionnaire as an objective instrument (4.76±0.44) and easy to understand (4.76±0.44). One participant added the following suggestion for improvement: "*In question 12.4., you should specify if the classes are lectures or if they are practical classes of biology* *including wet lab and experiments*". This suggestion will be taken into consideration in future questionnaires.

Data Collection and Analyses

The questionnaire was implemented after the attendance of the workshop, i.e. when participants finished the proposed exercises. The aims of the research as well as the objectives of the questionnaire were explained to teachers who voluntarily agreed to answer the survey. Descriptive statistical analysis was performed for quantitative data (Punch, 2009). For qualitative data, a thematic content analysis of the participants' responses to open-ended questions was carried out (Roberts, 2015; Schuster & Weber, 2006).

RESULTS AND DISCUSSION

Teachers' background on bioinformatics

The majority of the teachers (94.44%) correctly defined bioinformatics (Q1), and one teacher mentioned that bioinformatics is "*a didactic tool for science classes*". Among all listed notions (49), teachers mentioned frequently the following: informatics (12.62%), biology (8.74%), data (6.8%), tools (6.8%) and applications (4.85%). This analysis revealed that teachers recognized the scope of bioinformatics as the scientific field which develops or uses tools and applications of informatics to understand the biological data, which fits well with a general definition of bioinformatics (Luscombe, Greenbaum, & Gerstein, 2001; Sadek, 2004).

Teachers revealed to be interested in bioinformatics (Q3) and recognized its importance for scientific advances (Q5) (Figure 1). However, teachers considered that their academic background is not sufficient to feel prepared to teach using bioinformatics tools (Q12.1.) and highlighted the added-value of professional training (in-service) (Q12.2.) to implement bioinformatics activities in their classes (Figure 1). These results are in line with the literature (Machluf, Gelbart, & Yarden, 2012; Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2018; Wood & Gebhardt, 2013) and reinforce the importance of promoting initiatives of professional development oriented for bioinformatics training.

Attitudes towards bioinformatics integration

The importance of integrating bioinformatics in elementary (Q6) and secondary education (Q7) was highlighted by the participants (Figure 1), as well as the potential to use bioinformatics both at Biology classes and Information and Communications Technology (ICT) classes (Q2), mentioned by 77.78% of the teachers. It is acknowledged that bioinformatics-based activities foster students' hybrid abilities in computation and biology, nurturing a wide range of skills such as using bioinformatics to find, retrieve and organize data by identifying an appropriate data repository, to understand evolutionary related processes or to develop their critical thinking namely in which concerns open data access (Foster & Sharp, 2007; Mariano, Martins, Santos, & Minardi, 2019; Oliver et al., 2012; Sayres et al., 2018).

The majority of teachers (94.44%) assumed to use computers to explore online resources in their classes (Q8), but only 5 out of 18 (27.78%) revealed to have autonomously explored bioinformatics resources in order to implement them in their classes (Q9). Among the teachers who had previously explored bioinformatics resources, 3 out of 5 (60%) actually implemented the activities in their classes (Q9.1.). The two teachers who did not (40%), listed as the main reasons "*Lack of computers available*" and "*The need to better understand the explored bioinformatics tools"*. However, their intention is *"to apply the activities in the classroom soon*" (Q9.1.1.).

Around half of the participants (55.56%) considered that the school/institutions where they were teaching have the necessary conditions to integrate bioinformatics-based activities in their classes (Q11), which is in agreement with recent reports indicating that most schools in Europe are equipped with technological devices (European Comission, 2013). In contrast with this result, the main constrains identified by teachers to carry out the implementation of bioinformatics activities in the classroom (Q10) were: computers (7.87%) and internet (6.74%). Only 2 out of 18 teachers (11.11%) revealed positives attitudes regarding the possible constrains that can arise when implementing bioinformatics in their classroom mentioning that "*cannot identify any constrains. The school has the necessary resources (…) and students are motivated*" and "*the management of the time is possible especially in the 11th grade*". 66.67% of the participants indicated that the main constrains to implement bioinformatics-based activities in their classrooms were related with logistics aspects (resources and time) answering that "*computers are lacking in schools*"; "*the number of students per class is too high*"; "*the internet connection is weak*"; and "*bioinformatics resources are not in Portuguese*". Teachers mentioned that schools are well prepared to carry out bioinformatics exercises, however logistics aspects were mentioned as the main hinder to not apply these tools in the classrooms. This result stresses the importance to better characterize schools' reality in which concerns technology use.

16.67% of the participants identified both logistic constrains and lack of teacher's confidence as the main difficulties to implement the proposed approached in the classroom. Teachers emphasized their lack of confidence to approach some curricular topics using bioinformatics resources and highlighted their need to acquire specific training, which is corroborated by other studies (Cebesoy & Oztekin, 2018; Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2018). One teacher (5.56%) mentioned that "*The complexity of some processes and their interpretation by the students requires strong orientation and motivation, which should be taken into account when organizing the activity.*" This perspective was included in category: Constrains related with the student's performance.

Furthermore, the data showed that teachers considered that planning and implementing bioinformatics-based activities is more time-consuming and requires more resources than other activities (Q12.3.; Q12.4.) (Figure 1). These notions can be related with the lack of opportunities for teachers' training in bioinformatics. Training is crucial for teachers to feel more acquainted with bioinformatics tools and to clarify that planning and implementing bioinformatics-based activities can be framed within the time schedule for a class (90 minutes) as described by Martins, Fonseca and Tavares (2018). Another reason that can explain this result is the absence of didactic bioinformatics resources in Portuguese. In fact, the idiom of the majority of the platforms and of the exercises available is English which was previously reported as a barrier to non-English speakers (Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2017, 2018). This result highlights the importance of creating a portfolio of bioinformatics-based activities, in this case adapted to Portuguese, and making it available for the educational community in other to emphasize the adequacy of integrating bioinformatics in educational approaches.

Perceptions regarding workshop attendance

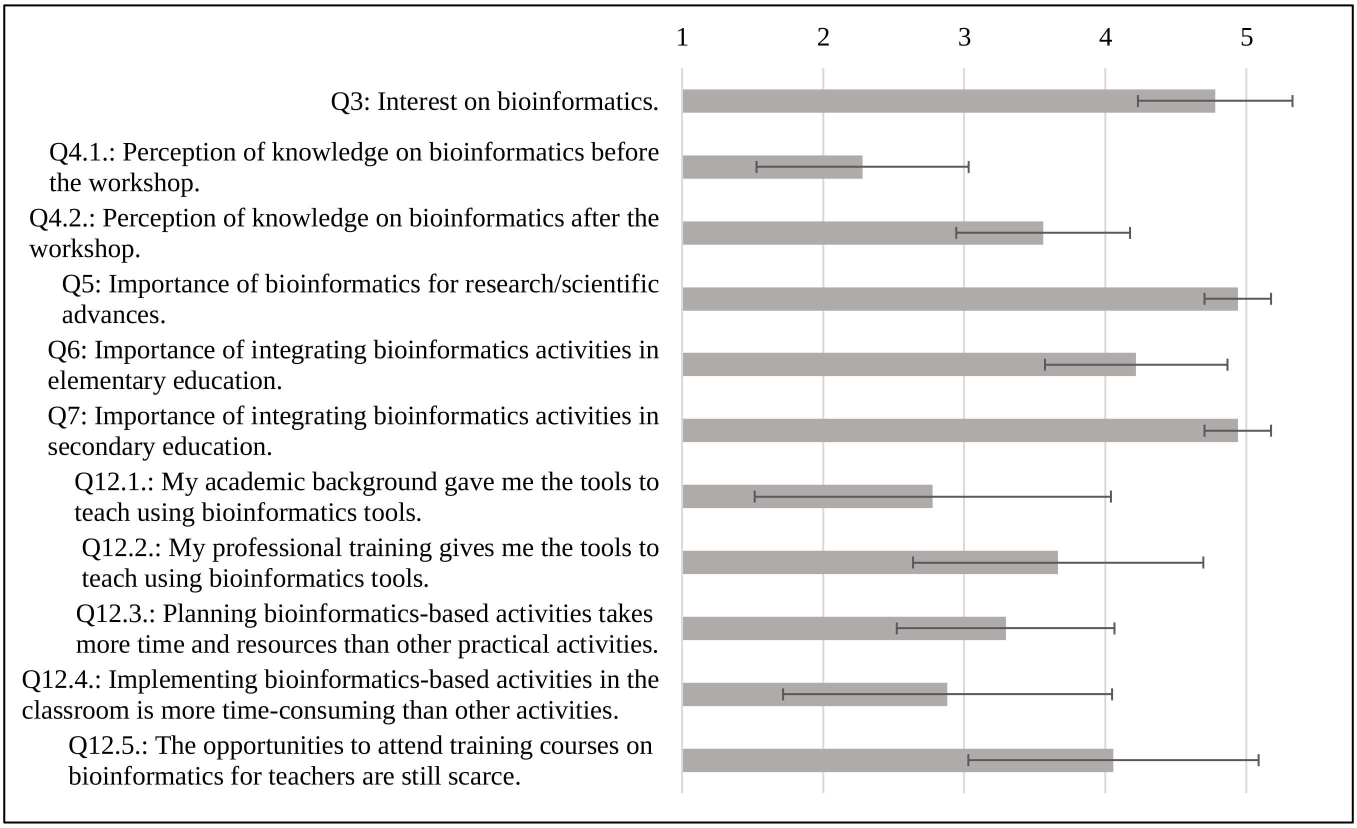
A careful analysis of teachers training on bioinformatics was carried out having in consideration the previous results reported by Martins, Lencastre & Tavares (2017, 2018), by Machluf et al. (2012, 2013) and by Marques et el. (2014). Despite the interest of all the participants in attending training courses on bioinformatics for teachers (Q16), it was mentioned that the availability of these courses is still very scarce (Q12.5.) (Figure 1). In fact, the importance of adequate teachers training in this scientific field, is further supported by the higher perception teachers have about their knowledge in bioinformatics after attending the workshop (Q4.2.), in comparison with that perception before the workshop (Q4.1.) (Figure 1).

Regarding the workshop itself, teachers were asked about the reasons that motivate them to attend this workshop and to choose this workshop among others (Q13). They were asked to list the main difficulties found when they were performing the workshop activities (Q14) and suggestions were collected in how to improve the workshop (Q15).

The 18 participants listed the main reasons that motivated them to attend the workshop (Q13). By carrying out an analysis of the five most frequent words mentioned, it was possible to list: class (6.84%); application (5.98%); classroom (5.13%); learn (4.27%); and utilization (4.27%). This general analysis suggests that teachers wish to learn how to apply and how to use the bioinformatics tools in their classes. Adding to this analysis, it was possible to identify three main categories of answers. "*To learn to apply*" – was mentioned by three participants (16.67%). These participants revealed that they chose this workshop in order to learn "*how to implement the tools of these area*" in their classrooms. Six out of the 18 participants (33.33%) highlighted as the main reason to attend this workshop "*Curiosity*". Teachers justified their attendance as an opportunity to learn more about bioinformatics, by curiosity and because they were "*interested in related topics such as genetics and all the fields that are related with DNA*". This result reinforces teachers' interest in this scientific topic. The third category is particularly important in the context of this study: "*The need of updating*". Mentioned by 9 participants (50.00%), this category included answers such as "*I felt the need of learning about this area* (…) *and to explore bioinformatics in a scientific and right perspective*" or "*I urgently need to improve my skills* (…) *to follow the quick development of these applications* (…) *and to implement them with my classes*". This result is in line with the considerations about the urgency of training courses reported above. Teachers are interest in this scientific area and the adequacy of the proposals to the schools is recognized, although they do not feel prepared to proceed with the implementation of the tools without previous specialized training (Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2018; Shuster, Claussen, Locke, & Glazewski, 2016; Wood & Gebhardt, 2013).

In which concerns with the main difficulties found by the participants while performing the activities of the workshop (Q14), three categories of answers were defined. 50.00% of the participants (9 out of 18) listed as the main difficulties' technical aspects such as internet access, and the lack of time or difficulties to read the paper version of the guidelines. In fact, these constrains were related with the organization of the workshop itself and not with difficulties related with the bioinformatics-based activities performed. However, the internet connection was fixed even during the workshop and the digital version of the guidelines was sent by email to the participants. In this regard, we can assume that the logistic constrains were solved and the workshop work-flow was not affected. Two out of 18 participants (11.11%) revealed to have difficulties in interpreting "*aspects associated with gene sequences/nucleotides*" and to "*understand the steps to follow*". In contrast with these results, 38.89% (7 out of 18) reported no difficulties and one teacher did not answer this question.

Figure 1. Answers given by participants according to a Likert Scale (Range 1 to 5). Grey bars represent the mean value and the error bars refer to the standard deviation.



Finally, suggestions for workshop improvement were asked to the participants (Q15). 44.44% of the participants did not answer this question. 33.33% of the participants listed suggestions for improvement. Essentially participants claim for: "*More exercises*"; "*I would like to attend a training course (longer) in this area, once 3 hours are not sufficient to understand all the information discussed*"; and "*to increase the font size of the text in the guidelines – paper version*". 22.22% highlighted that "*do not think that the workshop needs to be changed*".

CONCLUSION

Teachers revealed to be interested in bioinformatics and recognized its importance for scientific advances, which is in frame with the expected teachers' perceptions about bioinformatics as a scientific discipline. Teachers were open and motivated to integrate bioinformatics in their teaching practices. Regardless their will, teachers believe that key constrains have to be overcome, emphasizing the need of suitable training through dedicated courses. Thus, the main take-home message from this workshop is the urgent need of training courses for teachers in order to fuel the integration of bioinformatics in the curriculum and education daily practices. Adding to this, it is important to better understand the reasons why teachers admitted that their schools have the necessary conditions to implement bioinformatics-based approaches, but contradictorily they indicated as the main constrains to this implementation: poor internet connection and lack of computers. A reedition of the workshop occurred in July 2019 with 40 participant teachers. In this workshop, new data were collected in order to increase the robustness of this study. Adding to this, a website is under construction and will be soon available for teachers, with bioinformatics-based exercises in Portuguese in order to meet the participants request of having more available resources in their native language.

We believe that the current study is a wakeup call for educational stakeholders to boost bioinformatics educational integration aiming to meet the challenges of a society capable to understand the scientific advances and take informed decisions.

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PROFESSIONAL DEVELOPMENT FOR ICT-BASED TEACHING

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Using information and communications technologies (ICT) in the classroom requires new skills on the part of educators. We have elicited current best practices for professional development of educators from the participants in this workshop, what knowledge teachers need and how it is best imparted. We found that even given their different starting points, teachers in different regions are often feeling unsure about how to use ICT in a pedagogical context, and there is no clear consensus on how to best train teachers in this use, but that the digitalisation of schools will require a long-term commitment from school management and political leadership.

Keywords: Teacher Professional Development, ICT Enhanced Teaching and Learning, Technology in Education and Training

INTRODUCTION

The increased use of information and communications technologies (ICT) in the classroom to support students' learning places new demands on teachers at all levels, from pre-school to graduate school. This in turn increases the expectations on the teachers' abilities to develop their own proficiency of using this technology: internationally, such proficiency is commonly referred to as *digital literacy*, while within the Scandinavian educational context the term *digital competence* is more common (Hanell, 2018; Ilomäki et al., 2016; Krumsvik, 2008). Digital competence refers here to a holistic perspective incorporating proficiency with pedagogical judgement and with the focus on pedagogy and subject matter. In other words, digital competence is knowledge about how digital tools affect our everyday life, and how to use digital tools to support critical thinking, creativity, and innovation.

Teachers are now required to have a working understanding of:

- hardware, in the various forms of computers, mobile phones, and electronic tablets, but possibly also peripherals such as network routers, digital projectors, and printers;
- software, from word processors and drawing programs to specialised educational software, and learning management systems;
- the limitations of computer systems, being able to critically evaluate claims of current and future functionality, the impact of social media on rumors, social unrest, and political events.

For most teachers, having these skills is not a goal in itself, but a prerequisite for developing new learning situations. Many are uncertain of how to best use digital systems for best effect on students' learning or may even be uncertain whether they are helped at all by digital systems. In many cases, there might also be a considerable learning effort required simply to start using a digital tool, and often enough, the actual use requires some skill and effort. These issues may make such tools less suitable for use in the educational situation by students, but also divert time from the actual teaching effort. The use of technology is also limited by personal factors such as teaching vision and understanding of the technology's influence on teaching (Hylén, 2013). Still, the digital competence of teachers is required and we need to find ways to develop digital skills in teacher education and in-service training to meet the goals regarding digitalisation in the curriculum. These ways should be based on the priorities of teachers, we thus need to elicit information on what knowledge teachers feel they lack and how they would prefer to address this.

Despite governmental expectations of increased digital competence among teachers, there is still much to do to assist teachers with accessing knowledge on what might enhance their practice. The purpose of this workshop was therefore to address teachers' professional development by encouraging the sharing of knowledge among teachers (Ertmer et al., 2012) and to address both local and global settings (Albion et al., 2015).

BACKGROUND AND PREVIOUS RESEARCH

Previous studies show that digital tools, defined as word processors, spreadsheet programs, drawing programs, programming environments, etc., develop creativity, problem solving and critical thinking (Albion et al., 2015). Various aspects of digitization and digital tools have therefore been integrated into the school curriculum in most countries in the Western world. According to the curriculum in for example Sweden, students are to develop an understanding of how digitalisation affects individuals and society, develop the ability to use and understand digital systems and services, relate to media and information in a critical and responsible way, and solve problems and translate ideas into action in a creative way (Skolverket, 2017). Digital tools are already used to varying degrees in primary school education, and there is a great deal of research on learning and digital tools that shows both the educational potential of digital tools (Newhouse, 2017), as well as the new challenges that teachers face when tools are to be integrated into practical teaching situations (European Schoolnet, 2017; Skolverket, 2019). In the STEM subjects, ICT has been reported to enhance engagement, motivation, and learning by stimulating inquiry-based learning, and enhance communication between students and teachers (Newhouse, 2017). In addition, it has been demonstrated that ICT lets students investigate subjects relevant to their lives and control their own learning (European Schoolnet, 2017).

In line with the previous studies, the Erasmus+ project Functional Information and Communication Technology Instruction On the Net (FICTION) investigates how science teachers in primary and secondary schools currently use digital tools in their teaching practice, how they can be supported in their choice of digital tools within their teaching practice, as well as what additional professional training they need in order to be able to use these tools. Further, the project aims to develop guidelines for what type of tools that are most useful within the teaching practice of STEM education and how to best acquire the requisite skills in using these tools. The FICTION project partners come from three countries: Södertörn University and the Ronna school from Sweden, Limerick Institute of Technology and Coláiste Mhuire Co-Ed from

Ireland, and the University of Genoa, Liceo statale Niccolò Machiavelli Firenze, and Pixel from Italy.

Initial results by the Swedish partners have shown that schools have invested in infrastructure and equipment to support ICT and the use of digital tools for teaching. However, there are still obstacles of administrative character such as scheduling, lack of time, insufficient competence development, and lack of choice on what platforms and systems to work with (Josefsson et al., 2019). Swedish public school teachers are required to use digital tools in their teaching, however there is a lack of knowledge among teachers on how to use digital tools that needs to be taken into account when promoting the use of digital tools in teaching (Josefsson et al., 2019). In line with these findings and based on previous research on digitization and digital competence (Albion et al., 2015; Ertmer et al., 2012; Hanell, 2018; Ilomäki et al., 2016; Krumsvik, 2008) the purpose of this workshop was to address teachers' professional development by encouraging the sharing of knowledge among teachers (Ertmer et al., 2012), and to address settings other than the ones involved in the FICTION project. To interpret the participants' statements and reasoning during the workshop we mainly draw on the previous research presented and the initial findings from the FICTION project.

