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Using Teachers' Inquiry-oriented Curriculum Materials as a Means to Examine their Pedagogical Design Capacity and Pedagogical Content Knowledge for Inquiry-based Learning

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ABSTRACT

The study aimed at examining preservice elementary teachers' inquiry-oriented curriculum materials in an attempt to unravel their pedagogical design capacity (PDC) and pedagogical content knowledge (PCK) for inquiry-based learning (IBL), after attending a professional development program (PDP) centered around inquiry-based teaching and learning. In so doing, we identified the PCK for IBL dimensions (e.g., integration of inquiry within teachers' curriculum designs and evaluation of student learning) underpinning their curriculum materials and for each dimension, we aimed at finding the characteristics of the teachers' curriculum materials and capturing their PCK and PDC concerning that particular dimension. The participants were 44 preservice elementary school teachers enrolled in a PDP that was organized in four phases. In each phase, the teachers were assigned to a different role, namely, teachers as learners (Phase 1), teachers as thinkers (Phase 2), teachers as curriculum designers (Phase 3), and teachers as reflective practitioners (Phase 4). The data sources involved mainly teachers' curriculum materials that were analyzed with the use of grounded theory methodology and the constant comparative method. The data analysis revealed that the teachers' curriculum materials were developed along five PCK for IBL dimensions. Moreover, a number of characteristics of the teachers' curriculum materials were identified for each one of these dimensions, which in turn were clustered along three levels of increased sophistication and revealed our teachers' PDC per dimension. We also managed to identify three different PCK for IBL profiles. Finally, the findings indicate that, even though our preservice teachers attended our specially designed PDP, they have conceptualized in diverse ways the underlying principles of IBL.

KEY WORDS: inquiry; inquiry-based learning; professional development; pedagogical content knowledge; pedagogical design capacity; teacher education

INTRODUCTION

The implementation of inquiry as a learning approach in science classes (i.e., inquiry-based learning; henceforth called IBL) has been a priority for more than three decades (National Research Council [NRC], 1996; 2000; 2007; Van Joolingen and Zacharia, 2009). The goal is to offer to all students the opportunity to enact scientific inquiry, as scientists do when studying the natural world. In this context, students are expected, among others, to state hypotheses, design and conduct experiments, collect and analyze data, reach to conclusions/explanations based on the evidence, and communicate and justify their explanations (Pedaste et al., 2015). Overall, this inquiry framework aims at showing to students that science is driven by research questions which need to be addressed through an open-ended process (Van Joolingen and Zacharia, 2009).

On top of revealing to students how scientists work, IBL is advocated by researchers and educators for its positive influence on students' science learning. It was found to have a positive impact both at an affective and a cognitive domain level (e.g., Lazonder and Harmsen, 2016; Minner et al., 2010). Therefore, many science curriculum reforms across the world have highlighted inquiry as one of the teaching approaches to be used within science classes (Kearney, 2011; Rocard et al., 2007).

Despite the multiple learning benefits that learners experience when engaged in inquiry-based activities, IBL continues to be absent from teachers' ordinary teaching practice repertoire (Kearney, 2011; Rocard et al., 2007). This failure might be attributed to several factors such as teachers' lack of knowledge about IBL, teachers' lack of skills for enacting IBL within a science class, teachers' personal choices of more direct and teacher-centered teaching approaches, or to the lack of proper resources, and lack of activities in school science textbooks that could be implemented through IBL (Crawford, 2016).

Research has shown that the teacher is the crucial player in implementing IBL (e.g., Keys and Bryan, 2001; Wallace and Kang, 2004). In so doing, they need to have, among others, a deep understanding of scientific inquiry, strong practical experience with designing, developing, implementing and assessing IBL, and skills for guiding and organizing students to conduct inquiry activities (Jeanpierre et al., 2005; Van

Joolingen and Zacharia, 2009). Magnusson and Palincsar (1995) argued that IBL also depends on the teacher's pedagogical content knowledge (PCK). PCK comprises a teacher's content knowledge, pedagogical knowledge, and knowledge about the context where a teacher works (Gess-Newsome, 1999). In the case of IBL, it was found that for its effective implementation teachers must possess high-level PCK for IBL (Crawford, 2000).

While research has revealed a number of factors explaining the failures and successes of IBL implementations in science classes, we are still missing a framework which guarantees effective professional development programs (henceforth called PDP) for teachers on learning about inquiry and later on adopting it in their own science classes (for a thorough review see Irakleous, 2015). Consequently, current research places emphasis on how best to prepare teachers to design and enact science instruction through IBL. It has been emphasized that PDPs need to involve teachers (among other activities) in designing their own curriculum materials (Voogt et al., 2011), because this type of challenge (i) provides opportunities for teachers to reflect on the curriculum starting from their personal knowledge, beliefs, and their goals for student learning (Parke and Coble, 1997), (ii) helps teachers to develop ownership and commitment for effective implementation of their curriculum (Bhusal, 2015), and (iii) contributes in (re) shaping their own practice (Voogt et al., 2011).

Preparing preservice teachers for implementing IBL is even more challenging because they have limited experience in the classroom and, as a result, they fail to translate IBL theory and frameworks into classroom practice (Haefner and Zembal-Saul, 2004). In addition, they have limited experience in designing and implementing IBL curriculum materials. According to Avraamidou and Zembal-Saul (2010), the preparation of preservice teachers must offer opportunities to experience curriculum materials (e.g., through the phases of design and implementation) that they will use later on as in-service teachers. Hence, it is important for preservice teachers to experience IBL not only at a theoretical level but also at an empirical/practical level (i.e., through the design and implementation processes), before entering schools as in-service teachers.