DESIGN OF THE WORKSHOP

The workshop started with a ten-minute presentation of the organisers and the FICTION project by the moderator. The introduction was followed by an outline of the questions to be addressed during the workshop and why these were of interest to discuss.

The participants were divided into three groups and were asked to discuss the following issues during the workshop:

- What is the current approach to teaching digital competence in your region? What are the driving forces?
- What are your personal experiences of using digital tools in schools? What works, what does not?
- What do teachers feel they need in order to perform well?

There was in total seventeen participants, mainly teachers and researchers at university level. As such, the participants were not necessarily directly involved in teaching at a primary or secondary school level, but had an interest in the questions that the workshop concerned. The workshop participants were associated with universities in Australia, Finland, Germany, Japan, South Africa, Spain, and Sweden.

The discussion lasted for one hour and during that time the two attending organisers circulated among the groups and took part and notes in the discussions. Any errors in our notes are fully our responsibility.

RESULTS OF THE WORKSHOP

Our assumption, as noted in the introduction, that there is a strong need for additional training, in particular for in-service teachers, was confirmed by the participants. Not only was training in the technology itself perceived as important, but also time to practice using it and working out how to best fit it into everyday teaching practices. The benefits for the students have to be the primary focus. Working out all this requires contact with other teachers for exchanging experiences on best practice. The time required to do this should not be underestimated, as it encompasses multiple stages: learning practical ICT skills, understanding the purpose of ICT in teaching and finally changing teaching styles and examination methods to make effective use of ICT. There are large individual variations in attitudes among teachers—it was noted that pre-service teachers tend to be more open to the use of ICT for teaching and might eventually work as catalysts for the introduction of ICT at their respective schools. An important point is that since technology is in constant flux, periodic retraining is necessary. The necessary resources for training and reflection require the long-term commitment of school management and school politicians. It must be understood that digitalisation is a tool for improving teaching, and should not be used as an excuse for cutting down on resources for schools—teachers are still necessary. Indeed, a suggestion was made that future teaching teams may need to be interdisciplinary, with both technology and pedagogy experts.

The discussion made clear that there is a wide variation in access to technology in different regions. Almost all schools in Australia and Sweden were reported to have Internet access, and digital competence written into the national curricula. In contrast, Internet access and resources varies a lot among schools in South Africa depending on socio-economic differences: from well-equipped schools to those with hardly any digital technology. An estimated 60% of South African schools have Internet access. A complication is that while the technology may be present, it is not always available for use: in one school, for example, the computers were locked up in a special room to which most of the teachers did not have access. The result was that the computers were unused and eventually not up to date.

Teacher skills vary from those who are competent in computer use to those “who do not know how to switch on the computer”. A comment was made that many in-service teachers might not even be interested in using computers, not from lack of exposure to them, but from the attitude that computers will not contribute to teaching, something which has been noted in previous research as well (Blackwell et al., 2013; Drossel et al., 2017; Prestridge, 2012; Young, 2016).

In Spain, the main use of digital tools by in-service teachers is indicated to be the use of interactive smartboards for presentations, which does not necessarily imply changing or improving existing teaching practice. Rather, it was reported that many teachers use their smartboards simply as projectors. Making use of the full potential of the smartboard requires designing the learning situation accordingly (Simó et al., 2018). In order to help teachers understand how to organise their teaching around ICT tools, our Spanish participant’s team had formulated guidelines for in-service teachers to increase the use of digital tools, with an emphasis on a deeper understanding of production tools. Summer courses have also been provided to in-service teachers to enhance their digital competence.

The situation in Germany is described as lacking a systematic approach: schools have received money to invest and buy technology, but no instructions for teachers on how to use potential tools. Specifically schools in Southern Germany were described as passive, waiting for others to take the lead and supply ready recipes for digitalisation. There is a feeling that Germany has fallen behind and lacks infrastructure, maybe only 50% of schools have Internet access. Teachers are uncertain and sometimes fearful of technology. In order to alleviate those fears there have been local efforts at staging ”impulse” workshops for teachers (Institut für Qualitätsentwicklung an Schulen Schleswig-Holstein, 2020), showing what can be done with digital tools in the classroom. As the technology becomes more familiar, teachers develop pedagogical creativity.

One of the participants reflected on why some teachers change their teaching practices and integrate ICT, while some do not, and summed up their thoughts on whether it is the teachers' views or the access to technology that drives the change. In the beginning, they stated, "I was thinking exposure was the problem."—if teachers were only given the opportunity to try different ICT tools, they would see new opportunities and integrate the new tools into their teaching. However, today they have changed their mind on the issue and emphasize the importance of teachers' attitudes towards technology. That said, they still do not deny the importance of exposure to ICT tools.

CONCLUSION

The consensus was that (strategic investments in) professional development were considered important in enhancing teachers' digital skills. The workshop participants agreed that this will continue to be important as these technologies will be constantly changing, hence teachers will have to constantly develop their teaching practice to respond to these changes. The participants also agreed that one of the big benefits with this investment was that digitalisation has the potential to empower students to work more effectively, giving them more control over how to learn a subject. This said, it should be taken into account that both Internet access and resources vary a lot among schools. The same applies to the teachers' knowledge and attitudes towards technology integration and the support from school management and school politicians. All these are important components if we aim to use ICT in classrooms to its full potential.

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IN-SERVICE TEACHER MENTORING FOR THE IMPLEMENTATION OF MODULES ON CUTTING-EDGE RESEARCH TOPICS

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The negotiation of cutting-edge research topics in science courses may contribute to the scientific literacy of students. However, incorporating such an approach into teaching practice requires appropriate preparation and support, for teachers to meet the challenges of such a venture. In this context, this study examines the support provided by mentor-teachers to other in-service teachers who are called to implement in their classrooms modules on cutting-edge scientific subjects with social implications. In total 5 mentors and 32 in-service teachers participated in the study. The mentoring meetings were recorded and the discussions were analyzed in terms of content and mentoring roles assumed by mentors. Data indicate that mentors focused their support on science-specific instructional knowledge and tended to do so using mostly directive skills, but also trying to adapt their role according to mentees' needs.

Keywords: Mentoring in Teacher Education, In-service Teacher Training, Teaching Innovations

INTRODUCTION

One of the long-established aims of research on science education is the improvement of educational practice through the operationalization and dissemination of the research results. Yet, spreading innovations in a wide range of educational contexts requires an ongoing supportive training procedure that would guide teachers throughout the whole implementation period, as they often have to change their attitudes and beliefs, to expand their professional knowledge and repertoire of teaching practices while addressing the restrictions imposed by the school context (van Driel et al., 1998). In order for teachers to meet the demands of educational innovations and to be able to effectively integrate them in their teaching, they should receive appropriate training and support.

Subjects related to cutting-edge research usually define an area of science that is uncertain and incorporates issues around which the scientific community has not yet come to commonly accepted conclusions (Levinson, 2006). Integrating such topics in science classes familiarizes students with the process of scientific research and provides them with the opportunity to experience scientific knowledge as an ongoing procedure and to elaborate on its social implications (Wong et al., 2008). However contemporary scientific research topics have not yet been broadly incorporated in school science curricula and teaching practice. Therefore, there is a need to disseminate the implementation of such innovations to more school contexts and also to train teachers on these issues in order to overpass the entailed difficulties.

Certainly the task of applying modules associated with cutting-edge research topics entails a series of difficulties on behalf of the teachers, which are mainly focused on their content knowledge scarcity and on the lack of specific teaching strategies to approach such topics (Peers et al., 2003).

One of the methods that have shown encouraging results as a means of teacher professional development is *mentoring in collaborative settings* (Feiman-Nemser, 2012). Through mentoring conversations, teachers grow professionally by collaboratively inquiring and reflecting on their everyday practice, exchanging ideas and paving the way for change (Bradbury & Koballa, 2007). Therefore, the content of these conversations as well as the mentor's style (directive or not) determine to a great extent the effect of this interaction.

Even though research on science teacher mentoring is growing, it is mostly related to pre-service or early career teachers and the studies that employ mentoring as a means for in-service science teacher training are still few (e.g. Appleton, 2008). Based on this approach, the aim of the present study is to give an insight on the support mentor-teachers provide to other in-service teachers in order to implement modules on cutting-edge research topics. The specific research question is:

How do mentor-teachers support in-service mentee-teachers in order to implement modules on cutting-edge research topics in their classrooms?

and it is examined through the following sub-questions:

(i) *What topics do mentoring conversations focus on?*

(ii) What roles do mentor-teachers assume during their mentoring conversations with the mentee-teachers?

METHOD

Research design

The study was carried out in the framework of the EU IRRESISTIBLE project (www.irresistible-project.eu) which aimed to develop and implement teaching material on contemporary scientific research topics and their social implications.

According to the design of the project, 5 highly skilled teachers (one primary education teacher and 4 secondary education physics and chemistry teachers) developed and piloted a teaching module on Nanotechnology, with the support of nanotechnology experts and science education researchers. Afterwards, these 5 teachers (hereinafter referred to as "mentors") acted as multipliers and trained 32 mentee-teachers serving in primary and secondary schools in implementing a module on a cutting edge research topic.

The 3 modules that the mentees were trained on and applied were: *Nanotechnology Applications* , *Microplastics in the ocean* and *Carbohydrates of baby formulas*. As all three modules were developed within the IRRESISTIBLE project, they dealt with contemporary scientific research subjects and their social implications and used an inquiry-based approach for learning.

The mentoring process lasted for about 9 months (during which each group held about 8 mentoring meetings) and was divided in three successive phases.

- In the *orientation* phase, mentors and mentees elaborated on (i) the scientific content of each module, (ii) the involved social implications and (iii) aspects of inquiry-based learning.
- In the *redesign* phase, mentees thoroughly examined the modules and then re-designed them in order to adapt them to each school context.
- The *implementation* phase concerned the enactment of the modules in real class conditions and the mentees' reflection on the mentoring experience.

During each phase, mentors supported their mentees by 2-5 group mentoring meetings and with personalized support.

Data collection and analysis

In an effort to investigate the mentoring interactions, our main data source was the audio-recordings of all the group mentoring meetings.

Due to the explorative nature of the research, qualitative methods of content analysis were used.

First, all recorded mentoring conversations were transcribed verbatim. As regards the topic of mentoring conversations, we used as categories the knowledge bases of teacher professional knowledge (Gess-Newsome, 2015) that were addressed, namely: subject-matter knowledge, general pedagogical knowledge, instructional knowledge, knowledge of students and curricular knowledge. Issues that referred to organizational and administrative aspects of the mentoring process formed a sixth category entitled organizational issues (Table 1). Then, we calculated the percentage of mentoring discussions' extent that was dedicated to each topic.

Table 1: Categories of analysis regarding the topic of mentoring conversations

Categories	**Description**
Subject-matter knowledge	Discussion on the scientific subject of each module & social aspects
General Pedagogical Knowledge	Discussion on classroom management & learning theories
Instructional knowledge	Discussion about inquiry-based learning, negotiation of social aspects and ways to explore students' ideas Assistance in lesson redesign Demonstration of experiments and activities Providing feedback on teaching
Knowledge of students	Discussion of students' cognitive abilities, common alternative ideas and skills
Curricular knowledge	Discussion on the modules' objectives
Organizational Issues	Organizing visits, Sharing materials, Meetings arrangement

For the characterization of mentors' roles in these conversations, we based our analysis on the

MERID model (Crasborn et al., 2011; Figure 1), which identifies the mentor's use of directive skills and his/her initiative in introducing the topics as two behavioral dimensions that, vertically arranged, define 4 complementary mentoring roles: initiator (introduces topics & uses non-directive skills), imperator (introduces topics & uses directive skills), advisor (responds to issues introduced by mentees & uses directive skills) and encourager (responds to issues introduced by mentees & uses non-directive skills).

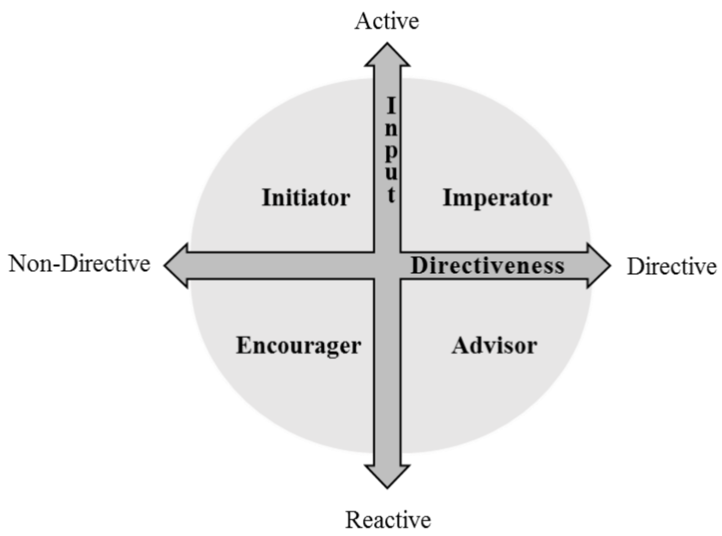

Figure 1: Representation of the MERID model (Crasborn et al., 2011)

In that way we constructed two coding keys, one addressing mentors' degree of directiveness and one addressing their degree of input (see Table 2). Analysis continued by recording the percentage of mentors' extent of speech that belonged to each category. Combining these two dimensions, we were able to define the percentages of the resulting mentoring roles.

Table 2: Categories of analysis regarding mentoring roles

Categories		**Description**
Directiveness	**Directive**	The mentor provides directions, confirms / rejects , evaluates, expresses opinion , gives advice, demonstrates activities, gives information
	Non-directive	The mentor asks questions, enhances reflection .
Input	**Active**	The mentor introduces the topic for discussion
	Reactive	The mentor responds to issues introduced by mentees

RESULTS

The results regarding the content of mentoring conversations (Figure 2) show that the most discussed topics were related to the negotiation of instructional knowledge (teaching strategies, negotiation of social implications and lesson design) and organizational issues. Issues regarding scientific knowledge have been discussed to a limited extent, as well as students' pre-existing knowledge, ideas and interests. Equally limited was the negotiation of issues of general pedagogical knowledge, fact that is mainly attributed to the increased teaching experience of the in-service mentee-teachers. On the other hand, mentors dedicated a significant extent of their conversations to the explanation and clarification of the innovative elements of the modules.

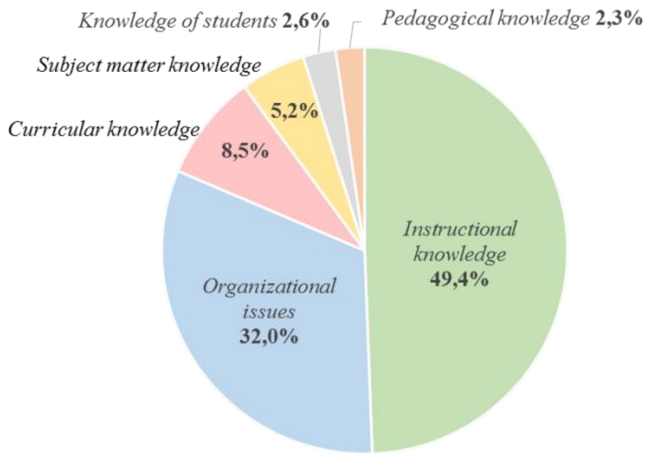

Figure 2 : Percentage of mentoring discussions dedicated to different areas of professional knowledge

Regarding the roles adopted by the mentors (see Table 3), we should first point out that the mentors participated in the mentoring discussions with all four different roles, with a tendency to use more frequently directive skills and to introduce discussion topics, adopting the imperator role. The second more frequent role was the advisor, according to which mentors shared their opinion on issues raised by the mentees. Finally, mentors assumed the initiator and encourager role, only during a small extent of the conversations.

Table 3: Percentages of mentoring roles assumed by each mentor

	Mentoring Roles			
	Initiator	Imperator	Advisor	Encourager
Mentor-A	9,8%	59,3%	26,5%	4,4%
Mentor-B	14,9%	51,5%	26,1%	7,5%
Mentor-C	10,1%	48,5%	34,3%	7,1%
Mentor-D	9,0%	35,2%	44,4%	11,4%
Mentor-E	8,3%	43,4%	40,6%	7,7%

Moreover, mentors tended to adapt their practices to the mentees' needs, and particularly to limit their directional practices when mentees had the necessary background knowledge on a subject that allowed them to participate more actively in the discussion. Specifically, as shown in Figure 3, when mentors discussed about the innovative scientific content of the modules, they tended to utilize almost exclusively directional practices. Therefore, in these cases they only adopted the imperator and advisor role.

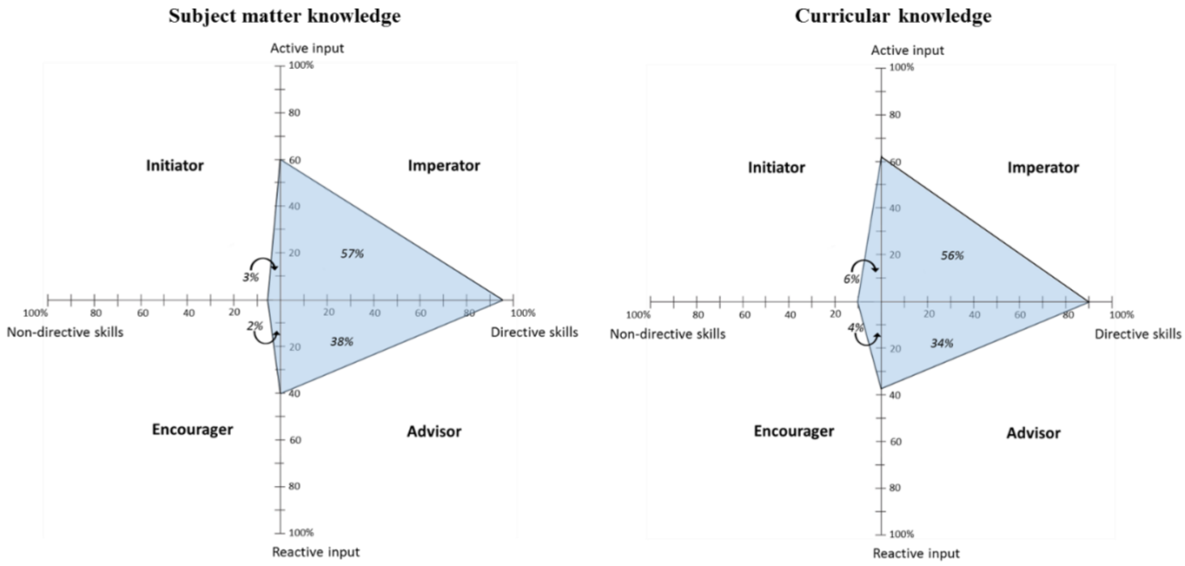

Figure 3: Pictorial representation of mentoring roles during the negotiation of issues related with subject matter knowledge and curricular knowledge

On the other hand, their use of directional practices was significantly limited when discussing topics on which mentees had profound background knowledge, like general pedagogical issues or students' ideas and interests. In these cases mentors adopted more dominantly the encourager role (Figure 4).