In this study, we aim at contributing toward this line of research. Specifically, we offered the opportunity to preservice teachers to design and develop IBL curriculum materials after attending a specially designed PDP. In this PDP we required from teachers to undertake a series of roles (i.e., learner, thinker, designer, and reflective practitioner) to offer them the opportunity to see inquiry and IBL from different angles/perspectives and, thus, develop a more coherent understanding of inquiry and IBL. The overall idea was to examine how an inquiry-oriented PDP, which has been developed and refined after a thorough literature review of the domain (for details see Irakleous, 2015), influences the development of preservice teachers' IBL understandings both at a theoretical (e.g., what IBL is and how it is enacted) and practical (e.g., designing IBL curriculum materials) level. For accessing these understandings, we collected and analyzed their IBL curriculum materials, which they were the end products (i.e., artifacts) to be produced by the preservice teachers in our PDP. This research falls under the wider efforts of optimizing PDPs for introducing IBL to preservice teachers.

THEORETICAL BACKGROUND

Teachers are the key players of implementing IBL (Crawford, 2000). However, implementing IBL has proven to be a hard task, especially for newer teachers (e.g., Papaevripidou et al., 2017). As a result, researchers have been urging the science education community, to develop proper PDPs for training teachers to understand what IBL is about and how it could be implemented in their own science classes. Over the years, it became apparent that training teachers to use ready-made inquiry-based curriculum materials (i.e., instructional resources, such as lesson plans, activity sheets, and textbooks) were not enough for preparing teachers to implement effectively IBL curriculum materials in their classes and, to do so, the teachers themselves had to get involved with the design process of these curriculum materials, as well (e.g., Ball and Cohen, 1996; Brown et al., 2006; Kim et al., 2007). In other words, research has highlighted the importance of having teachers, especially preservice ones, experience the curriculum materials to be used in their future teaching (Remillard, 2005), as well as the importance of designing such materials on their own (Brown et al., 2006; Kim et al., 2007; Papaevripidou et al., 2017).

However, revising existing curriculum materials or designing and developing new ones requires from the teacher to use a significant amount and variety of resources (Knight-Bardsley and McNeill, 2016). The identification and use of these resources depend on the teacher's pedagogical design capacity (PDC; Brown, 2009). PDC is defined as the teacher's competence to identify the necessary resources, either through his/her own personal resources (i.e., subject matter knowledge, beliefs, and PCK) or the resources embedded in the curriculum materials (i.e., physical objects, domain representations, and procedures) themselves, to design and develop curriculum materials or alter existing ones (Brown, 2009; Knight-Bardsley and McNeill, 2016). According to Brown (2009), who initially introduced the construct of PDC, teaching could be considered as a design activity, in which teachers use resources, personal and curriculum related ones, to enact teaching that promotes student learning. Brown has situated the whole PDC process while teaching in a class, during which teachers design at a real-time their own instructional episodes by altering the existing curriculum materials or by improvising and developing new ones. In this study, we use a broader definition of PDC, as argued by Knight-Bardsley and McNeill (2016), which includes all available instructional resources (e.g., PDPs and instructional tools) and not just curriculum resources. Given this, we examine preservice teachers' PDC through their developed IBL oriented curriculum materials. In this context, preservice teachers are expected to make pedagogical decisions and use personal and instructional resources, including the ones introduced through our specially designed PDP, to accomplish particular IBL related instructional goals, which in turn are transformed into IBL curriculum materials. In this respect, teacher's IBL curriculum materials could be used as the means for examining a teacher's PDC. For instance, the IBL curriculum materials (e.g., lesson plans, instructional tools, and activity sheets) could reveal the personal and instructional resources used by the teacher during the design and development process of the materials.

Teachers' capacities for designing IBL curriculum materials could evolve through training (Feiman-Nemser, 2001; Irakleous, 2015; Papaevripidou et al., 2017). In this respect, preservice teachers need to be engaged in training through PDPs to develop and improve their PDC for IBL. Such training is crucial since novice teachers carry a number of insufficiencies such as insufficient understanding of what inquiry is, how IBL activities are designed, and what resources are necessary to design and develop proper IBL curriculum materials (Abell, 2007; Davis et al., 2006; Forbes and Davis, 2010). Supporting the development of preservice teachers' PDC for IBL during their teacher education years could offer them the opportunity to start their science teaching career as well prepared as possible. However, to succeed in this endeavor, we first "need to better understand how teachers draw on their instructional and personal resources" (Knight-Bardsley and McNeill, 2016, p. 648). Without such an understanding, it would be impossible to design proper PDPs that target the enhancement of preservice teachers' PDC for IBL.

One of the major personal resources that teachers' draw on is PCK (Brown, 2009; Knight-Bardsley and McNeill, 2016). PCK is a multifaceted construct, which entails among others knowledge of the learners (e.g., knowledge of their needs, difficulties, skills, and competencies), knowledge of the curriculum and teaching materials, knowledge of the learning approach to be implemented (e.g., inquiry) and its associated learning strategies, knowledge of how to assess learners, and knowledge of why all these (e.g., curriculum, learner needs and competencies, teaching method and strategies, and assessment) are needed for promoting student learning. Magnusson et al. (1999) have reported five PCK dimensions needed for science teaching, namely, knowledge of orientations toward science teaching, curriculum and teaching materials, learners' background and capabilities/competencies, instructional strategies, and assessment. Davis and Krajcik (2005) have further extended the aforementioned dimensions to encompass inquiry (i.e., PCK for IBL). Specifically, the construct of PCK for IBL requires knowledge of orientations congruous with the inquiry, students' perception of inquiry, inquiry-based teaching materials, learning strategies for implementing inquiry, and techniques for assessing inquiry. Even though, in this study, we identify our own dimensions of PCK for IBL through grounded theory methodology (Section 3.3), there is a considerable overlap between the dimensions of Davis and Krajcik (2005) and ours. We have not used the dimensions of Davis and Krajcik (2005) because of the nature of our PDP (i.e., teachers experiencing inquiry through different roles). We also wanted to see the dimensions coming out from our data analysis than fitting our data in existing dimensions, which were the result of studies with a different context.

Brown (2009) argued that teachers use PCK as a resource to design instruction, which means that looking into teachers' own IBL curriculum materials should reveal their PCK for IBL, which in turn reflects on their PDC (e.g., poorer PCK results in poorer personal resources, which in turn result in lower PDC). Hence, in this study, we examined both preservice teachers' PCK and PDC for IBL through their own IBL curriculum materials. By having such an insight, it could prove useful for identifying the support needed to enhance teachers' PCK and PDC in a PDP.

One of the critical aspects of this study was the study's PDP itself, which was designed after a thorough review of the literature of the domain (Irakleous, 2015). The primary goal of this PDP was to introduce IBL to preservice teachers. To do so, the preservice teachers had to undertake a number of roles to experience IBL through different perspectives. According to this framework, teachers have to enact four distinct roles, namely, teachers as learners, teachers as thinkers, teachers as curriculum designers, and teachers as reflective practitioners.

Having teachers undertake the role of active learners was found to benefit teachers' professional development because it allows them to experience the same learning paths as their students (Clarke and Hollingsworth, 2002; Kazempour and Amirshokoohi, 2014), which eventually result in enabling teachers' understand what inquiry is about and what skills it requires (Loucks-Horsley et al., 1998).

The role of teachers as thinkers involves reflecting on the learning experiences gained when undertaking the role of the learner in combination with the theoretical underpinnings of inquiry, which come from the PDP facilitators. Theoretical readings, class discussions, and other reflective activities could be used to support teachers to develop a theoretical framework about IBL (Akerson et al., 2007).

The role of the teacher as a designer requires moving from theory to practice. In this case, teachers are asked to transform their understandings of inquiry into IBL curriculum materials. This means that by looking into their IBL curriculum materials, someone could infer their perspectives on inquiry and IBL.

Finally, the role of the teacher as a reflective practitioner requires from teachers to implement their IBL curriculum materials into their own classes, adjust their teaching according to their participants needs, collect evidence to evaluate and reflect on the effectiveness of their teaching, and bring reports of their field experiences to the course and analyze teaching strategies with their mentors and colleagues. Ferraro (2000) has strongly argued about positioning teachers in such a reflection mode since it positively affects teachers' professional development.

For the purposes of this study, we focused on the IBL curriculum materials that our preservice teachers designed, developed and implemented when attending our PDP. More specifically, we examined their IBL curriculum materials, which were designed and developed within the teacher as a designer phase and were later implemented during the teacher as a reflective practitioner phase. First, we identified the PCK for IBL dimensions underpinning their curriculum materials and, second, for each dimension we aimed at finding the characteristics of their curriculum materials to capture their PCK and PDC.

In particular, we aimed at addressing the following questions:

1. What are the characteristics of preservice teachers' IBL curriculum materials after the study's PDP and what information do they provide concerning their PDC for IBL?
2. What information do the characteristics of preservice teachers' IBL curriculum materials provide concerning their PCK for IBL?

METHODOLOGY

Participants and Setting

The participants were 44 preservice elementary school teachers (n females=32, n males=12) who were attending an undergraduate elementary teaching methods course in the context, of which the PDP was enacted. The PDP, which was taught by two university professors and three teaching assistants, was split into four phases according to the four distinct roles that teachers were assigned to during their participation in the PDP. These were as follows: Teachers as learners (Phase 1), teachers as thinkers (Phase 2), teachers as curriculum designers (Phase 3), and teachers as reflective practitioners (Phase 4).

Procedures

During Phase 1 (teachers as learners), the teachers worked in pairs and went through three IBL curriculum materials, namely, inquiry learning spaces (ILSs), in the context of electric circuits and one in the context of the extinction of dinosaurs. An ILS is an online computer-supported environment that fosters IBL designed in the context of the Go-Lab project (http://www.go-lab-project.eu/). The developer of an ILS can integrate remote or virtual labs (http://www.golabz.eu/labs) and a number of apps/tools (http://www.golabz.eu/apps) to support learners' IBL as they move through the different inquiry phases suggested by the Pedaste et al. (2015) inquiry learning framework. The four ILSs were completed by the participants in four 1.5 h meetings.

In the first meeting, the participants engaged with the first ILS that consisted of five inquiry phases, namely, the orientation, the conceptualization, the investigation, the conclusion, and the discussion phase. The teachers were introduced to electric circuits, starting from the simple electric circuit and transitioned to series and parallel circuits. In the orientation phase, they watched a video to collect useful information about the different ways of connecting electrical circuits. In the next phase, teachers formulated investigative questions and hypotheses about the relationship between the number of light bulbs and their brightness (e.g., how the brightness of light bulbs is affected by the addition of light bulbs in a series and in a parallel circuit). The formulation of their investigative questions and hypotheses was accomplished through two apps, namely, the question scratchpad (i.e., tool for forming research questions) and the Hypothesis Scratchpad (i.e., tool for forming hypotheses). These apps entailed predefined concepts and conditions that the teachers could drag and drop to generate investigative questions and hypotheses. In the investigation phase, they designed their experiments with the use of the experimental design tool (i.e., tool for designing an experiment). Specifically, the teachers used this tool to select from the given set of variables the variable that should be altered (independent variable), the variable that should be measured (depended variable) and the variables that should be kept constant. In doing so, the teachers should define and then drag the appropriate variables in the "vary," "measure," and "keep constant" columns. Then, the teachers used the electric circuit lab to perform their valid experiments and to collect data. Specifically, the teachers set the number of bulbs in a series circuit and afterward in a parallel circuit. When they run the experiment, they recorded their observations about the brightness of the bulbs when the number of bulbs increased or decreased with the use of the experimental design tool. Once they felt that they collected enough data that could be used to answer their investigative question and the related hypothesis, they moved to the conclusion phase. In this phase, teachers used the conclusion tool (i.e., tool for writing evidence-based conclusions) to check whether the data collected could be used to support the hypotheses developed previously in the hypothesis scratchpad tool and answer the investigative questions posed in the question scratchpad tool. Specifically, the conclusion tool offered the possibility to teachers to retrieve their hypotheses and questions to argue if their hypotheses could be confirmed or rejected.