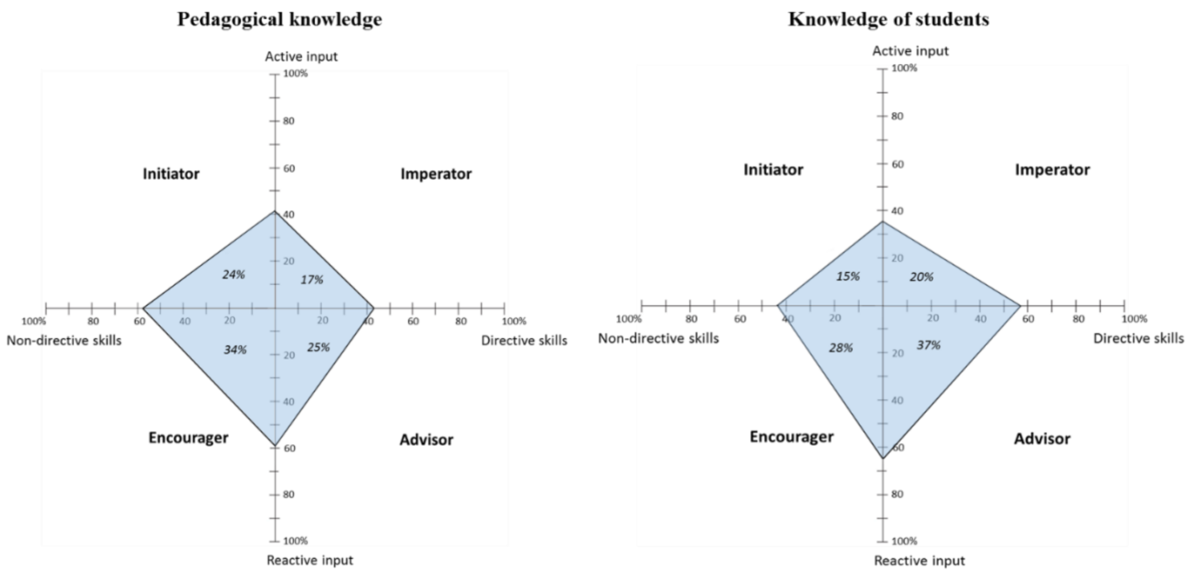

Figure 4: Pictorial representation of mentoring roles during the negotiation of issues related with general pedagogical knowledge and knowledge of students

DISCUSSION AND CONCLUSIONS

The results regarding the content of the mentoring discussions initially showed a strong tendency of mentors to discuss issues that were oriented towards different aspects of science teaching strategies, such as inquiry-based learning, lesson planning etc. Adding to the above, the long discussion of issues related to the teaching objectives of the modules, the students' ideas and the scientific content, the results show a strong orientation of the mentors' discourse on science-specific topics. Although these findings contradict those of related studies that reveal a mentoring focus on general teaching skills or general pedagogical knowledge (Bradbury & Koballa 2007; Bang & Luft 2014; Barnett & Friedrichsen 2015), this divergence can be attributed to the fact that in our study mentees were not novice but experienced teachers and to the very clear and specific targeting of the mentoring relation, which was the provision of suitable support to mentees in order to implement innovative modules in their classes.

Concerning mentoring roles, the participating mentors more frequently adopted directive practices to support the mentees, often resorting to advice giving and demonstrating. Moreover, the majority of mentors provided active input to the discussions, leading to the overall adoption of an imperator role. These results are in line with findings from other studies that highlight the predominance of imperator role among mentors (Hennissen et al., 2008; Crasborn et al., 2011; Mena et al., 2017). In fact, Hennissen et al. (2008) argue that this tendency is even more overt among untrained mentors, as in the case of the participants in the present study.

However, even if mentors adopted mostly the imperator role, they also managed to adapt themselves to the evolving needs of the mentees and to their degree of expertize on each subject. The dynamic shift of the roles is particularly interesting, taking into account that one of the most important and influential factors determining the success of a mentoring process is the extent to which the mentoring approach is flexibly adaptive to the learning needs of the trainee (Hobson et al., 2009).

From the above we can deduce that the mentoring process unfolded on the background of the implementation of modules on contemporary scientific research, was a dynamic process which provided mentee-teachers with professional development opportunities and concentrated features of an effective science teacher education effort. Therefore, mentoring could be used for the professional growth of experienced science teachers, beyond the limited scope of the induction phase, as a means of disseminating educational innovations, provided that teacher-mentors have previously received training on the novel practices.

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RELATIONSHIP OF EMOTIONS WITH ASSOCIATED VARIABLES TO THE SCIENCE TEACHING ON IN-SERVICE TEACHERS

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A research has been carried out with 339 Chilean in-service teachers (early childhood, primary and secondary education) of science teaching. In relation with the emotions of teachers, highlighting the influence of variables associated with election to be teachers, such as intrinsic career and working with student's value, and self-efficacy as teachers, such as in instructional strategies, classroom management and student engagement.

Keywords: emotions, in-service teachers, science teaching.

INTRODUCTION

Although there is a remarkable amount of research dedicated to the quality of teaching or the classroom environment generated by teachers, attention has hardly been paid to teachers as human beings who have their own motives, goals and emotional experiences (Frenzel, 2014). An exception is research on burnout, associated with the high risk that teachers present.

Although all workers experience emotions during their work (Weiss and Brief 2001), teaching can be especially emotional work (Frenzel 2014; Hargreaves 1998; Saunders 2013; Schutz 2014; Schutz and Zembylas 2009; Uitto, Jokikokko, et al. 2015). According to Schutz and Lanehart (2002), emotions are intimately involved in virtually all aspects of the teaching and learning process and, therefore, an understanding of the nature of emotions within the school context is essential. Teachers' emotional ties with students are often at the centre of their work (Day and Leitch, 2001), and teachers often experience enjoyment, anxiety and anger as they teach (Frenzel, Becker-Kurz, et al. 2015; Frenzel, Goetz, et al. 2009a, Taxer and Frenzel, 2015). In addition, teachers 'emotional experiences during class can directly affect their behaviour (Day and Leitch, 2001; Kunter, Tsai, et al. 2008), students' emotional experiences (Becker, Goetz, et al. 2014) and learning outcomes (Frenzel, Goetz, et al. 2009b). It follows that the emotional experiences of teachers could influence the configuration of their interactions and the implementation of what they learn in professional development. Emotions are to some extent dispositions, although they are also very context sensitive (Schutz, 2014, Schutz, Aultman, et al. 2009). On the other hand, teachers' emotions are related to a variety of important outcomes related to teaching, including teacher effectiveness in the classroom (Sutton, 2005), their well-being and health (Chang, 2013; Taxer and Frenzel 2015), and the emotions and motivation of the students (Becker, Goetz, et al. 2014; van Doorn, van Kleef, et al. 2014).

The research confirm that teachers' emotions are related to the effectiveness of instruction in terms of cognitive and motivational stimulation, classroom management and social support (Pekrun, Muis, et al. 2018). The enjoyment of teaching by teachers is positively related to appraisals of monitoring, development, understanding, support for autonomy, enthusiasm and support of students. On the contrary, negative relationships have been found between the anger and anxiety of teachers and the perceptions of students about the instructional behaviour of teachers, including the elaboration, understanding, support for autonomy, enthusiasm of students, and teachers support after failure (Frenzel, Goetz, et al. 2009a, 2009b; Frenzel, Pekrun, et al. 2016). However, negative emotions can sometimes have beneficial effects. Thus, Stough and Emmer (1998) discovered that beginning teachers, whose students showed hostile reactions to their comments, experienced negative emotions such as frustration and anger. As a result, some of them altered their classroom management strategies by modifying their comments to better control student interactions.

Importantly, teachers often exercise some level of control over their emotions through emotional regulation (Sutton 2004; Taxer and Frenzel 2015). As with other types of self-control, emotions are regulated to achieve goals, and different strategies can be used to achieve those goals. Existing research on how teachers modify their emotions has focused predominantly on teachers' use of deep-acting emotional work strategies, such as the act of internalizing the desired emotion so that the expressed emotion matches the emotion felt (Grandey 2000). Also, superficial action such as the act of expressing an emotion not felt (Grandey 2000; Hülsheger, Lang, et al. 2010; Näring, Briët, et al. 2006; Näring, Vlerick, et al. 2011; Philipp and Schüpbach 2010; Yin, 2015).

The three basic emotions that have been found to be the most notable and most frequent among teachers (Frenzel 2014; Hagenauer, Hascher, et al. Volet 2015; Sutton and Wheatley 2003) are enjoyment (pleasant, related to activity and results), anxiety (unpleasant, related to the result) and anger (unpleasant, activity and related to the result). Using two daily studies, Frenzel, Becker-Kurz, et al. (2015) analysed the frequency of each teacher's emotions by calculating the proportion of class periods in which each of the emotions was present. On average, teachers reported that they experienced enjoyment in 97%, anger in 44% and anxiety in 25% of their classes.

In summary, the well-being of the teachers and students, and the good functioning of the classrooms are related to the emotions of the teachers. The participation of teachers in cognitive and motivational stimulation, in classroom management and in social support, in turn, affects the cognitive growth, motivation, social and emotional behaviour of students in class and relationships with the teacher. Consequently, the behaviours of students and teachers in class can be seen as a cause and an effect of the emotional experiences of teachers during teaching.

Therefore, given the relative shortage of available research on teachers' emotions, the main objectives are to know the emotions of teachers, and how they can be affected, as well as affect other dimensions of classroom processes in a group of in-service Chilean teachers.

METHODOLOGY

The research has been carried out with 339 in-service teachers of Early Childhood (90), Primary (166) and Secondary (77) during science teaching training course. Age is between 23 and 65 years old (mean = 39,5), with a predominance of women (270) in relation to men (69).

It has been used to research emotions the Teacher Emotions Scales (TES), and various constructs to know attitudes and beliefs in relation to the teaching of science: Factors Influencing Teacher Choice (FIT-Choice), Dimensions of Attitude Toward Science Instrument (DAS), Ohio State Teacher Efficacy Scale (OSTES), Science Teaching Efficacy Belief Instrument (STEBI-A).

In the analysis and interpretation of the results, an analysis were carried out with the SPSS 24 program of calculation of bivariate correlations between emotions and the remaining dimensions to show significant correlations.

RESULTS

1) There are numerous significant correlations (See Table 1) between the three dimensions of emotions studied and the factors that influence career choice, and beliefs associated with the teaching of science in the group of in-service teachers. In general, the correlations are positive in relation to enjoyment, while they are negative with the other emotions studied (anger and anxiety). The difficulty in teaching science and the perception of social status correlates negatively with enjoyment but also with anxiety.

Table 1. Significant bivariate correlations of emotions with other dimensions, positive in brown and negative in green (r> | .111|* p <.05) N = 339).

Pearson correlations	JOY	ANGER	ANXIETY
INTRINSIC CAREER VALUE	0,562	-0,373	-0,363
WORK WITH CHILDREN	0,373	-0,150	-0,338
PRIOR TEACHING LEARNING	0,365	-0,110	-0,227
SOCIAL STATUS	0,207	0,084	0,136
SATISFACTION CHOICE	0,464	-0,105	-0,222
RELEVANCE TEACHING SCIENCE	0,472	-0,088	-0,209
DIFFICULTY TEACHING SCIENCE	-0,157	0,052	-0,139
INSTRUCCIONAL STRATEGIES	0,393	-0,315	-0,524
CLASSROOM MANAGEMENT	0,463	-0,262	-0,486
STUDENTS ENGAGEMENT	0,567	-0,148	-0,414
OUTCOME EXPECTANCY	-0,004	0,045	0,020

DISCUSSION AND CONCLUSIONS

In relation to teachers' emotions, highlight the influence of variables associated with control, such as in instructional strategies, in the management of classes and in the engagement of students; and the influence of valuation variables, such as intrinsic value of the career or the value of working with students; and the influence of dimensions associated with achievements, such as satisfaction with the choice of career, relevance or difficulty of teaching science.

As previously noted (Frenzel, 2014), teachers 'emotions are related to the effectiveness of instruction in terms of teachers' cognitive and motivational stimulation, classroom management and social support. As Baird, Gunstone, Penna, Fensham and White (2007) conclude, a balance between affection and cognition is important for effective teaching.

Measures should be taken to improve emotions in practicing teachers, starting them already in the initial training. In this sense, they should take actions that clearly protect against negative emotions and/ or enhance positive ones such as promoting the intrinsic value of the career of being a teacher, the valuation of work with students, self-efficacy in instructional strategies, classroom management and in student engagement.

As previously indicated (Frenzel, 2014), teachers' emotions are related to the effectiveness of instruction in terms of cognitive and motivational stimulation of teachers, classroom management and social support. As Baird, Gunstone, Penna, Fensham and White (2007) conclude, a balance between affect and cognition is important for effective teaching.

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RESULTS OF IMPROVED PROGRAM TO DEVELOP TEACHERS' ABILITIES TO CONSTRUCT AND EVALUATE ARGUMENTS

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A teacher who introduces argumentation into his or her classes must have the ability to construct his or her own arguments, as well as the ability to properly evaluate the arguments of his or her students. However, even though some Japanese teacher training programs include constructing and scoring arguments, it has been reported that teachers' confidence in teaching argumentation has not improved enough (Yamamoto & Kamiyama, 2018). In this research, we developed an improved program for training teachers that includes a proposal for teachers to introduce argumentation into their own classes. We then demonstrated the effectiveness of the program in developing teachers' abilities to construct and evaluate arguments, as well as improving teacher confidence in teaching argumentation. In addition to the lectures and exercises included in the program prior to improving it, we also added sessions on "proposal to introduce argumentation into classes (30 min.)" and "exchanging proposals (40 min.)." The program was implemented for 35 teachers working in primary schools, middle schools, and high schools during 2017 and 2018. Surveys conducted on teachers' abilities to construct and evaluate arguments as well as on teacher self-efficacy before and after the program showed improvement in teachers' abilities to construct and evaluate arguments as well as in teacher self-efficacy ($p<.01$ for all results). These results indicate that this program is effective at having teachers properly construct and evaluate arguments. The results also indicate that the program is beneficial in improving teachers' confidence in teaching. However, roughly one-third of the teachers provided a negative response with regard to confidence; thus, confidence has not been improved enough. The program will therefore need to be further developed with practical activities, in which teachers will further introduce argumentation into their actual classes and then reflect on the results.

Keywords: argument, teachers' abilities, confidence

INTRODUCTION

When introducing argumentation into science classes, importance is placed on the teacher's own understanding of argumentation and on his or her ability to construct arguments (Zohar, 2008). A teacher who introduces argumentation into his or her classes must also have the ability to properly evaluate the arguments of his or her students. For example, Osborn, Erduran, and Simon (2004) have incorporated activities into a teacher training program where teachers themselves construct and evaluate arguments. Iordanou and Constantino (2014) report that putting into practice activities in which evidence is used to engage in argument over pairs of contrasting opinions and constructing arguments using more evidence than in a standard curriculum had the result of increasing the meta-level awareness of teachers.

Similar activities have been put into practice even in East Asia. In Japan, Yamamoto and Kamiyama (2018) have implemented a teacher training program that incorporates explaining, constructing, and grading arguments. However, this program is composed only of lectures and drills on provided material. Teachers do not engage in practical activities to incorporate argumentation into their own classes, and thus teachers were not able to build enough confidence to teach argumentation in their classes. Previous research indicates that confidence to teach argumentation is a factor contributing toward teachers introducing argumentation, and that it is also affected by the teacher's experience teaching argumentation and his or her level of knowledge on his or her students (McNeill, Katsh-Singer, González-Howard, & Loper, 2016). Therefore, teachers can expect to not only improve their abilities to construct and evaluate arguments, but also to gain confidence in introducing argumentation into their teaching, by gaining experience in imagining the students in their own classes, and in proposing arguments to be constructed by their students and the situations in which these arguments are introduced.

In this research, we develop an improved program for training teachers based on the program implemented by Yamamoto and Kamiyama (2018), in which we have also included a proposal for teachers to introduce argumentation into their own classes. We then shed light on the results of this program. Our research questions are as follows:

· Was the improved program effective at developing teachers' abilities to construct and evaluate arguments?

· Did the improved program increase teachers' confidence in teaching argumentation?

METHOD

Subjects

The subjects for this research included 35 teachers currently working in Japan (18 elementary school teachers, 8 middle school teachers, and 9 high school teachers). The program was conducted for 12 teachers (6 elementary school teachers, 4 middle school teachers, and 2 high school teachers) from April through May 2017 and then again for the remaining 23 teachers from April through May 2018.

Program

The program comprised three sessions. The first session was a "lecture on what argumentation means and its significance (20 min.)," while the second session included a "lecture on grading exercises and the current state of students' abilities to construct arguments (20 min.)," "exercises to gain first-hand experience in teaching and evaluating argumentation (40 min.)," and a "briefing on actual class conditions (10 min.)." Although the first two sessions were the same as the program implemented by Yamamoto and Kamiyama (2018), a third session was added covering "proposal to introduce argumentation into classes (30 min.)" and "exchanging proposals (40 min.)" as a means for teachers to consider arguments to introduce into their own classes. Figure 1 shows one of the arguments for a teacher to introduce into his class.

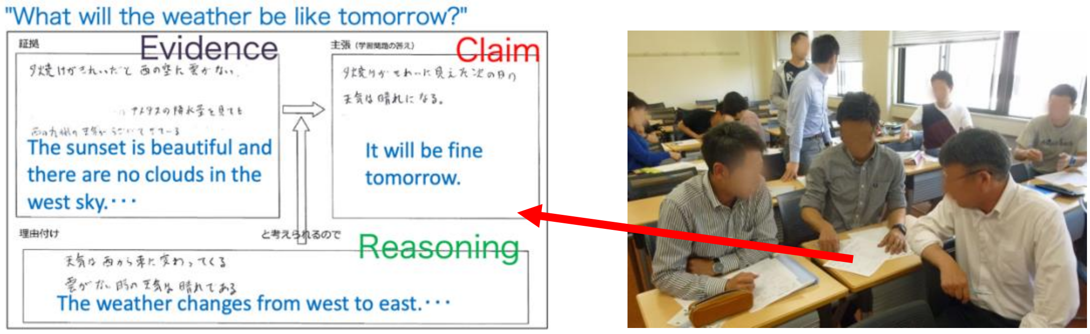


Figure 1. One of the arguments for a teacher to introduce into his class.

Test and survey

The 35 teachers participating in the program were provided with questions on constructing and evaluating arguments, both before and after the program was conducted. Each took around 10 minutes. A survey was also conducted on teachers' confidence in teaching argumentation (teacher self-efficacy) in order to gauge their beliefs on argumentation.

Figure 2 shows the argument construction question, and Figure 3 shows the desirable answer. The question was taken from Sakamoto et al. (2012). Teachers were asked to provide an explanation in their own words of a question in which a circuit in a hidden area was to be selected from two choices. Teachers were assigned a score out of two points in three areas (for a total of six points), based on a rubric evaluating "whether an answer was given (presence/absence of component)" and "whether the answer was scientifically correct (correctness of contents)." The three areas were the following: their "claim" as an answer to the question, their "evidence" mentioning the brightness of miniature light bulbs in each circuit (the fact of the matter), and their "reasoning" mentioning the size of each current (voltage/power) connected in parallel. These answers were judged by two independent judges with a concordance rate of 98.1%.

The circuit of ① and ② has the part of the cell hidden.

In the circuit of ①, the brightness of the light bulb was brighter than that of one cell. In the circuit of ②, the brightness of the light bulb was the same as that of one cell.

Which of the following A and B applies to how to connect the cells of each of the circuits 1 and 2? And why did you think so?

Explain these things scientifically. Write an explanation.

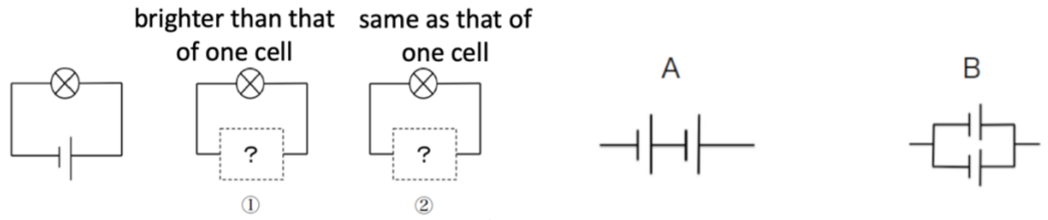


Figure 2. Argument construction question.

Claim: ① is A, ② is B.