In the subsequent two meetings, the teachers engaged with two additional ILSs in the context of electric circuits that maintained the same format with the previous one. Specifically, in the context of the second ILS, the teachers have investigated the relation between the number of light bulbs and the total electric current, first in a series circuit and then in a parallel circuit. In the context of the third ILS, the teachers were introduced in the concept of resistance and then to Ohm's law, as the purpose of this ILS concerned the investigation of the relation between the voltage and current in a series and parallel circuit.

The difference between each ILS lied on the type of supports and scaffolds that teachers could receive throughout the curriculum. The inquiry activities that were included in the first ILS were guided mostly by the instructors and the activity sequence that both provided structured scaffolding to teachers to foster their familiarization with the inquiry. In the context of the subsequent ILSs, the teachers shifted from structured inquiry to guided inquiry (ILS 2) and finally to open inquiry (ILS 3). The degree of learner autonomy was increased throughout the activity sequence, and consequently, the level of instructor intervention and guidance fainted out.

After the completion of these ILSs, the teachers as learners engaged with another ILS in the context of the "Dinosaurs extinction." Specifically, the teachers initially were prompted to reflect on why the dinosaurs extinct in the past, and then examined the implications of the assumption that dinosaurs' extinction was caused by an asteroid that fell on Earth. The purpose behind engaging teachers with this specific ILS was two-fold. First, we aimed at giving teachers as learners the opportunity to engage in a new subject domain to see the impact of inquiry on facilitating learners' understanding and development of inquiry competence in a new context. Second, given the fact that the context of dinosaurs' extinction concerns a compelling topic for learners across ages to deal with, this ILS would be given to teachers to use it as the starting point to familiarize their students with the inquiry process and the tools used in an ILS for the purposes of the science fair project (Phase 4, teachers as reflective practitioners for more details).

During Phase 2 (teachers as thinkers), the teachers were asked to study the ILSs they previously worked with to identify the phases of inquiry and their interconnections, to inductively formulate the underpinnings (i.e., PCK for IBL) of the inquiry-based framework that guided the design of the environments. After that, the instructors of the course provided to the teachers a theoretical paper that focused on the inquiry learning and the inquiry learning cycle suggested by Pedaste et al. (2015). They were asked to compare it with their perceived frameworks and to reflect on how the reading of paper enhanced their knowledge about inquiry learning and teaching. The goal was to reflect on their perceived PCK for IBL.

During Phase 3 (teachers as curriculum designers), the teachers were asked to form pairs, choose a topic among a given list of subject domains (Table 1) from the national curriculum of the upper elementary school classes, and design their own ILS that would implement it with an elementary school student for the purposes of a Science Fair project. In so doing, the teachers were expected to study the existing curriculum materials that appear in the school textbooks and make an effort to redesign them (i.e., PDC for IBL) to transform them into a sequence of inquiry learning activities progression. It is important to note that even though the existing national curriculum materials are in the process of reform, through which all curriculum materials will be developed on the tenets of IBL, a big part of the curriculum materials are still inconsistent with the IBL framework (i.e., the framework of Pedaste et al., 2015). The selected topics that were given to teachers to choose from correspond to curriculum materials that were not aligned with the IBL framework (i.e., not aligned with the framework of Pedaste et al., 2015) that the participants became familiar as learners and as thinkers during Phases 1 and 2, respectively. Consequently, the purposeful selection of these curriculum materials was expected to serve as a design challenge for the participants to illustrate how their PCK and PDC for the inquiry would inform their curriculum designs.

Table 1: Teachers' topic selection used for the design of their ILS

Pair	Unit's topic
1, 6	Friction
2	Free fall
3	Balancing
4, 5	Light: Shadows
7	Hydrostatic pressure
8, 10	Sinking and floating
9	Static electricity
11	Color light
12, 13	Light: Lenses
14	Simple pendulum
15	Light diffraction
16	Springs
17, 21	Acids and Bases (Ph)
18, 20	Transfer of heat - thermal insulation materials
19	Forces
22	Electromagnetism

ILS: Inquiry learning space

To facilitate teachers as curriculum designers' role, a set of tasks organized into stages were followed. Specifically, at first stage, the instructors of the course administered a Science Fair Proposal Assignment to teachers to help them organize the inquiry activities that would incorporate in the ILS. The teachers were prompted to design activities that would be aligned with the principles of IBL and the phases of inquiry they went through as learners proposed by Pedaste et al. (2015). The proposal consisted of three parts. In the first part, they had to state the problem that would be integrated into the orientation phase and mention the related variables. In the second part, they were asked to formulate two investigative questions and the corresponding hypotheses that would be tested in the context of two inquiry cycles. In the third part, they were prompted to provide all necessary information and documentation on important aspects of their investigations such as (i) Which variables would be altered and how? (ii) Which variables would be measured and how? (iii) Which variables would be kept constant and how? and (iv) What equipment would be needed for conducting the experiments? The proposal was used as a plan that would assist teachers in thinking the organization and content of the orientation, conceptualization and the investigation phases of their ILS. Teachers received feedback by the course instructors on their completed proposals before proceeding in transforming their inquiry proposals in activity sequence in the form of ILS.