Evidence: In the circuit of ①, the brightness of the light bulb was brighter than that of one cell. In the circuit of ②, the brightness of the light bulb was the same as that of one cell.

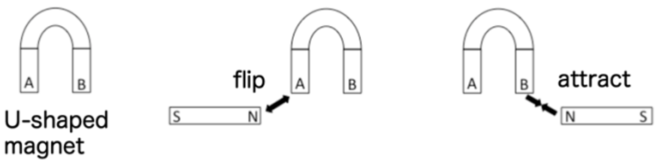
Reasoning: If you increase the number of cells to two in series connection and turn on the light bulb, the current (or any of voltage, power and electricity) will increase compared to when connected to one cell.

Even if you increase the number of cells to two and connect the light bulb with parallel connection, the current (or any of voltage, power, and electric quantity) does not change compared to the time when one cell is connected.

Figure 3. Desirable answer in the argument construction question.

Figure 4 shows the argument evaluation question. For the question on evaluating arguments, teachers were asked to evaluate answers from child X, Y, and Z (cases X, Y, and Z hereafter), who were presented with a U-shaped magnet of unknown polarity and told to determine the polarity by bringing the north pole of a bar magnet into contact with the U-shaped magnet. In judging these answers, teachers were asked to focus on students' "claim" as answers they gave for each pole, their "evidence" mentioning how the bar magnet reacted in the way it did (the facts of the matter), and their "reasoning" indicating that magnets of the same polarity are repulsed while magnets of opposite polarity are attracted. Teachers were then assigned a score of either zero or one point based on their "judgment" that all cases X, Y, and Z were found insufficient and then their "reason" mentioning why they were insufficient as arguments. These answers were judged by two independent judges with a concordance rate of 99.5%.

What are the poles of A and B of the U-shaped magnet? And why did you think so? Explain these things scientifically.



If you can judge that the children's descriptions X, Y and Z are sufficient for scientific explanation, enter ○ in the "judgment" column. If you judge that it is not enough, enter △. And briefly state in the "reason" column why you have judged that.

【Child X】 judgment [ ] reason [ ]
A is N pole and B is S pole.
When the N pole was brought close to A, the magnets was flipped, and when the N pole was brought close to B, the magnets attracted each other.

【Child Y】 judgment [ ] reason [ ]
When the N pole was brought close to A, the magnets was flipped, and when the N pole was brought close to B, the magnets attracted each other.
The magnets have the same poles are flipped and the other poles attract each other.

【Child Z】 judgment [ ] reason [ ]
A is N pole and B is S pole.
The magnets have the same poles are flipped and the other poles attract each other.

Figure 4. Argument evaluation question.

Teachers were also asked before and after the program how they felt about the seven belief categories from Katsh-Singer, McNeill, and Lope (2016), and were instructed to rate each category as "strongly believe so" (four points), "believe so" (three points), "do not believe so" (two points), or "strongly do not believe so" (one point). Of these categories, we provide a report on teacher self-efficacy in this research.

RESULTS

Argument construction question

Table 1 shows the score distribution for the argument construction question. The results of a Wilcoxon signed-rank test revealed component elements with significant improvements to score distribution between the pre- and post-tests. These are indicated in bold. For "claim," teachers mostly received full scores for both "presence/absence of component" and "correctness of contents" during both the pre- and post-tests. For "evidence," a significant improvement was observed for both "presence/absence of component" and "correctness of contents" (*p*<.01). For "reasoning," although teachers mostly received full scores for "presence/absence of component" during the pre- and post-tests, only 20 teachers received full scores for "correctness of contents" during the tests.

Argument evaluation question

Table 2 shows the score distribution for the argument evaluation question. Nearly all teachers received full scores during the post-test for both their "judgment" and "reason" for case X (in which the student's reasoning was lacking) and case Y (in which the student's claim was lacking). For case Z (in which the student's evidence was lacking), the number of teachers who received full scores increased from the pre-test to the post-test (*p*<.01).

Survey on beliefs on argumentation

Figure 5 presents "teacher self-efficacy" before and after the program. A Wilcoxon signed-rank test showed a significant improvement between the pre- and post-tests (*p*<.01).

Table 1. Score distribution for the argument construction.

		pre-test			post-test			
	score	2	1	0	2	1	0	
presence/absence of component	claim	32	1	2	35	0	0	
	evidence	13	0	22	**26**	**3**	**6**	**
	reasoning	27	3	5	32	1	2	
correctness of contents	claim	30	1	4	33	0	2	
	evidence	14	0	21	**26**	**2**	**7**	**
	reasoning	19	3	13	20	1	14	

Note: Components that showed significant improvement in the score distribution between pre-test and post-test are shown in bold.

Table 2. Score distribution for the argument evaluation.

		pre-test		post-test		
	score	1	0	1	0	
judgment	case X	32	3	35	0	
	case Y	32	3	35	0	
	case Z	**16**	**19**	**28**	**7**	**
reason	case X	28	7	34	1	
	case Y	30	5	34	1	
	case Z	**11**	**24**	**26**	**9**	**

Note: Components that showed significant improvement in the score distribution between pre-test and post-test are shown in bold.

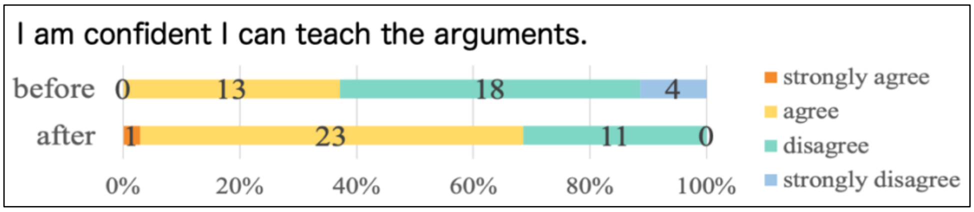


Figure 5. Confidence in teaching arguments.

DISCUSSION AND CONCLUSIONS

As a result of implementing this program, teachers were able to obtain overall good scores during their post-tests for the argument construction question and argument evaluation question. Teachers maintained an awareness of component elements when writing their arguments, and were able to check these component elements when evaluating arguments. This is likely a direct result of their activities during the program, in which they constructed arguments and scored the arguments of students. The teachers were able to properly construct and evaluate arguments even when the content changed.

Furthermore, the survey conducted on beliefs on argumentation showed that scores increased for "teaching confidence" after the program, so it can be inferred that the program had the effect of improving teachers' confidence in teaching. However, roughly one-third (11) of the teachers responded negatively ("do not believe so") during the post-test, suggesting that confidence was not sufficiently improved. In order for teachers to improve their confidence in teaching argumentation, a program accompanied by activities that are more practical will be required, in which teachers introduce argumentation into their actual classes and then reflect on the results.

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AN EMPIRICAL PILOT IN ASSESSING STUDENT TEACHERS' BIOGRAPHY AND INSTRUCTIONAL BELIEFS

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Switzerland is undergoing a curricular change. Curriculum 21 has been ratified by all 21 German-speaking and is currently being implemented. With this innovation, German-speaking Switzerland will move toward a more technology-oriented education. What has been Manual Training or Wood/ Metalwork Classes is now replaced by composite subjects such as Nature and Technology. These subjects now structurally anchor technology-oriented content at the compulsory school level (Stuber, Heitzmann, & Käser, 2013) and are supposed to be implemented in the sense of the Anglo-Saxon concept of Science – Technology – Society – Environment (Labudde, 2012, p. 86). The technology orientation includes an instructional orientation toward a technical understanding or understanding technology, which, eo ipso, needs to be part of teacher education programs (Keller, 2017). To put things bluntly: Who else than technology/ technics-oriented teachers should teach technology and technics? Yet, technics or technology is not explicitly part of their initial studies, perhaps because in "the mandatory school, i.e. K-12, there is no specific subject 'Technology', but there is a subject called 'Textile and Technical Design'" (Kruse & Labudde, 2016, p. 62). Therefore, student teachers may at the most specialize in textile and technical design or in information technology/ computer science and teach technics and technology in an integrated way. But what are factors they would consider to impede tech instruction? In other words: What are factors that hinder high quality technology instruction by means of teacher beliefs? In this presentation we will give insights to a quantitative exploratory study.

Keywords: Science & technology education, pre-service teacher education, technology instruction

INTRODUCTION

Currently, Switzerland is moving toward a more technology/ engineering-oriented education. What has been *Manual Training* or *Wood/ Metalwork Classes* is replaced by composite subjects such as *Nature, Man, Society*, *Nature and Technology* or T*extile and Technical Design*. These subjects now structurally anchor technology at the compulsory school level (Stuber et al., 2013) and are supposed to be implemented in the sense of *Science – Technology – Society – Environment* (Labudde, 2012, p. 86). Also the subject area of media & information technology education touches the general technology branch, especially when informatics is extended to computer programming, digitalization of work routines and robotics. All this includes an instructional orientation toward a *technical understanding* or *understanding technology* (National Research Council, 2002), which, eo ipso, needs to be part of teacher education programs (Keller, 2017). Current cohorts of student teachers at the Swiss universities of teacher education are supposed to be educated toward these contents. But in praxis, who else than technology-affine teachers should teach technology? Technology was not explicitly part of their initial studies, and even current students do not receive a uniform technology-oriented education. Perhaps because in "the mandatory school, i.e. K-9, there is no specific subject

‘Technology’, but there is a subject called ‘Textile and Technical Design’” (Kruse & Labudde, 2016, p. 62). Also, *Textile Design* is not pure technology and technology is not solely design-oriented. The same is true for media and information technology, digital technology, engineering or any other area.

At the moment, student teachers may – at the most – specialize in textile and technical design or in information technology/ computer science, and consequently teach technology in an integrated way. From the fact that there is no systematic technology education in the course of their university studies, the question arises under which circumstances student teachers individually integrate technology-oriented instruction into their teaching. Thus, we need to know about predictors of technology-oriented instruction. Our question is: What are preconditions that support student teachers pursue technology-oriented instruction in compulsory K-9 school, i.e. primary and lower-secondary school?

THEORETICAL BACKGROUND

It is generally difficult to draw a comprehensive picture of instructional integration processes, especially in terms of a rather opaque field of “technology” education. Thus, in first part of the theoretical section, we want to clarify our conception of technology. In the second theoretical part – because we ask the question “What are preconditions that support student teachers pursue technology-oriented instruction in compulsory K-9 school, i.e. primary and lower-secondary school?” – we want to focus on holistic theories of behavior prediction and integrate them into a framework of technology education.

The term technology

The most debatable term in this study is *technology*. Looking at a large body of research in technology integration in instruction, we see that the term *technology* is mainly used to refer to computer-like systems, digital devices or applications that are programed to substitute analog antecedents. For example the use of computers in classrooms, the implementation of tablets or apps, or having online examinations (e.g. Lumpe et al., 1998; Palak & Walls, 2009; Ottenbreit-Leftwich et al., 2010; Ertmer et al., 2012; Kim et al., 2013; Hutchison & Woodward, 2014; Beschorner et al., 2018). In sum, most studies find teacher beliefs, values, pedagogical self-concept, reflected, goal-oriented intentions, and value for learning outcomes as main factors for technology implementation.

Yet, the term technology not solely refers to digitalization. Although there may be various understandings around the world and particularly within European countries, and also differences between US and Europe, we want to employ a definition that, to our knowledge, addresses most conceptions: “Technology comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves.” (National Research Council, 2002, p. 3). Thus, *technology* and *technics* are defined as a construct of informatics & digital literacy as well as technical & engineering knowledge and any innovative combination of any of these fields. Within this broad conception of technology one needs to consider engineering school education, too. Yet, this has been hardly explored. Van Haneghan et al. (2015) find that teachers' experience with engineering is of advantage when it comes to teaching engineering topics. Also, the value teachers see in teaching engineering has an effect on the implementation of engineering topics (Park et al., 2016). Similarly to technology integration, engineering instruction is also related to how well prepared (content-wise and pedagogically) the teachers feel themselves (Wang et al., 2011; Rich et al., 2017)

Pedagogical knowledge, beliefs, socialization, and motivation as instructional predictors

Teachers work within a context of not-well-structured problems and infinite variability of outcomes. By definition, "well-structured problems are constrained problems with convergent solutions that engage the application of a limited number of rules and principles within well-defined parameters. Ill-structured problems possess multiple solutions, solution paths, fewer parameters which are less manipulable, and contain uncertainty about which concepts, rules, and principles are necessary for the solution or how they are organized and which solution is best" (Jonassen, 1997, p. 65). To solve ill-structured problems teachers need a broad spectrum of reactions, competence, and experience. Jonassen (1997) argues that ill-structured problems are solved best if one can a) articulate the problem space and contextual constraints, b) identify and clarify alternative opinions, c) assess the viability of alternative solutions by argumentation and beliefs, and d) apply, monitor and adapt the solution. Taking into account that this whole process is situational, the most relevant predictors of solving an ill-structured interaction may be the teachers' mindset and their ability to consider the contextual/ interactional constraints (i.e. pedagogical knowledge). A prominent model of teacher resources for instructional practice has been proposed by Kunter et al. (2013). It integrates professional cognitive competences (e.g. pedagogical content knowledge), beliefs and motivational variables as the most valuable predictors of instruction:

a) *Pedagogical (content) knowledge* represents what the teacher knows about teaching content matter to students in a particular stage of development. Thus, pedagogical content knowledge includes knowledge about the content area, knowledge about instructional methods, and knowledge about the developmental stage of the students.
b) *Teacher beliefs* of instruction can be seen an interactive process guided by individual norms, one needs to understand the beliefs of the involved individuals (Raymond, 1997; Pane, 2010). Beliefs are often formed by prior teaching experiences, e.g. how they were taught to teach in their teacher education program or even how they were taught themselves during their schooling. Especially the latter reaches out into the wide field of socialization and biographical backgrounds.
c) Hurrelmann (1986, 2002) draws on socialized cognition, knowledge, biography and social contexts in order to explain purposeful behavior and decision-making. General, but also family and school socialization develops motivation and interest in any domain, also in technology (Deci & Ryan, 2000; Renn et al., 2009; Ardies et al., 2015; Adenstedt, 2016).

Therefore, we want to emphasize home, school and hobby/ interest as major predictors of technology socialization.

d) *Motivation* can be defined as the result of situation-belief interaction (J. Heckhausen & Heckhausen, 2018). Motivation results in action. In the motivational process intention plays a central role: The Rubicon model of action phases (H. Heckhausen & Gollwitzer, 1987; Gollwitzer & Oettingen, 2001; Achtziger & Gollwitzer, 2007) – a sequential, psychological model – predicts a person's behavior. In the model, the intention-building is central as it activates planned behavior. Based on van Hooft, Born, Taris, van der Flier, and Blonk (2005), who articulate that planning is essential and can be assessed in a questionnaire. This methodological idea is in line with Fishbein and Ajzen (2010) who argue that asking a person is a good proxy for the person's true intentions.

Based on the above mentioned, we developed a research framework that includes the major dimensions of instruction and their relevance in general educational contexts. In our case we focus teacher prerequisites related to their instruction in compulsory school (see Figure 7).

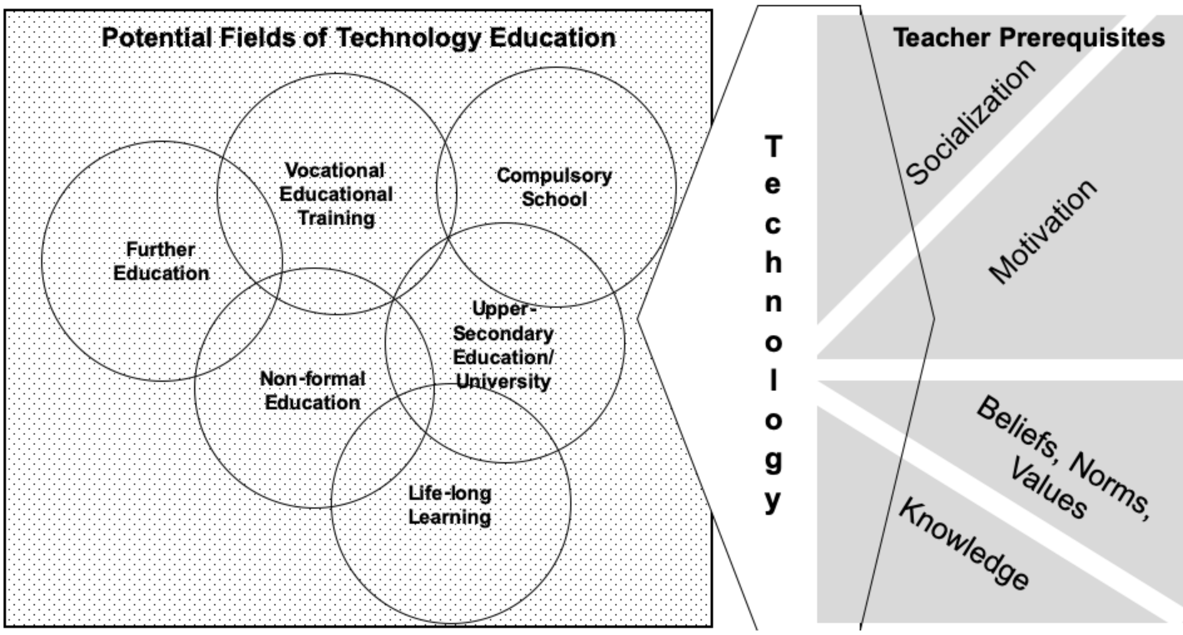

Figure 7: Framework of teacher prerequisites and implementation fields for technology education

In Figure 7 the major variables for successful technology implementation are teacher socialization, motivation, beliefs, and knowledge. These variables combine self-attribution as well as objective evaluation.

METHOD

Instruments

We used a questionnaire to assess the biographical background (socialization) and the intention to implement technology instruction and self-confidence in technology instruction. All items were rated on a 5-point Likert scale (do not agree --- fully agree). The instruction included clarification of the term, i.e. it means digital technology as well as engineering.

Technology socialization was newly developed, has 4 items (e.g. Technology played a role in my family during my childhood"), showed uni-dimensionality in principal component analysis and reliability was α=.78; The intention to implement technology instruction was adapted from van Hooft et al. (2005), included 4 items (e.g. "I know exactly how to implement technology in my instruction"), showed uni-dimensionality in principal component analysis and reliability was α=.78.

In addition to the two theoretical variables above, we assessed a lack professional and instructional self-confidence as hindering elements to implement technology instruction. These single item indicators were "I think my content knowledge is insufficient." and "I think my pedagogical competence does not suffice."

Sample and context of data acquisition

In autumn 2016 we deployed questionnaires to 69 student teachers (66% kindergarten & primary level, 34% lower-secondary level; 2 courses in primary level – 4-4.5% male students; one course in lower-secondary – 64% male students). All participants were enrolled in a class on "quantitative research methods". As the class was compulsory in the education program the backgrounds of the students were manly randomized, i.e. they were neither biased in terms of interest, nor preferred subjects. 77% of the students were female, kindergarten and primary level are dominated by female students (Phi=.66, p.000). On average, they were in their second year of study. Data were analyzed with SPSS 24. Two-tailed Spearman-correlations were computed and Kruskal-Wallis test/ separate Mann-Whitney U tests were used for comparisons between the three groups. Because of the small sample and the exploratory purpose of the study, we give exact p-values that need to be interpreted carefully, but also with tolerance.

RESULTS

The implementation intention correlation was .24, p=.066, the correlation between the single item indicators was .46, p=.000. The pedagogical confidence was not associated to the socialization (r=.20, p=.118), but the confidence in content knowledge was (r=-.27, p=.035). With reference to the implementation intention, both pedagogical confidence (r=-.35, p=.006) and confidence in content knowledge (r=-.50, p=000) showed statistical significance. The the Kruskal-Wallis test for overall comparison resulted in two-sided p-values for technology socialization (p=.006) and the other variables in a range of p=[.366;.515]. Mann-Whitney U tests with corrected alpha level of p=.05/3 tests=.017 showed that the group of lower secondary students scored higher on technology socialization than any of the primary teacher groups (p=.010; p=.004), the two primary teacher groups did not differ (p.=872).

DISCUSSION

This study framed the term "technology" in a content area of informatics & digital literacy as well as technical & engineering knowledge and any innovative combination of any of these fields. We also picked up the issue of technology instruction without a subject named "technology" in Switzerland and investigated the relation of a technology-oriented socialization and the implementation of technology instruction. Furthermore, we explored the association of pedagogical and professional self-confidence with respect to socialization and implementation. The results seem promising and showed that a stronger self-reported technology orientation during childhood is associated with how technology education enters instruction. Confidence in pedagogical and professional knowledge share a stronger association with the implementation than socialization does, but it seems that socialization can play an important role. As this is a pilot study with a small sample size we still need to be careful in interpretation. But if the effect holds true in a large sample we have evidence that school sets itself into a vicious cycle of technology education and its mandate to educate kids toward a good fit into society. The reason is that technology at school is part of the socialization, and if it is left out we will not have teachers with sufficient technology socialization that trust themselves to teach technology. A second exploratory finding is that lower-secondary teacher students rate their technology socialization higher than the primary school peers, but they are not more confident in their abilities. Thus, a "women underrate their abilities" explanation in which the female-dominated primary teachers do not trust their abilities as much as the male students, does not apply. We speculate that this effect may rather appear because students perceive subjects in different way: in lower-secondary education they have separate subjects, in primary/ kindergarten they teach holistically. We hope for more research on this assumption, especially because it is just out of an exploratory approach in a small sample pilot study.

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EVALUATING SCIENCE TEACHERS' TEACHING PRACTICES: STRENGTHS AND WEAKNESSES

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Teacher's evaluation is considered critical for teachers' professional development. Evaluation systems with different characteristics are used worldwide. According to the literature, the most common practice to collect data for the evaluation of teachers is classroom observation. Despite students' perspectives being considered as a viable and reliable source of teachers' evaluation, students' insights have not been used for teachers' evaluation. Within this context, the aim of the present study was to highlight the strong and weak aspects of science teachers' teaching practices. For this purpose, we designed and implemented an evaluation system for secondary education science teachers. Our data were collected with classroom observations and with questionnaires for exploring students' perceptions. Thirty-two (32) science teachers serving in secondary education were evaluated and 1154 students completed the questionnaire. The results indicated that teachers' strengths are related to the subject matter knowledge, the use of representations, questioning, the instructional objectives, classroom management, and the knowledge of students' difficulties. Their weaknesses concern some of the instructional strategies and methods, students' alternative conceptions, and assessment. These findings provide an overview of teachers' everyday practices and indicate the aspects of teaching in which teachers need support as well as potential areas that future professional development programs could focus on.

Keywords: Evaluation, Teacher Professional Development, Science Education Policy

INTRODUCTION

There is a strong correlation between the quality of education and the quality of practices in teaching. The quality of teachers' classroom practices constitutes a central issue for those who are concerned with teachers' professional development (Kallery & Psillos, 2001, p.166). Teachers' knowledge, teachers' practices, and teachers' professional development have been the subject of studies by many scholars (e.g., Van Driel & Berry, 2012).

In modern education, evaluation is seen as a meaningful and essential process for teachers' professional development. To highlight the strengths and weaknesses of teachers' practices, different evaluation systems have been applied worldwide. The most common method to collect data for teachers' evaluation is classroom observation with the use of a scoring rubric. (Isoré, 2009). However, scholars highlight that "classroom observation, no matter how well-focused, can only capture certain aspects of what a teacher has planned and indeed is undertaking in the classroom" (Shinkfield & Stufflebeam, 1995, p. 228).

On the other hand, students spend most of their school life behind a desk or participating in activities designed by the teachers. In turn, they can provide a more holistic look at teachers' teaching practices. Despite students' opinions perceived as a reliable and viable source of data (e.g., Peterson, Wahlquist, & Bone, 2000, Aleamoni, 1999), they are not systematically used as a source for teacher's evaluation (Isoré, 2009, Santiago, 2009).

Based on the above, we designed and applied an evaluation system specifically for science teachers using both a student questionnaire and an observation tool (scoring rubric), and we formed evaluation criteria (see Table 1), based on aspects of Pedagogical Content Knowledge (PCK). The present study aims to evaluate science teachers serving in secondary education and to highlight the weaknesses and strengths of their everyday practice. Based on this closer examination of individual teacher's needs, we provide a foundation upon which the future development of professional upgrading programs could be based.

METHOD

Evaluation criteria and levels of achievement

The evaluation system uses 21 criteria (see Table 1) in which teachers' practices are evaluated. The criteria are divided into four categories based on the PCK analysis of Jang (2011): Subject Matter Knowledge, Instructional Representations and Strategies, Instructional Objective and Context, and Knowledge of Students Understanding. In each criterion, the evaluation is based either on results from classroom observations or on students' opinions or both.

Tools of the evaluation system and data collection

Classroom observations were recorded using a scoring rubric designed by the authors and evaluated by experienced educational advisors. Students' opinions about teachers' performance were collected with the use of a questionnaire originally designed by Jang (2011) and adapted to the context of our study. Both tools use a five-point Likert scale. For each teacher, the observer performed direct first-hand observations of two one-hour lessons and scored the teachers' performance for every aspect of teaching. Students of two different classes answered the questionnaire. The science teachers were evaluated during the lesson of their major subject (e.g., Physicist – Physics).

Data were collected from both observation and students' questionnaires to collect data for the quality of the practices that teachers use in everyday teaching and the frequency that these practices are used, respectively. Furthermore, students' perceptions of the usefulness of some methods that their teacher use is essential for the evaluation of the teacher in some aspects of teaching.

Sample

The study was conducted in Central Northern Greece. Thirty-two (32) science teachers from Gymnasium and Lyceums participated in the study. Seventeen (17) of the teachers with major in Physics, twelve (12) with major in Chemistry, and three (2) with major in Biology. The sample was representative. The questionnaires were completed by 1154 students (579 male and 571 female), 484 Gymnasium students (12-15 years old) and 571 Lyceum students (16-18 years old).

Table 3: Evaluation criteria and the aspects of teaching recorded (R for scoring rubric and Q for students' questionnaire

Domain 3:Instructional Objectives and Context	
Criteria	**Aspects included in each criterion**
Instructional objectives and goals	*Instructional objectives and goals (communication and understanding) (R)* *Understanding of the lesson goal (Q)*
Interactive atmosphere	*Teaching Adjustment based on students' reaction (Q and R)* *Discussion on students' questions (Q)*
Students participation	*Students participation (R)*
Motivation for learning	*Motivation for learning (Q)*
Additional teaching material	*Additional teaching material (Q)*
Classroom management and mutual respect among students	*Classroom management (Q and R)* *Mutual Respect (R)*

Domain 4: Knowledge of Students Understanding	
Criteria	**Aspects included in each criterion**
Alternative conceptions investigation	*Teachers' Questions before introducing a new topic (Q)* *Alternative conceptions investigation (R)* *Strategies to handl students' alternative conceptions (R)*
Knowledge of students' difficulties	*Knowledge of students' difficulties (Q and R)*
Assessment during the lesson	*Use of different ways to access understanding (Q)* *Formative Assessment during lesson (R)* *Variety of assement methods and adjustment related to students' diversity (R)*
Summative assessment (test, etc.)	*Summative Assesment (tests, etc) (Q)*

Domain 1: Subject Matter Knowledge	
Criteria	**Aspects included in each criterion**
Knowledge of the content	*Knowledge of the content (Q)* *Adequete presentation of the topic (Q)* *Adequately answering of students' questions (Q)*
Quality of the language used during the lesson	*Quality of the language used during the lesson (R)* *Didactic tranformation (Q)*
Connection between the teaching notion or phenomenon and everyday life	*Connection between the teaching notion or phenomenon and everyday life (Q and R)*

Domain 2 : Instructional Representation and Strategies	
Criteria	**Aspects included in each criterion**
Instuctional Strategies	*Instructional Strategies (Variety and appropriateness) (R)* *Strategies maintaining students' interest (Q and R)*
Students' attentiveness related reactions during instruction	*Students' attentiveness related reactions during instruction (Q and R)*
Instructional representations	*Use of examples, analogies, graphs, everyday objects (Q)* *Appropriateness and usefulness of instructional respresentations (R)*
Use of ICTs	*Use of ICTs (Q)*
Use of experiments	*Demonstration of Experiments (Q)* *Students' experiments*
Inquiry	*Type of Inquiry (R)*
Scientific skills promoted by the teacher	*Scientific skills promoted by the teacher (R)*
Questioning	*Conceptual Level of teaching questions (R)* *Students' participation in questioning (R)*

Data analysis

The data from the questionnaire were statistically analyzed for each teacher and the mean of students' responses was calculated. The results from the scoring rubric and the means were inserted in a Sheet of Personal Evaluation. The evaluator compared and synthesized the results for each aspect of teaching recorded and made decisions about teachers' level of achievement on every criterion based on the following scale: Exceptional (Q:4.00-5.00, R:4 & 5), Adequate (Q:3.00-3.99, R:3), Weak (Q:2.00-2.99, R: 2) and Inadequate (Q:1.00-2.99, R:1). After the individual evaluation of teachers, a descriptive statistical analysis was performed to describe the strengths and the weakness among the science teachers of the total sample.

RESULTS & DISCUSSION

Subject Matter Knowledge

The results showed that the teachers were rated as exceptional or adequate in the criteria included in Subject Matter Knowledge (see Table 2). Teachers have good knowledge of their subjects. The quality of the language used during the lesson was exceptional for the majority of the teachers (Table 2, *Quality of language use during the lesson: Exceptional*) while the minority of them use some inappropriate expressions (mirror mistakes in verbs or expressions that seem to represent animistic views) but their use does not seem to affect learning (Table 2, *Quality of language use during the lesson: Adequate)*. The connection of the topic to everyday life seems to be a common practice for a large percentage of the teachers (Table 2).

Table 4: Evaluation results' statistics for criteria included in the SMK domain

Level of achievement	Knowledge of the content		Quality of language use during the lesson		Connection to everyday life	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	32	100	24	75	14	43.8
Adequate	0	0	8	25	14	43.8
Weak	0	0	0	0	3	9.4
Inadequate	0	0	0	0	1	3.1

Instructional Representations and Strategies

Teachers use a variety of teaching methods and techniques in which students are engaged and maintain students' interest in the lesson (Table 2: *Instructional Strategies*). Most of the teachers give students the opportunities to express their opinions (Table 2: *Opportunities for students to express their opinions*).

Moreover, teachers make proper use of instructional representations that seem to have a positive effect on the learning process. However, weaknesses are found in ICT-based teaching and the use of experiments during instruction. The vast majority of the teachers either use experiments rarely or never in their practice (Table 4: *Use of experiments, Weak and Adequate*) while another large percentage of them avoid using Information and Computer Technologies in their everyday practice (Table 3: *Use of ICT, Weak and Adequate*).

Table 5: Evaluation results' statistics for criteria included in the IRS domain

Level of achievement	Instructional Strategies		Opportunities for students to express their opinions		Instructional representations		Use of ICTs	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	18	56.3	14	43.8	24	75	6	18.8
Adequate	7	21.9	12	37.5	4	12.5	8	25
Weak	7	21.9	6	18.8	4	12.5	7	21.9
Inadequate	0	0	0	0	0	0	11	34.4

Teachers use mainly structured inquiry to promote basic skills (Table 4: *Types of Inquiry and Scientific Skills promoted by teacher*). Most of the teachers were rated as adequate or excellent in questioning. Teachers escalate the conceptual level of their questions (from basic to high level) in order to guide students to understand and explain the ideas or phenomena of the taught topic.

Table 6: Evaluation results' statistics for criteria included in the domain IRS

Level of achievement	Use of experiments		Types of Inquiry		Scientific skills promoted by the teacher		Conceptual level of teachers questions	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	7	21.9	4	12.5	4	12.5	9	28.1
Adequate	6	18.8	13	40.6	13	40.6	15	46.9
Weak	14	43.8	7	21.9	11	34.4	0	0.0
Inadequate	5	15.6	8	25	4	12.5	8	25.0

Instructional Objectives and Context

Teachers are also positively evaluated in the criteria included in the domain of Instructional Objectives and Context. Most of the teachers communicate the instructional objectives in multiple ways and achieve an understanding of them for most of the students (Table 5: *Instructional Objectives)*.

Table 7: Evaluation results' statistics for criteria included in the domain IOC

Level of achievement	Instructional objectives and goals		Interactive atmospheres		Students participation	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	22	68.8	11	34.4	16	50
Adequate	10	31.3	11	34.4	15	46.9
Weak	0	0	10	31.3	1	3.1
Inadequate	0	0	0	0	0	0

Most of the teachers are successful in creating an interactive atmosphere in the classroom for the students to participate in the lesson, a not so palatable percentage of them is found weak in creating an interactive atmosphere. Also, as we can see in Table 6 (*Additional Teaching Material*) almost half of the teachers rarely or never provide additional teaching material.

Table 8: Evaluation results' statistics for criteria included in the domain IOC

Level of achievement	Motivation for learning		Additional teaching material		Classroom management and mutual respect among students	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	4	12.5	7	21.9	20	62.5
Adequate	20	62.5	12	37.5	11	34.4
Weak	8	25	6	18.8	1	3.1
Inadequate	0	0	7	21.9	0	0

Knowledge of Students Understanding

In the domain of Knowledge of Students Understanding, the results highlight the most significant weaknesses of teachers' everyday practice. The majority of the teachers don't investigate and therefore do not handle students' alternative conceptions. Also they rarely assess students during the lesson and when they do it is for the students' compliance (Table 7: *Assessment during the lesson: Weak)*.

Table 9: Evaluation results' statistics for criteria included in the domain KSU

Level of achievement	Students alternative conceptions		Knowledge of students difficulties		Assessment during the lesson		Summative assessment	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	7	21.9	21	65.6	9	28.1	9	28.1
Adequate	4	12.5	9	28.1	10	31.3	17	53.1
Weak	5	15.6	2	6.3	13	40.6	6	18.8
Inadequate	16	50	0	0	0	0	0	0

However, teachers seem to have a good knowledge of the difficulties of the students in the topic they teach, and they focus on these in order to address them properly (Table 7: *Knowledge of Students' Difficulties)*.

Regarding students' summative assessment most of the teachers are evaluated as adequate (Table 7). However, because the findings of this specific criterion are based only on students' responses, students seem to question the usefulness of the type of assessment that teachers employ.

CONCLUSIONS

The findings of the present study provide an overview of the Greek science teachers' weaknesses and strengths regarding their everyday practices. This closer examination of the individual teacher's needs indicates potential areas that future professional development programs could focus on.

Even though this study focuses on the strengths and the weaknesses of teachers' practices, if we take into account the theoretical background of the Greek teachers and the lack of pre- and in-service teacher education in the country, we believe that we could describe some potential reasons for science teachers' strengths and weaknesses. On the one hand, the weaknesses observed and described above may be connected to a lack of teachers' knowledge related to *General Pedagogy* (e.g., Shulman, 1986), *Knowledge of students* and *Knowledge of Assessment* (Magnusson, Krajcik, & Borko, 1999), and students beliefs about learning and the aim of teaching science (Van Driel, Beijaard, & Verloop, 2001). On the other hand, the strengths of the teachers are related to aspects of teaching that could be developed through their experience (Clermont, Borko, & Krajcik, 1994) as a kind of *craft knowledge of teachers* (Van Driel et al., 2001).

From the methodological point of view, the combination of the students' views with observations using a tool (scoring rubric) designed in collaboration with experienced educational advisors who have a good knowledge of the educational system in which teachers act in their every-day work, seems to be fruitful as it produces a holistic view of the practices that take place in the real everyday classroom (Shinkfield & Stufflebeam, 1995, p. 228).

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INTERDISCIPLINARY REFLECTIVE TOOL ON SCHOOL SCIENCE AND MATHEMATICS

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In this paper, we focus on the importance of interdisciplinary communication between the teachers' didactical interaction with textbooks of school science and mathematics. We adopt an interdisciplinary approach to argue that the scientific learning needs to be realised through making explicit the use of mathematical symbolism, as well as the mutual conceptual compatibilities or incompatibilities between science and mathematics. We argue that the students may face concrete learning obstacles for each discipline due to the lack of appropriate didactic communication between science and mathematics teachers. Drawing upon this perspective, we focus on the mathematical signs that co-appear in school science and mathematics, with the purpose to identify the divergences and the convergences between the associated meanings and intentionalities for each course. For this purpose, we introduce an interdisciplinary reflective tool that we developed, in order to create a communicational space between the teachers of science and mathematics.

Keywords: Interdisciplinarity, Reflection, Teacher Thinking

INTRODUCTION

The interdisciplinary approach presented in this study highlights the need for reflection on the common signs that appears in textbooks. We consider the epistemological framework of interdisciplinarity as a dynamic process of integrating the distinction and the connection of disciplines, recognising and highlighting the different methodological and conceptual approaches, as well as their common formal language and symbolism. Interdisciplinarity in education aims to link departmental pedagogical approaches in a convergent teaching framework (Nikitina & Mansilla, 2003).

We adopt a systemic approach to didactic situations, which allows us to focus on the interactions between official documents, research results and school practices to facilitate the emergence of the implicit teaching-learning processes in science and in mathematics which are explicitly linked to common symbolisms and, thus, to study its reverse effects on the construction of academic knowledge in each area. In this paper, we discuss a reflective tool that focuses on the importance of linking the teaching of science and mathematics.

We present the reflective tool that we have developed to emphasize the importance of linking science and mathematics education by managing the variety of alternative or complementary points of view that is compressed in the apparent commonality of terminologies or expressions. The first results of its application with teachers of the two disciplines seem to support our design, as it helped in creating a common space for communication and didactic collaboration.

THEORETICAL FRAMEWORK

In the school reality of a class, the students receive distinct, though invisibly interactive, messages from teachers of different disciplines. The interactions of the messages and their decoding are not explicitly considered during the teaching process. The artificial fragmentation of the scientific knowledge as realised through the (we argue misconceived) separation of disciplines is reflected on the compartmentalisation of the respective school courses, which creates invisible obstacles to the understanding of scientific concepts. Consequently, the students may construct alternative ideas generated from arbitrary interconnections between the meanings that are extracted from the discrete teachings of different courses. In our work, we adopt the systemic approach of the school unit (Davis & Simmt, 2003), which allows the exploration of the teaching-learning processes in the school Mathematics and Physics through their common signs.

In addition, we adopt an interdisciplinary approach of teaching that highlights the need for reflection on the common signs of school textbooks. The aim of this approach is the interconnection of teaching practices of different disciplines in an integrated teaching programme (Nikitina & Mansilla, 2003). We assume that interdisciplinary teaching and communication (Watzlawick, Beavin & Jackson, 1967) amongst the teachers of a school unit are essential for the learning of scientific concepts. We posit that the mathematical and scientific signs that appear in the school science and mathematics textbooks may be utilised to create a communication space within which the teachers of different disciplines may start sharing the meanings that they assign to each sign and their reflections about these meanings.

Our theoretical perspective focuses on the phenomenology of signs in an interdisciplinary teaching-learning approach (Moutsios-Rentzos, Kritikos & Kalavasis, 2017), based on theories that have been developed especially for mathematics education (Radford, 2006; Steinbring, 2005). In line with these ideas, we introduce a communicational semiotic system, which consists of a basic communicational triad “epistemic object – interpreter – sign” (Moutsios-Rentzos, Kritikos & Kalavasis, 2019; Moutsios-Rentzos, Pinnika, Kritikos & Kalavasis, in press) as shown in Figure 1.