As a second stage, they were asked to develop their ILS with the use of the authoring tool of the Go-Lab platform, which allows teachers to integrate tools and resources that are uploaded on the Go-Lab platform, in phases consistent with the Pedaste et al. (2015) IBL framework (see more info at www.golabz.eu). To engage their students in authentic investigations, the teachers were asked to use physical and virtual labs for conducting the experiments for the purposes of the first and second inquiry cycles, respectively. Furthermore, the teachers were asked to design assessment tasks to capture and monitor their students' inquiry skills (i.e., identifying variables, interpreting data from a table, identifying flaws in an experimental design, etc.) and content knowledge that related to the subject domain of their project.

During Phase 4 (teachers as reflective practitioners), the teachers in pairs collaborated with an elementary school student (age of students ranged between 10 and 12) with whom they met during afternoon hours at their home to engage him/her in IBL through two ILSs. The first ILS concerned the "dinosaurs' extinction" (it was the one that teachers themselves went through during Phase 1 of their training), whereas the second ILS was the one they designed during Phase 3. The emphasis of the implementation of the first ILS was to help students familiarize themselves with the inquiry process, i.e., formulation of investigative questions and hypotheses, conduction of an investigation that enabled the identification and testing of variables that affect the size of a crater caused by the fall of an asteroid, drawing of conclusions, etc. The implementation of the first ILS was accomplished in two meetings of 60 min each. During the subsequent meetings with their student (the frequency of meetings varied from 6 to 10 meetings), the teachers implemented the ILS they developed as part of their training in the third phase of the PDP. Throughout the meetings, the teachers were asked to keep reflective journals in which they described the procedure followed in guiding their student through each phase and stage of inquiry-based cycle. Furthermore, they were asked to present the assessment tasks they designed for capturing their student's development of inquiry competence and conceptual understanding, the actual responses provided by their student and elaborate on his/her learning difficulties.

By the end of the course, the teachers guided their student in preparing a poster to report on all phases of inquiry they went through during the implementation of the second ILS. This poster, along with practical investigations related to their subject domain, was presented during the Science Fair day at their school. During the Science Fair, the participants shared their reflections and received feedback from the instructors and peers.

Data Collection and Methods of Analysis

To answer both research questions, multiple data sources were collected, namely: (i) The science fair proposal assignments, (ii) the ILSs that teachers developed, (iii) teachers' reflective journals that were maintained during implementing their ILSs with their student, and (iv) assessment tasks developed by the teachers and students' responses on these tasks that pertained to their initial and final status about inquiry competence and conceptual understanding about the subject domain of their ILS.

Grounded theory methods (Charmaz, 2006), in conjunction with the constant comparative method (Glaser, 1965) were followed for analyzing the collected data. Specifically, the main focus during the analysis was on the content and the structure of the activities that teachers incorporated within their ILSs, while at the same time attempts were made to identify possible links between these activities and their Science Fair proposal assignments, and links between the inquiry learning framework that the teachers were already familiar with during Phase 2, and their teaching and learning experiences reported in their reflective journals. After several iterations of data examination, the focus of the analysis became broader, and finally, five PCK for IBL dimensions were elicited that were considered as critical to guide the identification of the characteristics of teachers' curriculum materials illuminated in their ILSs. The five dimensions that were revealed from the data analysis were as follows: (i) Teachers' curriculum design orientation, (ii) degree and type of reconstruction of the national curriculum unit, (iii) types of the designed activities, (iv) integration of the inquiry learning cycle within their curriculum designs, and (v) evaluation of students' learning gains. Given that these dimensions concern teachers' pedagogical decisions and provide evidence about the personal and instructional resources they used during the design, development, and implementation process of their curriculum materials, the revealed dimensions were considered as a multifaceted prism through which inferences about their PDC and PCK for IBL statuses could be extracted.

To draw inferences about teachers' PDC for IBL (Research Question 1), we looked at the characteristics that were elicited for each dimension of analysis. In doing so, the following steps were followed:

1. The derived characteristics for each dimension of analysis were grouped in clusters that shared commonalities and were subsequently coded in terms of the main themes they represented. Although codes were developed *in vivo*, using the participants' own language within their reflective journals, other codes were developed with insights from previous literature. For instance, Miller and Seller's (1990) curriculum design orientations were used as a coding scheme for characterizing teachers' curriculum design orientations. Miller and Seller suggested three broad orientations (i.e., (i) transmissive, (ii) transactive, and (iii) transformative) that pertain both on the teacher's and student's role during the learning process and reflect how teaching and learning are facilitated in the context of a classroom environment. More specifically, a transmissive curriculum design orientation assumes knowledge is content, controlled by the teacher, and transferred to students through demonstration and telling. A transactive curriculum design orientation, on the other hand, assumes knowledge is constructed by learners through the process of learning, and the role of the teacher is to facilitate learning and to create environments which stimulate

learners' interests, recognizing that learning is social and at the same time individual. Finally, a transformative curriculum design orientation refers to the case of curricula that learning is developed through self-reflection, self-awareness, and self-learning; the learner is offered opportunities to "reassess new knowledge in relation to existing knowledge and reflect on the underlying assumptions and biases that are the foundation of that existing knowledge" (Harris and Cullen, 2009, p. 57).