A *sign* includes all the means of signification that may be employed within a communication and activates the communicative triad. For example, it could be a symbol, an image, a natural language word, as well as their combination as a complex whole constituting a phrase, an equation etc.

Interpreters are the participants in the communication processes. In the case of a school class, they usually are teachers or/and students. In our present study, we focus on the teachers-interpreters. Figure 1c represents the case in which the same teacher acts in a different way when teaching different disciplines. For example, in Greece, primary school teachers teach both Science and Mathematics. In addition, the same student may behave in different ways when attending different courses, because of the different teaching framework that activates specific representations from the corresponding representational registry (Duval, 2006).

Objects are the epistemic objects, fields, or courses, whilst the *meaning* includes the entirety that emerges from the communication interactions. Our conceptualisation allows for an important identification that occurs in everyday classroom teaching. The students are constantly asked to assume different roles, to be different interpreters in different courses, as for the same sign they have to assign meanings appropriate for the specific course. For example, the concept of “area” functions in ways that do not necessarily converge in Science and Mathematics. Consequently, in the proposed approach, we explicitly acknowledge and build upon the fact that the students do encounter the same mathematical symbolism in different disciplines, positing that the communication between the teachers of different courses is crucial for the students to give to their experiences of the phenomena distinct, yet connected, uni-disciplinary and inter-disciplinary meanings.

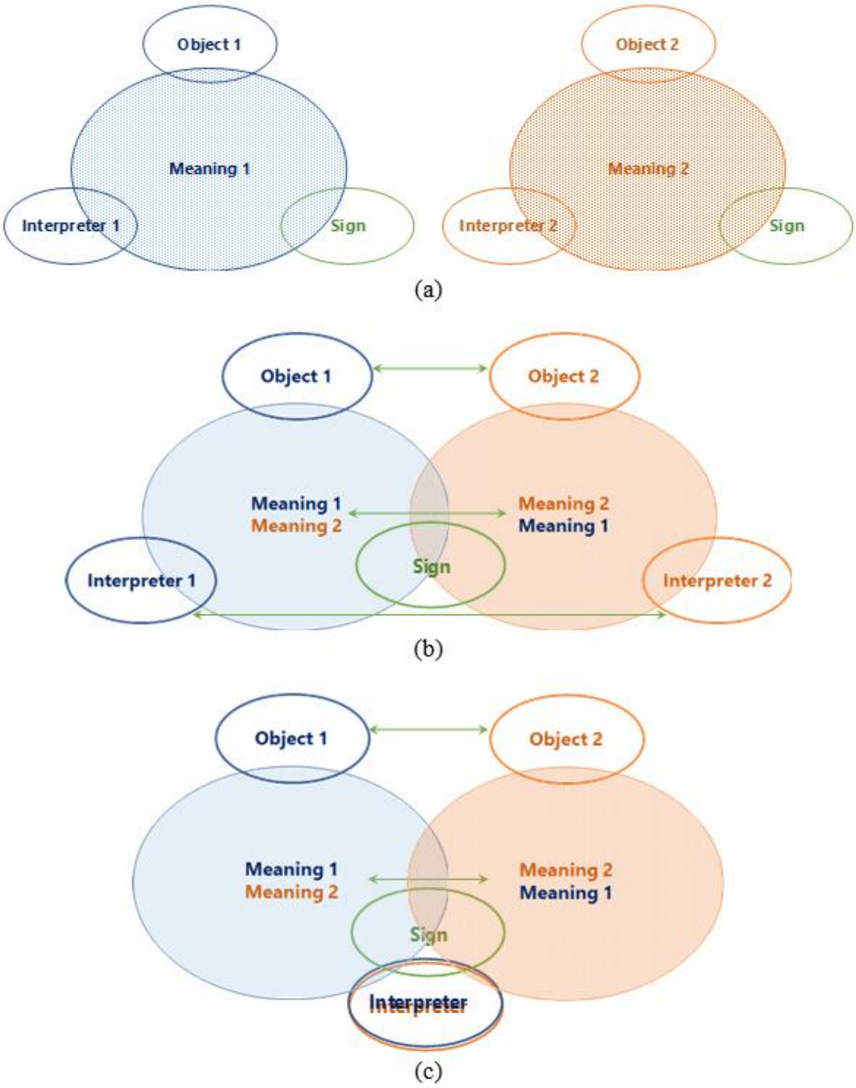

Figure 1. The proposed perspective of communicational space (adopted from Moutsios-Rentzos, Kritikos & Kalavasis, in press).

RESEARCH

The construction of the Interdisciplinary Reflective Tool (IRT) was based on a series of pilot studies that we had designed, focusing on the importance of the interconnection between Mathematics teaching and Physics teaching. In this paper, we present one of these pilot studies that is based on the case of the capacitor's capacitance. Our sample consisted of 28 teachers [6 Kindergarten teachers, 10 Primary teachers, 8 Mathematics teachers (Mathematicians), 3 Physics teachers (Physicists), and 1 Chemistry teacher (Chemist)] who attended the postgraduate programme "Didactics of Mathematics, Science and Information and Communication Technologies in Education: Interdisciplinary Approach" of the University of the Aegean, Greece. Moreover, we in included in our study the Greek school textbooks of Physics and Mathematics of the respective school grades.

The main research question was “Does the lack of interconnection between Mathematics teaching and Physics teaching affect the construction of Concepts in Physics?”. We chose as example the concept of capacitor’s capacitance, because we knew that this concept is taught only for a few lectures in high school Physics, without any explicit linking with Mathematics teaching, whilst the conceptually linked hyperbola equation y=a/x had been taught in depth in Mathematics. Therefore, our hypothesis was that the participants may incorrectly link the capacitance’s formula C=Q/V to the hyperbola equation y=a/x, due to the apparent commonalities of the *form* of the employed signs.

In such situation, as shown in Figure 2, the same students receive messages from Mathematics and Physics courses, with seemingly similar signs, usually without appropriate links between the distinct Mathematics and Physics teachings. As a result, the students may incorrectly think that the calculating formula C=Q/V for the capacitance is conceptually similar to the hyperbola equation y=a/x. Besides, research from science education suggests that one of the common alternative conceptions that the students hold about the capacitance C is that C is proportional to the capacitor’s charge Q (Kritikos & Dimitracopoulou, 2017).

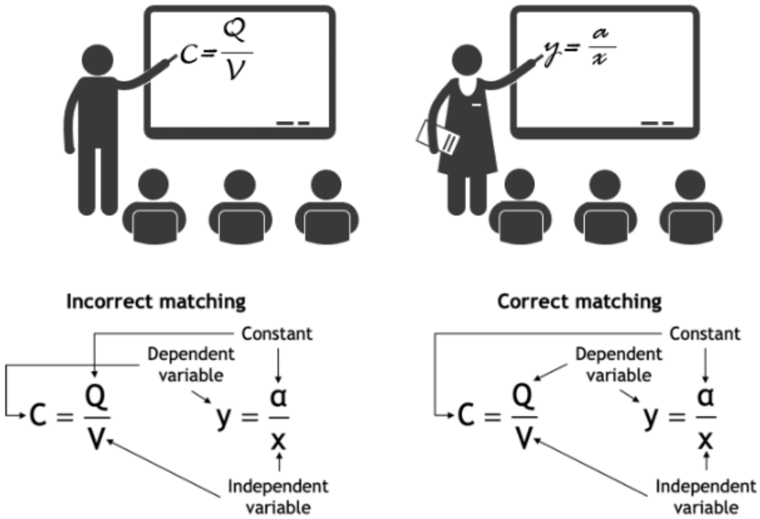

Figure 2: Interacting meanings in non-communicating discrete Mathematics and Physics teachings.

Methodology

Considering that most of the participants did not have any knowledge of the capacitor and its capacitance, we illustrated a short superficial instruction. In particular, we mentioned that the capacitor is an electrical element that has the capability to store charge when connected to a voltage source. In addition, the calculating formula C=Q/V for the capacitance was given, explaining the symbols C, Q and V. Notice that that we deliberately did not mention that the capacitance was not affected by either the load or the voltage, since it was a demand of the workshop activity (Figure 3) that the participants were involved with.

A capacitor is charged by a battery of voltage V. Thus, it stores charge Q. The capacitance C of the capacitor can be calculated by the formula:

$$C = \frac{Q}{V}$$

If we replace the battery (V) with another of double voltage (2V), then the capacitance C will be:

a) doubled. b) halved. c) the same.

Choose the correct answer by marking X in the corresponding cell in the table below. For each incorrect answer, write in the corresponding cell the grade (maximum of 10) that you would give to a student who had chosen it.

a	b	c

Figure 3. Workshop activity: Capacitor's capacitance.

The purpose of this activity was to investigate whether the semiotics of the formula y= a/x and the school mathematical knowledge "when the denominator of a fraction changes, then the fraction changes inversely" affect the learning of a concept in Physics. This mathematical knowledge is incomplete, as the numerator is not declared –though considered to be– as a constant. As a result, this could constitute an interdisciplinary learning obstacle in the students' paths towards constructing appropriate scientific meanings about the capacitor's capacitance.

In this pilot study, we focused on identifying the diversity of sources that appear to be related to students' alternative conceptions. For this reason, we reviewed and studied the sections about capacitor's capacitance in the Physics school textbooks, as well as the sections about the proportional quantities and the straight-line equation y=ax in the Mathematics school textbooks.

RESULTS

Findings from the workshop activity

The results from the workshop activity showed that only Science teachers (4 out of 28) responded correctly (answer c; see Figure 3). Among the 24 incorrect answers, 21 were that when the voltage gets doubled, the capacitance gets halved (answer b), whilst 3 thought it would get doubled (answer a; see Figure 3). For the 24 non-Science teachers, the question had not any conceptual content compatible with the physical meaning of the capacitance, as their knowledge was superficial from their school years. However, they spontaneously answered, relying mainly on their mathematical knowledge. Therefore, the conceptual content that they activated was based on Mathematics rather than Physics. Those who chose "b" as the correct answer were particularly strict in evaluating the students who would choose answer "c", whilst they were lenient about those who would choose "a". One of the participants justified his evaluation with the following explanation: *"…The student who chose (c) did not realize that changing V would result a change on the fraction, whilst the one who chose (a) at least saw that something would change…"*. We argue that in this phrase, it is evident the crucial interdisciplinary effect of the mathematical knowledge "when the denominator of a fraction changes, then the fraction changes inversely" (implying that the numerator remains constant), which is also related to the hyperbola equation. Note that in Greece the same students that have been taught the hyperbola equation y=a/x, have been also taught the calculating formula C=Q/V for the capacitance; nevertheless, they have been taught in different courses, by different teachers, in different learning contexts. The apparent commonality of the empoloyed signs between the two writings may be incorrectly matched by the students, as shown above in Figure 2. As a result, the symbol C in the left-hand member of the relation is assigned to the independent variable y, which is also in the left-hand member. The symbol Q is assigned to the constant a, as fraction numerators. The only correct match is between the symbol V and the independent variable x. As indicated by the participants' responses, semiotic form (in this case mathematics) matching (even incorrectly) prevailed over the conceptual content (in this case physics), as no one sought to investigate the physical meaning, nor the relationship between Q and V magnitudes.

Findings from school textbooks

An additional issue arises from a phrase in a Physics school textbook (Alexakis et al., 2013), related to the quotient and the role of equality: "*Capacitance C of a capacitor is called the scalar physical magnitude that is equal to the quotient of the capacitor's electrical charge Q by the capacitor's voltage V. C=Q/V* " (p. 32). Mathematics education researchers (Jones & Pratt, 2012; Knuth et al., 2008) identify two main functions of the equality sign: relational and operational. Relational equality refers to the equivalence relationships (y is equal to x), whilst operational refers to the result of an operation. The quotient refers to operational equality, so that capacitance is considered to be the result of an operation, in this case the operation of division. However, the value of the symbol C does not depend on the Q/V operation, since the capacitor's capacitance exists even if there is no voltage or charge at its terminals. Instead of the term "quotient", a more legitimated term would be the "ratio", which refers to relational equality and imposes a proportional correlation of the numerator with the denominator. Of course, the problem of indeterminate form 0/0 arises when the voltage and charge are 0. To avoid this teaching barrier, but also the confusion caused by incorrect matching, we consider the mathematical form Q=CV to be more appropriate. Thus, the equation y=ax is recalled from Mathematics. In a Mathematics school textbook (Vlamos, Droutsas, Presvis & Rekoumis 2013), a paragraph is entitled "*The function y=ax*" and begins with the subparagraph "*Proportional quantities – The function y=ax*". The same paragraph refers to a ratio rather than a quotient: "*We see that in the straight-line y=ax the ratio y/x is always constant and equal to a, that is: y/x=a, for x ≠ 0*" (p. 68). Drawing on their mathematics knowledge of the equation y=ax students can move on to the relation Q=CV, where the common signs is compatible with the correct matching, as shown in Figure 4.

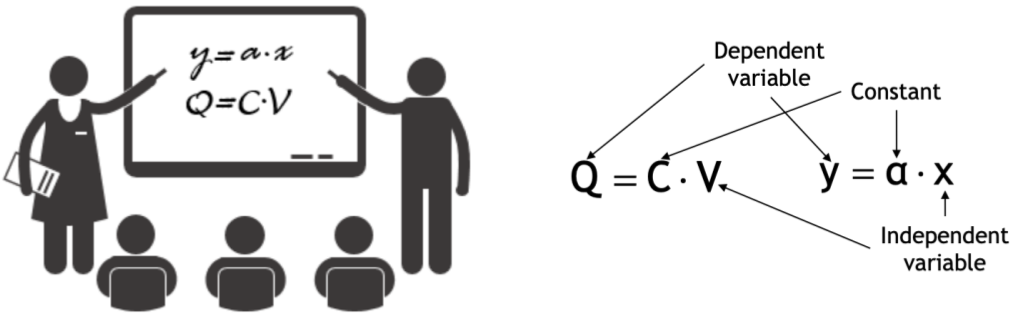

Figure 4: Interacting meanings in communicating Mathematics and Physics (co)teachings.

This is in line with our finding that teachers, who did not activate any physical meaning, they activated a mathematical meaning. Therefore, it is important the spontaneous mathematical meaning, which is activated anyway, to assist in the construction of the intended physical meaning. In an interdisciplinary (co)teaching environment, the role of the independent variable x may be emphasized in combination with the voltage V of the battery, the value of which is independent of the capacitance. Furthermore, the analogy between dependent-independent values and results-cause could be shown up as follows. The value of the dependent variable y is determined by the value of the independent variable x, such as the value of the charge Q is the result of the cause V. Thus, an additional matching arises that concerns not only the magnitudes but also the relationships between them. In addition, in the formula Q=CV the pair of values V=0, Q=0, is allowed regardless of the value of C.

At this point, we have to make clear that the use of the formula Q=CV instead of C=Q/V does not promise the correct physical meaning, but at least it avoids the creation of incorrect meaning through incorrect matching.

DISCUSSION – TOWARDS THE INTERDISCIPLINARY REFLECTIVE TOOL

The artificially imposed compartmentalisation of disciplines creates barriers to the communication of teachers of different disciplines. However, students make links between meanings with similar semiotics. We posit that when these links are scientifically incompatible, learning barriers emerge, which are often not attributed to the incorrect linking between the different disciplines, since the search for the didactical causes within a discipline is made with reference to the didactics of that particular discipline exclusively. For example, if a student expresses the alternative idea that the capacitor's capacitance is proportional to its charge, often the search for the factors of the student's holding this conception is limited to the didactics of Physics. Even in the case that mathematical causes are sought, they will rarely be found in the didactics of Mathematics. With our proposed interdisciplinary approach of (co)teaching in Mathematics and Physics, we look for the causes of learning barriers, through both didactics of Mathematics and Physics (Moutsios-Rentzos et al., 2017; Moutsios-Rentzos et al., 2019; Moutsios-Rentzos et al., in press). This search requires the collaboration of teachers from both disciplines, where each one contributes from its own perspective. Therefore, we do not refer to the unification of teaching disciplines, but to the convergence of teaching practices when common signs appear, which if not presented in a converge way (either by parallel teaching or by coteaching), can lead to learning obstacles in both of the two cognitive disciplines.

In order to assist teachers of different disciplines to communicate their teachings, we designed the Interdisciplinary Reflective Tool (IRT), which aims to highlight the importance of linking Science and Mathematics teaching. According to the protocol of the tool, the participants initially work individually, answering questions in a questionnaire. Questions refer to selected pieces from science and mathematics school textbooks. Subsequently, the participants work in groups of the same discipline, answering group questionnaires, based on the same pieces of the textbooks. In this way, we aim at interdisciplinary reflection amongst teachers of the same discipline. Then, we ask the participants to choose the two most important problems that converge both for the teaching of science and mathematics. Finally, we ask all the groups of different disciplines to reflect interdisciplinary, presenting in the plenary session the two most important problems that they had chosen before as a group. The final step includes a discussion on the solutions of the problems, using the resources of each lesson, but also between them, as the boundaries between the disciplines have been permeable. Below, we cite a sample of questions of the protocol, based on the concept of "area".

- Based on your experience as a teacher, think about the uses and meanings of the concept of "area" in Physics and Mathematics.

- Do you think that the meaning of concept of “area” is different in Physics than in Mathematics?
- Do you consider that the uses of the concept of “area” are different in Physics than in Mathematics?
- Study the following examples on the meaning of the concept of “area” from the school Physics and Mathematics textbooks. Concentrate on the impressions of the concept of “area”, its uses and its meanings.

1. Could you identify any representations of area and signs of measurement units that may cause problems in the students’ understanding of Mathematics ideas? In specific:

   In the representations you identified, according to your opinion, which problems about learning Mathematics derive from inappropriate already taught/learnt Mathematics knowledge?

   In the representations you identified, according to your opinion, which problems about learning Mathematics derive from inappropriate already taught/learnt Physics knowledge?

2. Could you identify any representations of area and signs of measurement units that may cause problems in the students’ understanding of Physics ideas? In specific:

   In the representations you identified, according to your opinion, which problems about learning Physics derive from inappropriate already taught/learnt Physics knowledge?

   In the representations you identified, according to your opinion, which problems about learning Physics derive from inappropriate already taught/learnt Mathematics knowledge?

3. What would you advise:

   a fellow Mathematics teacher, in order to help her/him to avoid the aforementioned potential problems that the students may face?

   a fellow Physics teacher, in order to help her/him to avoid the aforementioned potential problems that the students may face?

   the textbooks authors?

   the curriculum designers?

Concluding, the IRT supports teachers of different disciplines to communicate and reflect in various ways of interdisciplinary reflection. One way is self-reflection, when separately each member of a group studies the given examples. Another way is group (collective) reflection when the members of a group express their opinion about the obstacles in learning. In the framework of a single-discipline group, the reflection is one-perspective, whilst in the plenary session, the reflection is cross-perspectives. Finally, we plan to design a web-supported IRT platform, in which teachers may communicate either asynchronously or in real time and reflect in any of the aforementioned ways.

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EVALUATION CONCEPTIONS AND SCIENCE TEACHING CHALLENGES IN THE CONTEXT OF TEACHING PLANNING

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This work discusses the relevance and the planning of the learning evaluation by four secondary chemistry teachers from the Joinville city (Brazil) starting from twenty-two questions formulated weekly in a continuing formation course and the use of Topological Model of Teaching. The questions were analyzed by inductive coding and classified into two categories: (1) Evaluation Conceptions and (2) Science Teaching Challenges. The problem of the study was focused on the conceptions and models of teachers´ learning evaluation from the questions elaborated in a context of continuous formation, and how the planning of didactic sequences by socio-scientific issues and the use of a teaching model allowed them to develop and qualify the evaluation in its planning.

Keywords: Evaluation, models in science, teacher preparation.

THE RELEVANCE OF TEACHING PLANNING AND THE EVALUATION MODELS

The planning and use of evaluative models has been emphasized in the literature as a possibility of structuring and orienting important processes to scientific education, as well as promoting teaching contexts based on interactivity and on the production of knowledge about human learning. The quality of the evaluation developed by the teacher depends, to a large extent, on the socio-scientific themes, concepts and activities chosen and the use of models that allow teachers to create authentic and original curricula and teaching proposals, and they must be meaningful in the situated context in terms of the different educational contingencies of educational systems (Giordan, 2008; Maceno, Lara & Giordan, 2018).

It is an important part of investigations the attention to the models in order to characterize and explain the nature of the evaluation planning and how teachers drive the evaluation processes during the teaching (Bell & Cowie, 2001). One of the essential aspects of understanding an evaluation model is to analyze the relationships between planning, conceptions and teaching purposes, since models and theories guide the teaching activity in the classroom (Giordan, 2008; Bell & Cowie, 2001). Equally relevant is to study the dilemmas (Bell & Cowie, 2001) and the challenges in the planning of learning evaluation (Grob, Holmeier & Labudde, 2018) that can be analyzed by the questions addressed by science teachers as socioscientific problems and reflection on diverse teaching situations. Thus, the main purpose of learning evaluation is to contribute to improving education and schooling in various aspects, elements and factors.

The evaluation also requires the analysis of processes and the judgment of the evidence, productions and quality standards. In this sense, the guidance and use of teaching and evaluation models allow teachers to interpret and understand human development. The models, with characteristics, comparative traces and functions, produce conceptions and meanings to the phenomena and processes of the classroom, besides the accompaniment, justification and strategies for the improvement of the learning environments (Giordan, 2008).

When used a teaching model, reference standards are established by the teacher, which allows understanding the related phenomena and guiding action by a paradigm of understanding about educational processes. Through support and guidance according to a model, the teacher uses theory, be it learning, language or philosophical, and creates explanatory modes for classroom phenomena. A model is meant the more it is used by the teacher so that it has use value to conduct daily teaching activities. By analogy, a teaching model can become an evaluation model, given the intrinsic relationship between them. It is expected that a teacher, by valuing a teaching model used to guide his action and for his own purposes, also establish new explanatory ways for the evaluation of learning. Thus, reflecting about teaching oriented by one model is a first step in reframing pedagogical practice, and it is also necessary to create new ways of understanding and conducting the evaluation.

The Topological Model of Teaching and the teachers' questions as data source

The scientific literature has several teaching models that guide the concepts and the knowledge of evaluation by science teachers. Among them, the Topological Model of Teaching (TMT) is a socio-cultural approach based to the theory of mediated action, which assumes that a classroom is endowed with its own culture, organization and characteristics (Giordan, 2008). It is configured as a model of teaching organization for the planning of activities, lessons and didactic sequences from the articulation of socio-scientific issues with a problem that is developed and solved along the sequence. The main objectives of the TMT highlighted in this work are to make use of questions to encourage and accompany the learning, to analyze in the conceptual dimension the rules and reasoning used, to contextualize the challenges of the classroom, to foment the questioning and debate of central issues to scientific education (ibidem).

When discussing a teaching model in a continuing formation course, teachers ask questions that, in addition to various topics, can be a source of information about their professional needs and the daily dilemmas they face in the classroom. Considerable part of the discursive interactions in a continuing formation course stem from teachers' questions. The use of questions helps in the elaboration of meanings, mastery and appropriation of other cultural tools by teachers as well as the understanding of educational processes. The question is crucial for the triggering of teaching action, being used with various functions. For Wertsch (1998), the question is considered a specific type of statement and is succeeded by its partner - the answer - as it is expected to occur. Questions are a discursive marker in different types of interaction, as well as being a link in interactional sequencing and can be used for initiation, development or termination of dialog units. When asked by teachers, questions can provide information about self-satisfaction with work, school climate, doubts and professional needs.

In this sense, the study problem was:

1. What are the conceptions and models of learning evaluation of the teachers from the questions elaborated in a context of continuing formation?

2. How did the planning of didactic sequences for socio-scientific problems and the use of the teaching model allowed them to develop and qualify the evaluation in their planning?

The problem of this study was to analyze the themes, contingencies and challenges that science teachers pointed out about the classroom through the analysis of questions elaborated during a continuing formation course. The questions were elaborated in a context of discussion of teaching plans based on the TMT and explored curriculum, discursive interactions, evaluation and other issues related to teaching.

METHODS

The study was conducted in one semester with four science teachers from the city of Joinville (Brazil) who worked in public high school. During one semester, a continuing formation course based on the TMT was developed, in which the teachers weekly produced questions about the texts read. Twenty-two questions were elaborated, analyzed and classified in two categories: (a) *Evaluation conceptions* and (b) *Science Teaching Challenges*. For the first category, one has considered four subcategories proposed by Hargreaves, Earl & Schmidt (2002) and to the second, the subcategories were emergent and inspired by the study of Grob, Holmeier & Labudde (2018).

According to Hargreaves, Earl & Schmidt (2002), there are four evaluation conceptions: the *technological*, focused on the organization, strategies, uses of techniques and methodologies to evaluate; *cultural*, focused on the interpretation of evaluations and their integration with the social and cultural context of schools under a socioscientific problem; *political*, focused on the incorporation and dynamics of power and control between administrators and schools for accountability; and *postmodern*, focused on experiences, multiculturalism, and questions about the impact of complexity, diversity, and uncertainty on evaluation.

In the study by Grob, Holmeier & Labudde (2018) it was investigated how peer evaluation affects student learning in science education. In the study, the researchers analyzed the teaching plans, individual interviews and focus groups of 17 swiss elementary and high school teachers and identified eight evaluation challenges from the perspective of the interlocutors. Based on the study by Grob, Holmeier & Labudde (2018), the second category of this work was proposed to identify the main challenges pointed out by teachers in science education.

The questions was analysed by Nvivo 12® software with the tecniches of word frequence, automatic analisy of *themes* and *sentiments*. Automatic coding by *themes* groups coded references and indicates possible nodes for analysis. Automatic *sentiment* coding indicates the overall tone of the content as positive or negative by coding entire sentences, paragraphs, or documents (Qualitative analysis software international, 2016).

DISCUSSION

For the twenty-two questions asked in the course of continuing formation, eleven explored the relation between teaching and evaluation (1, 2, 3, 5, 6, 7, 8, 9, 12, 15, 17), five encompassed exclusively evaluation (4, 11, 13, 14, 20) and six were not categorized because they were doubts about specific terminologies of texts read (10, 16, 18, 19, 21, 22).

Among the conceptions of evaluation (Table 1), the teachers indicated mainly the *cultural* one, with questions about curricular planning and development, how to explore real problems in the classroom, how to promote learning and interaction in social and cultural contexts facing the particularities of schools, how to contextualize topics, how to select concepts, the language forms, strategies and approaches to be used by the teacher to benefit students' curricular and cultural development, as well as the analysis of their productions and results achieved. In few questions, the *political* conception of evaluation was explored, with mentions to the dilemmas and challenges of discourse control, relationships and roles of teachers and students in the process of elaborating answers to the questions that aim to understand the learning situated in the classroom. Questions about structuring activities, teaching planning and the impacts of student diversity and information and communication technologies on culture and society were rare, but were asked by teachers.

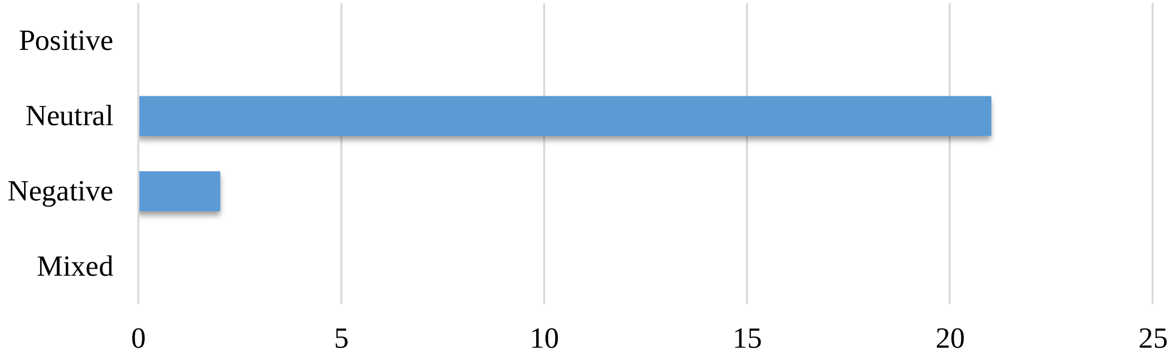
Subcategories	Description	Question
Technological	Structuring and development of measurement techniques	7, 20
Cultural	Interpretation and meaning of ideas, reflections, problematizations and judgments in school socialcultural contexts	1, 3, 4, 5, 6, 8, 11, 12, 15, 17
Political	Result of negotiation and dynamics of power and control in human interactions and by institutional requirements	2, 9, 13
Postmodern	Complexity, uncertainty and questioning in the culture and society caused by information and communication technologies and by the students´s diversity	14

Table 1. Evaluation conceptions of chemistry teachers. Source: the authors using the manual coding using Nvivo 12® software.

Complementing Table 1, when proceeding with word frequency analysis and automatic analisy of *themes* using the Nvivo 12® software, it was observed that the teachers presented questions about the following themes: problematization, environment, meanings, learning difficulties, contextualization, discursive interactions, evaluation, language, diversity, concepts and mediation. Such themes mainly evoke the conceptions of evaluation of *cultural*, *political* and *postmodern*. Complementing the ideia, the word cloud is show in the Figure 1 using the word frequency tool.

Figure 1. Frequency of words in chemistry teachers´ questions. Source: the authors using the word frequency tool using Nvivo 12® software.

The Graphic 1 show the automatic coding by *sentiments* of paragraphs indicated that the overall tone of the 22 questions was eminently neutral and in rare cases negative. The software identified 23 coding references in the document with all questions.



Graphic 1. Automatic coding by sentiments of 22 questions elaborated by teachers. Source: the authors using the automatic coding by sentiments using Nvivo 12® software.

Comparing the conceptions of teacher evaluation highlighted in this study with the results found in the literature, the differences are noticeable, since in most studies teachers evoke a *technological* perspective (Hargreaves, Earl & Schmidt, 2002; Celik & Walpuski, 2018; Freire & Fernandez, 2018) rather than *cultural*, *political* or *postmodern*.

Considering that the teachers in this study indicated more questions about the *cultural* perspective of evaluation under a predominantly neutral, it is possible to understand that their main concerns are about how to interpret learning in school contexts and how to integrate these contexts into scientific culture. According to Hargreaves, Earl & Schmidt (2002), from a *cultural* perspective, the challenge to evaluation is to rethink its nature and purposes in the classroom and how to integrate teachers 'collective judgment with their students' learning potentials. From this perspective, teachers seek to assess under a common understanding through dialogue to detect students' representations and ideas when seeking to solve authentic problems, which demands equally authentic evaluations (ibidem).

Among the challenges facing teaching science (Table 2), teachers mentioned the difficulties in contextualizing current issues while at the same time observing national curricular guidelines and the time available for teaching (challenge 1), which should also consider students´ diversity (challenge 2) and the language used by the teacher in the classroom (challenge 3).

In this way, the evaluation can be qualified from the creation of strategies and approaches by the teacher to overcome the students' lack of participation in the classroom dialogues and the incompleteness or limitation of the short answers expressed by them (challenge 4), also benefiting the relationship inside the classroom (challenge 5) and the understanding of making meaning, the analysis of student performance (challenge 6), the production of authentic answers to the questions addressed (challenge 7), and the constructive reflection on mistakes, problems and failures identified in the teaching of planning and the evaluation process (challenge 8).

Challenge	Description	Question	Total
1	Contextualization of current themes, national curricular guidelines and teaching time	1, 5, 6, 12	4
2	Teaching for diversity	2, 14	2
3	Forms of language used by the teacher	3, 8	2
4	Lack of participation in class discussions and incomplete / short answers of the students	4, 7	2
5	Relationship and roles of teacher and students	9, 17	2
6	Elaboration of meanings and analysis of students´ performance	11, 15	2
7	Elaboration of authentic answers by students	13	1
8	Identification and reflection on errors, failures and planning problems	20	1

Table 2. Science Teaching Challenges of chemistry teachers. Source: the authors using the manual coding using Nvivo 12® software.

In part, the results of this study are close to those obtained by Grob, Holmeier & Labudde (2018) regarding teachers' challenges in judging and making decisions about student performance and how to create plans for evaluation activities. As in this study, the need for progress at different levels of learning from evaluation and teacher-student relationships were also two challenges identified in the research by Nielsen, Dolin, Brunn & Jensen (2018).

CONCLUSION

In a context of professional development and planning of original proposals on socio-scientific issues from a teaching model, the questions addressed by the teachers explored the evaluation mainly as a cultural conception, that is, they were centered on the creation of pertinent curricula to the school and that could be at the same time, feasible, problematizing and propitiate the collective discussion about the selected issue, the elaboration of meanings and the learning. Nevertheless, concerns were raised about how to conduct the dynamics of negotiations and about the control and power of teachers and students in a shared way, such as considering the cultural diversity and current social demands for the classroom, the influence of technologies and how to organize activities and concepts in teaching planning.

One of the concerns in teaching planning is also the evaluation organization. In general, the study reported different challenges about evaluation: related to teaching (contextualization of planned subjects, available time, student diversity, teacher language, student performance analysis techniques), questions and answers, the answer authenticity, elaboration of meanings, errors, problems´ learning) and to the interactional dynamics (rules, participation, interpersonal relationships). Similarly, studies by Grob, Holmeier & Labudde (2018), Hargreaves, Earl & Schmidt (2002) and Bell & Cowie (2001) point out teachers' dilemmas in making evaluation a learning opportunity, requiring new teaching strategies as the classroom challenges emerge, it expands and qualifies the planning of teaching initially developed, providing a continuous and reflective creation of the teaching plan.

Although there are limitations on the information obtained by teachers' questions and their conceptions and models of evaluation, it can be said that they evoke a *cultural* perspective, which is congruent with TMT's purposes and indicates teachers' attention to social conventions, language and how to plan teaching proposals that enable the elaboration of meanings considering diversity and contextualization. The planning of didactic sequences for socio-scientific problems using TMT as a teaching model also allowed teachers to develop and qualify the evaluation in their planning by reflections on performance, the use of socio-scientific problems, the language in science teaching, the interactions discursive and think about mediation. By considering these aspects, teachers were able to introduce thematic of their interests in the continuing formation course and to reflect on how studies from the sociocultural perspective can contribute to science teaching.

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ASSESSING NOVICE AND EXPERIENCED STEM TEACHERS' PROFESSIONAL GROWTH

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Supporting novice STEM teachers during their first two years in the classroom is crucial for their occupational retainment. Experienced teachers that mentor them can also benefit from the mentoring process. This study examines a three-tier support system for novice teachers, including: 1) personal mentoring by experienced teachers, 2) participation in professional development workshops, and 3) being part of a STEM teachers' professional community formed through participation in a workshop. The study included novice STEM teachers (N=104) and experienced teachers (N=102). To understand the support system effect on both novice and expert teachers' growth, we used the framework of teacher development which identifies key aspects of social, professional, and personal growth. Interviews and a questionnaire with open- and closed-ended questions were utilized. Results showed that all three tiers of support facilitate substantive social, professional, and personal growth.

Keywords: Teacher Induction, Communities of Practice, In-service Teacher Training.

INTRODUCTION

Various induction programs that support novice teachers have been implemented worldwide (Bower-Phipps, Klecka, & Sature, 2016; Geva-May, & Dori, 1996; Luft, Firestone, Wong, Ortega, Adams, & Bang, 2011), because such support can make the difference between retention and attrition. Novice teachers require support in building competency for many of the aspects of successful teaching, including pedagogical knowledge (PK), pedagogical-content knowledge (PCK), and classroom management. Methods of support can include mentoring by more experienced teachers, professional development workshops, and being part of a community of teachers. Science, Technology, Engineering and Mathematics – STEM novice teachers' retention can be promoted by interpersonal support of other teachers, which can foster their morale and sense of belonging (Aspfors & Fransson, 2015). Communities of teachers provide an opportunity to learn and develop in an environment where novice and experienced teachers' voices have an equal impact, thereby empowering the novice teachers (Vangrieken, Meredith, Packer, & Kyndt, 2017).

The Teacher Induction Unit at our university supports novice STEM teachers' transition into the classroom, during their first two years of teaching. Most of these teachers are recent graduates of our undergraduate or graduate programs in STEM Education. As part of the unit's initiatives, these novice teachers receive three tiers of support: 1) personal mentoring by experienced teachers, 2) participation in professional development workshops, and 3) being part of a STEM teachers' professional community that is promoted by participation in our ongoing workshops. We analyzed the data collected based on the theoretical model of teacher development (Bell & Gilbert, 1994; Dori & Herscovits, 2005), which consists of three distinct aspects of growth over the course of one's career: *social* – interpersonal interactions with colleagues, such as valuing collaborative ways of working, *professional* – learning and developing new ideas and teaching activities (Avargil, Herscovitz, & Dori, 2012), and *personal* – emotional characteristics, including those needed to overcome the challenges inherent in integrating new ideas and methodologies into one's teaching. The three aspects are dynamic and interact with each other. Within each aspect of growth are three levels.

Self-efficacy, rooted in the social-cognitive theory (Bandura, 1986), is one's belief in her own ability to act in order to achieve desired performance. Self-efficacy develops by personal direct and indirect experiences, verbal persuasions by others, and self-belief, based on the emotional and physical feeling of the individual. Teaching self-efficacy is the teachers' belief of in his/her own ability to bring a positive change and students' learning outcomes (Siwatu, 2007). Science teaching self-efficacy relates to the teachers' belief in their ability to teach science (Ramey-Gassert, Shroyer, & Staver, 1996). Novice teachers have been found to have lower levels of teaching self-efficacy. A mentor, a role model with whom the teacher can identify, can contribute to a higher level of teaching self-efficacy through modeling and supporting. Support by colleagues and community can also make a significant contribution to the teachers' self-beliefs (Tschannen-Moran & Hoy, 2007).

Our research goal is to assess novice STEM teachers' professional growth as well as the professional growth of their mentors who are experienced STEM teachers. In what follows, we use the term 'teachers' growth' to refer to changes and development teachers go through, because the term 'professional development' is used to describe the workshops the teachers attended rather than their actual influence on the teachers.

METHOD

The research participants included 104 novice and 102 experienced STEM teachers who attended a series of professional workshops conducted in the Teachers' Induction Unit at our university. All the participants were involved in mentoring partnerships, either as a mentor—the experienced teachers—or as a mentee—the novice teachers. Mentors were expected to meet the novice teachers weekly, observe them in their classrooms, and provide feedback and support. The workshop duration was 60 hours for novice teachers and 30 hours for 2nd year teachers and mentors. Workshops consisted of four-hour sessions, in which real-life issues were discussed and support was offered by workshop facilitators and peers. Some of the sessions combined novice, 2nd year, and experienced teachers together to form a heterogeneous community. To build the community, novice teachers (first and 2nd year) met with the experienced teachers to develop strategies for addressing content-specific and pedagogical topics and to share their knowledge and perspectives about the many personal and professional issues that arise over the course of a teaching career. The sessions included discussion of STEM content-related topics, class management issues, and navigating a STEM education career path.