2. The emerged clusters were compared and contrasted in search of commonalities and differences in an attempt to reduce the number of clusters and integrate them into broaden categories.
3. During steps 1 and 2 we used teachers' reflective journals for triangulating the emerged clusters. Evidence from their reflective journals helped in understanding the rationale, struggles, emotions, and decisions followed by the participants during designing and enacting their curriculum materials. For instance, there were cases of teachers who expressed concerns about how to proceed when their students encountered specific difficulties during their enactments and expressed emotions like "I don't feel confident enough to deal with this…" or "I felt insecure when my student asked me about this…," etc.
4. Three distinct categories of characteristics for every dimension of analysis resulted after the second round of review, and after labeling them according to the characteristics they encompassed, they were hierarchically ordered in terms of the sophistication of the resulting outcomes. The most inferior category was labeled as Level 1, the most superior category as Level 3, and the one between as Level 2. We consider Level 1 to be the lower level of teachers' PDC, whereas Level 3 to represent the highest level of teachers' PDC.
5. Finally, the frequency of the 22 pairs of teachers' distribution along the five dimensions of analysis of their curriculum materials and across the emerged levels was calculated.

To draw inferences about teachers' PCK for IBL (Research Question 2), we combined information from Table 2 (PCK for IBL dimensions of teachers' curriculum materials, characteristics of each dimension, and emerged sophisticated levels) to Table 3 (classification of pairs of teachers' curriculum designs in the emerged levels along the five PCK for IBL dimensions). Given that our PCK and IBL dimensions resemble aspects of teachers' PCK for IBL suggested by other frameworks reported in the literature (Magnusson et al., 1999; Davis and Krajcik, 2005), in conjunction with the fact that homogeneity was found in the classification level for the majority of pairs of teachers' curriculum designs across the five dimensions of analysis (17 out of 22 pairs were classified in the same level for each dimension of analysis), we postulated that there exists a pattern to account for how the participants of the study designed and implemented their curriculum materials. As a result, we looked into the characteristics within each of the emerged levels for all the dimensions of teachers' PCK for IBL as a whole and extracted information about their PCK for IBL. Consequently, the characteristics that fell under each level enabled the identification of three different teacher profiles in terms of their PCK for IBL.

Finally, inter-rater reliability was followed and calculated during all steps of the coding process. In particular, 50% of the data was assessed by two independent coders, and the ratio of the agreement was calculated. The coders agreed on 89% of the coding in step 1, 87% in step 2, and 93% in step 3 of the process of analysis followed for answering research question 1, and on 94% in clustering individual teachers into the emerged profiles (research question 2). The differences of the coders in each coding step were solved after discussing them with the authors of the paper, and necessary adjustments and revisions were performed. Next, the other 50% of the data was used by the same independent coders for the second round of inter-rater reliability examination, and the agreement was 100%.

FINDINGS

The findings are presented in two subjections; one per the study's two research questions that this study aimed to address.

What are the Characteristics of Preservice Teachers' IBL Curriculum Materials after the Study's PDP and What Information do they Provide Concerning their PDC for IBL?

The characteristics of preservice teachers' IBL curriculum materials are presented below for each of the PCK for IBL dimensions, as they resulted from our analysis, separately. For each dimension, we also provide teachers' PDC for IBL with an increased sophistication (i.e., Level 1 through Level 3; Table 2).

Teachers' curriculum design orientation

The analysis of teachers' curriculum designs revealed three PDC levels with increased sophistication in terms of their curriculum design orientation that are described below.

Level 1 - Transmissive curriculum design orientation

This PDC level concerns the case of curriculum materials where the learner has a passive role, since the teacher focuses on rote learning, lecturing, and conceptualizes the learning experience as a transmission of facts, concepts, rules, and norms. The analysis revealed that six of the curriculum designs were clustered in this level.

A representative example of the activity sequence of a curriculum design in the context of "Sinking and Floating" that was clustered in Level 1 is provided in Table 4 and elaborated afterward.

According to Table 4, the teachers of pair 10 begin their instruction by providing their student with a scenario that relates to the materials that should be used for constructing a ship to be able to float in water. Although the student is expected to propose materials that might help the ship is floating in water, the activity that follows does not take into account the student's ideas. Instead, the teacher asks their

Table 2: PCK for IBL dimensions of teachers' curriculum materials, characteristics of each dimension, and emerged PDC levels of sophistication

	Level 1	Level 2	Level 3
(i). Teachers' curriculum design orientation	Transmissive curriculum design orientation	Transmissive and transactive curriculum design orientation	Transactive and transformative curriculum design orientation
(ii). Degree and type of reconstruction of the national curriculum unit	Replication of the national curriculum unit modification only of the problem provided to students	Partial reconstruction of the national curriculum unit design of extra inquiry activities	Total reconstruction of the national curriculum unit with strong priority to IBL
(iii). Types of the designed activities	Very structured inquiry activities - Conceptual understanding development is either missing or accomplished through delivery of ready-made statements - partial scaffolding	Structured and guided inquiry activities - introduction of concepts through examples from everyday life – conceptual and procedural scaffolding	Guided and open inquiry activities - Conceptually oriented activities interconnected with the inquiry activities - conceptual and procedural scaffolding that faints out gradually
(iv). Integration of the inquiry learning cycle within their curriculum designs	Inquiry as a linear process	Inquiry as a linear process but sometimes students are prompted to go back to recall what has been done or learnt	Inquiry as a cyclical and iterative process
(v). Evaluation of students' learning gains	Pre- or post-evaluation of students' rote learning through closed-ended questions	Pre- and post-evaluation of students' understandings about concepts relevant to the topic engaged with open-ended tasks	Pre- ongoing and post-evaluation of students' inquiry skills and understandings about concepts relevant to the topic engaged with open-ended tasks

PCK: Pedagogical content knowledge, IBL: Inquiry-based learning, PDC: Pedagogical design capacity

Table 3: Classification of pairs of teachers' curriculum designs in the emerged levels along the five PCK for IBL dimensions