Table 1. Research setting

Activity	Frequency	Content
Mentor-Novice meetings	weekly	Lesson planning Best practices and instruction pedagogies Observations Feedback
Novice teachers' workshops (N=104)	bi-weekly	Class managements practices Emotional support Pedagogical topics
Mentors' workshops (N=102)	bi-weekly	Mentoring skills Emotional intelligence Pedagogical topics
Teachers community meetings	bi-monthly	Emotional intelligence Content knowledge Pedagogical topics

*Data collected along three years

Research tools included open- and closed-ended questionnaires for all of the participants and semi-structured interviews with four novice teachers and their four mentors. The interviews included questions such as "Describe your relationship with your mentor/mentee," and "In what ways do you think you contributed to the mentor-mentee relationship?" The questionnaires included three parts: questions regarding the novice teachers' teaching self-efficacy (N=205), questions included in the Mentoring for Effective Primary Science Teaching (MEPST) instrument (N=88), adapted for secondary school (Hudson, Skamp & Brooks, 2005), and perceptions of the novice teachers regarding the workshops' effect on their professional growth (N=166). It is important to note that unlike the novice teachers who responded to the teaching self-efficacy questionnaire, the mentors were asked about their mentees' teaching efficacy. The data were collected and analyzed in a convergent parallel mixed methods design. Combining data from the interviews and questionnaires enabled deeper understanding and data triangulation (Creswell & Creswell, 2017).

RESULTS

Our findings show a gradual elevation in the novice teachers' teaching self-efficacy. We also found a significant difference between the novice teachers' teaching self-efficacy and the perceptions of the mentors regarding the novice teachers' teaching efficacy ($F_{(2, 202)} = 4.25$, $p<.05$), see Figure 1.

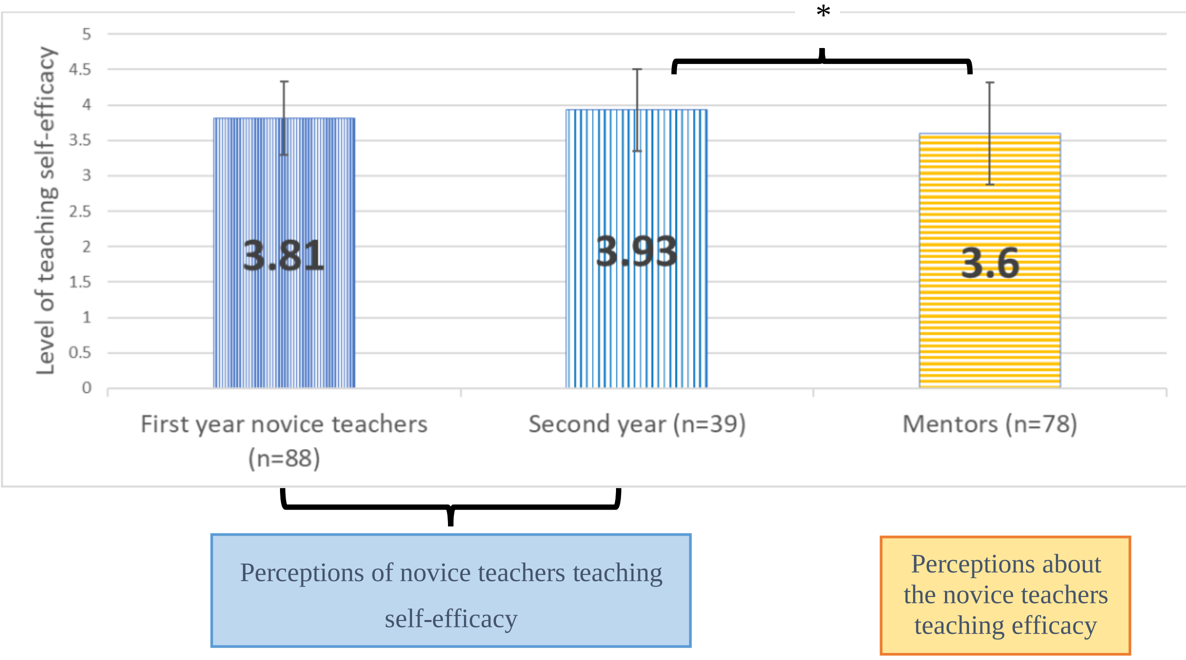

Figure 1. Perceptions regarding novice teachers' teaching self-efficacy

In order to compare the novice teachers' and mentors' perceptions of the mentoring factors, we used the MEPST instrument, adapted for secondary school (Hudson, Skamp & Brooks, 2005). Using this instrument, teachers grade mentoring elements of the mentoring process in a scale of one through five. The mentoring elements are grouped into five factors: personal attributes, system requirements, pedagogical knowledge, modeling, and feedback (see Table 2).

Table 2. Novice teachers' and mentors' perceptions on effective mentoring factors

Factors	Novice Teachers (N=40) M(SD)	Mentors (N=47) M(SD)
Personal Attributes	3.95 (.87)	4.11 (.92)
System Requirements	3.51 (.96)	3.68 (.87)
Pedagogical Knowledge	3.55 (.85)	3.95 (.71)
Modeling	3.75 (.83)	4.05 (.72)
Feedback	3.97 (.75)	3.89 (.76)

Novice STEM teachers and mentors viewed four of the five factors of effective mentoring with similar importance, as a significant difference in the mentoring process was found only between the perceptions of the experienced teachers—the mentors (M=3.95, SD=.71) and the novice teachers (M=3.55, SD=.85) in the pedagogical knowledge factor (t=–2.42, p<.05). The Modeling factor differences were borderline (t=-1.83, p=0.07).

Grouping the mentoring factors into personal, professional (system requirements and pedagogical knowledge), and social (modeling and feedback), we found correlations between these three factor groups and teaching self-efficacy. Teaching self-efficacy is also correlated to general self-efficacy.

Table 3. Self-Efficacy and Mentoring Factors Pearson correlation (N=87)

Factors Group	Teaching Self-Efficacy	Personal	Professional
Self-Efficacy general	.354**		
Personal personal attributes	.229*		
Professional system requirements and pedagogical knowledge	.301**	.766**	
Social modelling and feedback	.230*	.871**	.801**

*p<0.05, **p<0.001

Significant correlations between the teaching self-efficacy of the novice teachers and the mentoring factors show that development in a certain factor group is correlated with development in the other factor groups, as well as with the teaching self-efficacy.

Evidence for professional growth presented below is arranged by the three tiers of support – mentoring, workshops, and community.

(a) **Mentoring** facilitated the professional and personal growth of novice and experience teachers in different aspects.

(b) **Workshops** provided the novice teachers with both professional and social support. Meeting other teachers with difficulties like their own (social) helped them accept their struggle (personal) and seek solutions together (professional). As one participant [417221]said: "*I met other teachers in my situation, with similar struggles. I was exposed to many suggestions and examples of coping strategies*."

(c) **Community** activities in the meetings showed a gap in novice and mentor teachers' perceptions regarding the needs of novice teachers during their first years and their expectations from the mentoring process. Teachers discussed the mentoring factors in the community meetings and analyzed the gaps in expectations and perceptions of the mentoring relationships aims. The discussion helped communicate the needs and improve the communication and mentoring processes. Reflections about perceptions of the workshops' effect revealed that the community meetings enabled the teachers to understand a different perspective and to develop new classroom practices (professional). A novice teacher [417210] said: "*I watched how she was managing her very busy schedule and learned how to form habits*". In some cases, mentors initiated development activities (professional). An experienced teacher [417414] stated: *"…but* *now I can do more things, I can combine something I learned in a different program and create something new…*".

Table 4. Aspects of teachers' growth

Expression of growth	Techers' Statements
Personal	
Establishing a mentoring relationship based on equal partnership which contributes to the empowerment of the novice teacher	A novice teacher [50001820213]: "*I bring my ideas, she [the mentor] brings her ideas, we have a partnership.*"
Professional Mentor and novice thinking about possible solutions	A novice teacher [510011921211]: "*One of the ideas I found with the help of my mentor was to have a tutoring session after each subject I teach, and guide them in the subject via teamwork.*"
Social The experienced teacher is exposed to innovative ideas (professional), while the novice teacher feels meaningful	A mentor [511191720221]: "*Working with him and the other teacher felt like working as a team…his main contribution was in the green chemistry project, based on his prior knowledge and experience.. I consulted with him regarding the data analysis and we drew the conclusions together*."
Development of Mentoring Practices A mentor learned how to focus her feedback to make it productive	A mentor [50519821223]: "*although I saw the wider picture in terms of things I wanted to say [in the observations reflection on her lesson], I highlighted one or two aspects for improvement and two things that were good and she should continue to do, I neutralized background noises*."

DISCUSSION AND LIMITATION

The three tiers of support address complementary needs of novice and experienced teachers, cultivating the social, professional, and personal growth of novice and experienced teachers. Each tier addresses different levels of the aspects, contributing to the growth of novice and experienced teachers (Bell & Gilbert,1994). The induction years include a process of learning to teach and a process of socializing (Luft et al., 2011).The interactions between the three tiers provided the teachers with personalized support, a peer group in which they could see that their struggle was universal, and an opportunity to participate in a wider forum in which they could learn and contribute as equal members of the community (Vangrieken et al., 2017). Growth was enabled through learning content-specific STEM and pedagogical discussions. Empowering the novice teachers can enhance also the veteran teachers' self-efficacy and refines their teaching skills (Aspfors & Fransson, 2015).

A limitation of the research was that due to ethical constraints posed by the Ministry of Education, classroom observations could not be obtained.

CONCLUSIONS AND IMPLICATIONS

Retaining novice teachers in the school system requires providing them with effective support. Experienced teachers the partners for this mission. Creating a supportive community provides opportunities and scaffolds for the novice and experienced teachers to grow successfully in the teaching professions (Richmond, Bartell, Floden, & Jones, 2020).

The contribution of this research is the elucidation of the intertwined support tiers that provide a scaffolding to the novice teachers, while facilitating the growth of the experienced teachers.

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DESIGN AND ASSESSMENT OF A SCORING RUBRIC FOR EVALUATING SCIENCE TEACHERS' CLASSROOM PRACTICES

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The aim of the present study was the development of an evaluation system for secondary science teachers teaching practices based on PCK. In the present work, we present the evaluation framework, the evaluation criteria and the development of an observation tool and an evaluation scoring rubric for classroom observations. The evaluation criteria were designed to constitute aspects of teachers' PCK. A pilot study was carried out aiming at examining the reliability of the rubric and of the observation tool. In this pilot application two evaluators used the rubric and the observation tool independently to evaluate twelve science teachers. The data recorded by the two evaluators have a strong positive correlation as indicated by the values of the correlation coefficient Spearman rho. The results showed that the use of the tools led to reliable and objective findings.

Keywords: Evaluation Methods, Teaching Practices, Science Education Policy

INTRODUCTION

Over the last 30 years, researchers have formed and developed a notion that describes the aspects of teacher knowledge, namely Pedagogical Content Knowledge (PCK). PCK is α widely accepted notion among researchers (e.g., Berry, Friedrichsen, & Loughran, 2015) and teachers as it creates possibilities to find common bases upon which criteria for teacher evaluation systems can be build.

Data gathering differs among evaluation systems but the most common source of data is classroom observation (Isoré, 2009; Santiago, 2009), which provides data on teaching practices in real classroom settings. Concerning classroom observations, it is a common practice for evaluators to use a scoring rubric. A rubric contains the criteria and descriptions of performance, which define levels of achievement that match a score. Rubrics are used because they can guide evaluators in focusing on specific aspects of teacher performance and enhance a common scoring strategy. Additionally, rubrics can reduce the possibility of arbitrariness and misunderstanding and connect the evaluation procedure to a post-evaluation program of professional development (Panadero & Jonsson, 2013).

In what follows, we present the design and development of an evaluation scoring rubric and an observation tool and the assessment of these tools through a pilot study.

THE EVALUATION SCORING RUBRIC AND THE OBSERVATION TOOL

Evaluation criteria

The evaluation criteria are based on a PCK analysis that was first introduced by Jang (2011). The evaluation criteria are divided into four domains, namely: Subject Matter Knowledge (SMK), Instructional Representations and Strategies (IRS), Instructional Objectives and Context (IOC) and Knowledge of Students Understanding (KSU). Data are collected through classroom observations for 15 evaluation criteria. The domains, the criteria and the aspects of teaching recorded through observation (scoring rubric) are described in Table 1.

Table 1: The domains, the evaluation criteria and the aspects of teaching recorded through observation and included in each criterion

Domain 1: Subject Matter Knowledge	
Criteria	**Aspects included in each criterion**
Quality of the language used during the lesson	*Quality of the language used during the lesson*
Connection between the teaching notion or phenomenon and everyday life	*Connection between the teaching notion or phenomenon and everyday life*
Domain 2 : Instructional Representation and Strategies	
Criteria	**Aspects included in each criterion**
Instuctional Strategies	*Instructional Strategies (Variety and appropriateness)* *Strategies for maintaining students' interest*
Students' attentiveness-related reactions during instruction	*Students' attentiveness-related reactions during instruction*
Instructional representations	*Appropriateness and usefulness of instructional respresentations*
Inquiry	*Type of Inquiry*
Scientific skills promoted by the teacher	*Scientific skills promoted by the teacher*
Questioning	*Conceptual Level of teaching questions* *Students' participation in questioning*
Domain 3:Instructional Objectives and Context	
Criteria	**Aspects included in each criterion**
Instructional objectives and goals	*Instructional objectives and goals (communication and understanding)*
Interactive atmosphere	*Teaching Adjustment based on students' reaction*
Students' participation	*Students' participation*
Classroom management and mutual respect among students	*Classroom management* *Mutual Respect*
Domain 4: Knowledge of Students' Understanding	
Criteria	**Aspects included in each criterion**
Alternative concepts investigation	*Alternative concepts investigation* *Strategies to handl students' alternative concepts*
Knowledge of students' difficulties	*Knowledge of students' difficulties*
Assessment during the lesson	*Formative Assessment during lesson* *Variety of assessment methods and adjustment related to students' diversity*

Development and Description

The observation tool, a part of which is presented in Figure 1, is a practical guide for the observer. It helps him/her focus on specific aspects of teaching, record data by ticking the appropriate boxes, and take notes on them. These notes help the observer keep track of all the teacher's practices and the decisions he/she makes during instruction when the observer grades the teacher's performance in the rubric. The observer/evaluator uses an observation sheet for each separate lesson. Data are collected from two observations of each teacher by completing the score in the evaluation scoring rubric.

In the scoring rubric, the observer finds the aspects of teaching that have to be recorded and five short descriptions of the teacher's performance. Based on the observation tool and his/her recorded notes, the observer decides which description best fits the teacher's actions.

Observational Tool

Class: Subject:

Number of students: Time of observation:

Instructional Representations and Strategies

Note 1 for the main teaching practice and 2, 3, etc. for the other practices observed during the lesson.

Strategies

	Lecture		Students' Presentations		Experiments conducted by students
	Demonstration of experiment		Discussion or work in small groups		Use of models to introduce a notion or an idea
	Discussion led by the teacher		Inquiry		

Type of student involvement during instruction

	Passively attends teacher's lesson		Participates in discussion (led by the teacher or in small groups)		Carries out an experiment
	Participates in an inquiry activity		Completes work sheets as part of an activity		Writes a laboratory report
	Writes an assessment test		Uses a simulation		Uses lab equipment and technology to conduct an experiment
	Uses a PC program to analyse data		Makes a presentation or attends other students' presentations		Develops or uses a model to comprehend an idea

Use of Instructional Representations

☐ Examples ☐ Analogies ☐ Graphs and Diagrams

☐ Everyday objects ☐ other: ....

Observer Recordings

Appropriateness (manner and time of their use):

....

Usefulness for the students:

....

Figure 1: Part of the Observation Sheet

Each description corresponds to a score that the observer inserts under the name of each aspect. Figure 2 shows two of the aspects of teaching recorded, which concerns appropriateness and usefulness of instructional representations (IRS).

The development of the evaluation scoring rubric and observation sheet was done through a long collaboration with expert Science teachers, Educational Advisors, and Evaluators.

Criteria	**Aspects of teaching recorded**	**5**	**4**	**3**	**2**	**1**
Instructional Representations	**Appropriateness of the instructional representations (IR)**	IR: * Were appropriate for the activity * The time and the manner of their use was appropriate and consistent with the lesson goals	IR: * Were appropriate for the activity *The time of their use was sufficient and the manner was consistent with the lesson's goals	IR: were appropriate for the activity but not consistent with the lesson's goals	IR: were generally appropriate for the activity, but other IR could be more appropriate and more consistent with the lesson's goals	IR: were inappropriate for the activity and inconsistent with the lesson's goals
	Score:					
	Usefulness of instructional representations	IR seemed to help all the students understand	IR seemed to help the majority of students understand	IR seemed to help half or more of the students understand	IR seemed to help a minority of the students understand	IR seemed not to help the students understand
	Score:					

Figure 2: Part of the Evaluation Scoring Rubric

The implementation of the evaluation scoring rubric and the observation tool

The implementation of the evaluation, using the observation tool and the scoring rubric, is conducted through direct, first-hand observations of two one-hour lessons. The evaluator performs these observations as a spectator (Gay, 1992) and records them on the observation tool. After the observation, the evaluator grades the teaching in the evaluation scoring rubric.

METHODOLOGY

The aim of this study was to evaluate the reliability of the tools designed and the objectivity of the findings from the observation-based data. In order to assess the reliability of the evaluation scoring rubric simultaneous observations were carried out by two observers/evaluators. The first evaluator was an Educational Advisor and trained Evaluator serving in Secondary Education and the second one was the first author of the presented work.

Sample

The observations were carried out in six Gymnasiums and Lyceums, representative of the different context of the Greek educational system, which were proposed by the Educational Advisor. The two evaluators observed twelve (12) Science teachers (eight Physics and four Chemistry Majors) using the observation sheet and they independently evaluated every teacher using the Evaluation Scoring Rubric.

Data analysis

The data of the Scoring Rubrics were statistically analysed. The reliability of the rubric was assessed through the calculation of the Spearman rho coefficient between the two independent scores of the evaluators. The above mentioned methodology is the most common practice to assess the reliability and the objectivity of the findings of a rubric (Jonsson & Svingby, 2007). The data collected by the two observers were, also, analyzed with regard to everyday teachers' practices.

FINDINGS

A significant positive correlation was found between the scoring of the two observers/evaluators ranging from 0.704 to 0.894 ($p<.0001$). Additionally, the mean of the differences of the observers was calculated and was found 0.1905 (N: 252, St. Deviation 0.414, N refers to the number of scores for all teachers) indicating very small differences between the two observers. These findings suggest that the observers, using the scoring rubric and the observation tool, were led to score similarly teachers' performance based on their observations.

With regard to teachers' practices, the findings from the observations indicated that all or almost all teachers who participated in the study use appropriate language, a variety of teaching strategies that maintain students' interest, make proper use of instructional representations, communicate the instructional objectives, manage their classroom efficiently, promote mutual respect, know the students' difficulties regarding the teaching topic and succeed in having most of their students actively participate in the lesson (these teachers are evaluated as 'Excellent' on these criteria). On the criteria concerning the connection between the subject being taught and everyday life, the type of inquiry used (mainly structured inquiry), the scientific skills promoted, the questioning and the use of formative assessment during the lesson, the majority of the teachers were evaluated as 'Adequate' and a minority as 'Excellent'. One third of the teachers were evaluated as 'Weak' on criteria related to their knowledge of the students' understanding, specifically regarding investigating and handling students' alternative conceptions and the use of a variety of assessment methods.

However, the specific findings produced by the Observation Tool and Scoring Rubric cannot be generalized, as the sample of teachers observed is not big enough. The future use of our tool in a larger and more representative sample will provide a clearer picture of the teachers' practices.

CONCLUSIONS

The results indicate that the observational tool and the scoring rubric created a framework within which the observers, using a common scoring strategy, produced the same findings when evaluating the same teacher.

Based on the findings concerning the reliability of the tools and teachers' practices, we consider that the evaluation of the teachers through the proposed procedure and tools could provide rich and objective findings about teachers' every day practice.

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