	Dimensions of analysis of teachers' curriculum materials				
	(i). Teachers' curriculum design orientation	(ii). Degree and type of reconstruction of the national curriculum unit	(iii). Types of the designed activities	(iv). Integration of the inquiry learning cycle within their curriculum designs	(v). Evaluation of students' learning gains
Pair 1	L2	L2	L2	L2	**L1**
Pair 2	L1	L1	L1	L1	L1
Pair 3	L2	L2	L2	L2	L2
Pair 4	L2	L2	L2	L2	L2
Pair 5	L1	L1	L1	L1	L1
Pair 6	L1	L1	L1	L1	L1
Pair 7	L2	L2	**L1**	L2	L2
Pair 8	L3	L3	L3	L3	L3
Pair 9	L2	L2	L2	L2	L2
Pair 10	L1	L1	L1	L1	L1
Pair 11	L3	L3	L3	L3	L3
Pair 12	**L2**	L3	**L2**	L3	L3
Pair 13	L3	L3	L3	L3	L3
Pair 14	L3	L3	L3	L3	L3
Pair 15	L3	L3	L3	L3	L3
Pair 16	L2	L2	L2	L2	L2
Pair 17	L3	L3	L3	**L2**	L3
Pair 18	L2	**L3**	L2	L2	L2
Pair 19	L3	L3	L3	L3	L3
Pair 20	L1	L1	L1	L1	L1
Pair 21	L3	L3	L3	L3	L3
Pair 22	L1	L1	L1	L1	L1
Frequency	*L1=6, L2=8, L3=8*	*L1=6, L2=6, L3=10*	*L1=7, L2=7, L3=8*	*L1=6, L2=8, L3=8*	*L1=7, L2=6, L3=9*

L1, L2, and L3 stand for Level 1, Level 2, Level 3, The pairs which are bold those whose curriculum materials were not classified in the same level along the five dimensions of analysis. PCK: Pedagogical content knowledge, IBL: Inquiry-based learning

student to formulate hypotheses through providing the general structure of a hypothesis, an example of hypothesis in another context and then the words that can be used for formulating the hypothesis. In addition, the teachers prompt the student to

Table 4: Activity sequence of Pair 10 clustered in Level 1 (transmissive curriculum orientation)

Orientation phase: Presentation of the scenario: "In ancient times, the transport and the commerce depended on shipbuilding. People should consider the materials to use for constructing a ship that would enable it to float in water"
Conceptualization phase: Formulation of the hypotheses and investigative questions by the student. The teachers provide to the student the general structure of them, an indicative example and the words that they can be used
Investigation phase: Design and conduction of two valid experiments based on teachers' guidelines (e.g., the teacher indicates which variable should be altered, which variables should be kept constant, and which variable should be measured)
Conclusion phase: The students are asked to draw their conclusion based on the emerged data. The teacher provides the anticipated conclusion and asks students to make any necessary modifications to their conclusion to make it compatible to the desired one

formulate investigative questions. In doing so, they provide the general structure of the investigative question "Does variable A affect variable B?" Examples of investigative questions, and predefined terms that can be combined to form the questions. In the investigation phase, the student is asked to design and perform two controlled experiments. Instead of giving the opportunity to the student to identify the variables involved in the experimental design, the teachers define the variable that has to be altered, the variable that has to be measured, and the rest of variables that have to be kept constant. The teachers also specify the materials and apparatus that would be used and the procedure that the student should follow to perform the experiment. To guarantee that student's conclusion would not decline from the anticipated one, the teachers provide a ready-made conclusion at the conclusion phase and prompt their student to compare his/her conclusion with the anticipated one to ensure that s/he will not leave the course with any misunderstandings or "wrong" conclusions.

Level 2 - Transmissive and transactive curriculum design orientation

This PDC level pertains to the case of curriculum designs that combined transmissive and transactive orientations. Specifically, the curriculum designs that were classified in Level 2 appertain to the type of curriculum design orientations that aim to engage their students in inquiry-oriented and conceptually driven activities, but at some point the teacher reduces students' autonomy in IBL, as s/he intervenes to showcase "what needs to be learnt" or/and how a procedure should be accomplished. We provide below a representative example of the activity sequence reflected in the ILS of Pair 3 (Table 5) to illustrate evidence of the combination of the transmissive and transactive orientation in their activity sequence and elaborate on it afterward.

In the beginning of the lesson, the teachers utilized the initial assessment tasks they designed to elicit their student's prior understanding about how a beam balance functions and the level of acquisition of inquiry skills. Then, they proceeded on providing a problem to their student that concerned the possible ways that the seesaw could balance. They guided their student to formulate investigative questions and hypotheses regarding the variables that affect the balancing of a seesaw, design and perform controlled experiments using a real balance for the purposes of experiment 1 and a virtual lab for the purposes of experiment 2. Afterward, they asked their student to draw conclusions based on the data collected and reflect on whether the data enable the confirmation or rejection of the initial hypotheses.

The above-mentioned activity sequence activity description reveals that the student has a central and active role in the inquiry process, given that teachers provide enough learning space for him to engage in multiple scientific practices associated with inquiry (e.g., hypothesis generation and testing, formulation of investigative questions, design and conduction of valid experiments, data collection and analysis, etc.), and thus the curriculum orientation so far points to a transactive perspective. However, after the investigation of the two factors - mass and distance - that affect the balance of a seesaw, the teachers decided that at this point the student should come to understand the concept of torque, and therefore they proceeded with the introduction of the rule that applies when the seesaw balances through a ready-made statement. Right after, they asked their student to implement this role in some examples (e.g., "On the right side there are four triangles (mass=2 g) on 4th position. On which positions on the left side would you place the three rings (mass=4 g) to balance the scale?"). Consequently, the transactive orientation that was evident from the beginning of the lesson and maintained up to this point was discarded and gave way to a transmissive orientation. Even though the activities that preceded could be used as the basis for helping the student define the rule himself through an inductive manner, the teachers assigned a passive role to their student through transmitting ready-made knowledge to him.

Level 3 - Transactive and transformative curriculum design orientation

The curriculum designs that were clustered in PDC Level 3 entailed activities that shared both a transactive and transformative orientation. These particular curriculum designs encompassed not only activities through which the students were supported in constructing their own learning, and the instructor acted as a facilitator during students' learning development but also activities that welcomed students' self-reflection, self-awareness, and self-learning. The teachers whose curriculum materials were clustered in this level aimed to prompt their students to elicit their existing knowledge about a topic under study, then they proceeded on helping students to confront their prior knowledge with knowledge that emerged through inquiry-oriented activities, and at the end they engaged the students in self-reflecting activities for reassessing the new knowledge in relation to their existing knowledge. We provide below an example of a pair of teachers' curriculum design in the context of Acids and Bases which was clustered in Level 3.

According to Table 6, at the beginning of the lesson, the teachers presented some pictures from a stream that the water was contaminated. Through a well-articulated scenario that they introduced to their student, they prompted their student to propose his ideas of how to test the quality of water, and in the subsequent activity, the student studied a report by the Ministry of Health that explained the methods followed for testing the quality of water. Through this report, the student became familiar with the concept of pH (the teachers incorporated a simplified definition of pH) and learnt that to decide if the water of a stream is contaminated, water samples from different locations of the stream should be collected and analyzed. In the conceptualization phase, the student familiarized himself with the concepts of acids and bases and subsequently formulated hypotheses and investigative questions based on the variables he identified that would affect the pH of a water sample. Using a virtual lab and physical manipulatives, he conducted experiments to test his hypotheses, answer his investigative questions, and draw conclusions. At the end of the activity sequence, the student reflected on the findings that emerged through answering questions such as "What are the real-life applications of acids and bases?" and "What could be the effects / consequences (positive and / or negative) of the use of acids and bases for you, others and society?" He was also asked to prepare a report that would be presented during the Science Fair day on the following topic: "To eliminate the phenomenon of acid rain, the use of cars in large urban centers should be reduced. What is your opinion."

The example presented above illustrates that the teachers acted as facilitators of student learning through the designed activities, as they systematically engaged their student in inquiry activities that enabled him to actively construct knowledge and develope skills necessary for solving the problem under study. Furthermore, the format and structure of the designed activities, which encouraged him to self-reflect on how the developed understandings about the topic under study (e.g., water contamination) associates with real-life problems, fostered the development of civic awareness.

Degree and type of reconstruction of the national curriculum unit

The second dimension of teachers' curriculum designs' analysis was the type and the degree of the national curriculum reconstruction they performed while designing their own curriculum materials. This task was accomplished through

Table 5: Activity sequence of Pair 3 clustered in Level 2 (transmissive and transactive curriculum design orientation)

Pre-test administration to elicit student's ideas about the concept of balance
Orientation phase: The teachers provide to the student the following scenario "Yesterday afternoon, two brothers, Costas and George, went to Athalassa's park and were playing at a seesaw. They observed that when Costas moved down, the seesaw went up at the highest point. The two kids are wondering about the possible ways that the seesaw could be balanced. Can you help them?" The student is prompted to express his ideas
Conceptualization phase: Formulation of the hypotheses and investigative questions by the student after the general structure of a hypothesis and an investigative question is provided. The student is encouraged to integrate the variables he assumed that might affect the balance of the seesaw in the hypothesis and investigative question
Investigation phase: Designing and Conduction of two valid experiments
The teachers provide the Experimental Design Tool on which the student is expected to decide the variable that should be tested, the variables that should be kept constant, and the variable that should be measured
The student organizes and conducts the experiments with the help of the teachers
The student reports the results on a table
The teachers introduce the principle of torque through a statement like "to make the seesaw balance, we need to calculate the product of the mass of the object that hangs on the lever, times the distance between the point of mass and the fulcrum. This should be done for each object on each side of the seesaw. The products should be equal when the seesaw balances"
The student follows the rule for calculating the product of each mass that hangs on each side of the seesaw times the distance between the point of mass and the fulcrum and confirms that the rule applies every time the seesaw balances
Conclusion phase: The student draws conclusions based on the data collected

Table 6: Activity sequence of Pair 17 clustered in Level 3 (transactive and transformative curriculum design orientation)

Orientation phase: The teacher provides to the student a problematic situation, and the student is prompted to propose solutions to the problem
Conceptualization phase:
Familiarization with the fundamental concepts of acids and bases
Formulation of the hypotheses and Investigative Questions by the student through appropriate scaffolding
Investigation phase:
The student organizes and conducts the experiments with the help of the teachers
The student reports the results on a table
Conclusion phase:
The student draws conclusions based on the data collected
Discussion phase: The student reflects on the relevance of processes and outcomes of inquiry for society

comparisons between teachers' curriculum designs with the corresponding national curriculum teaching materials. The three levels that were revealed as a result of the aforementioned comparisons are presented below.

Level 1- Replication of the national curriculum unit – modification only of the problem provided to students

This PDC level refers to the case of curriculum materials that were almost fully aligned with the existing activities of the national curriculum unit. Specifically, the examination of these curriculum materials revealed that the format, the structure, and the content of the activities of the national curriculum were maintained. The only changes that were performed concerned either the orientation phase, and specifically the type of problem that was modified to be more authentic and aligned with students' everyday experiences or the use of a limited number of apps/tools that were available in the grasp authoring environment.

The curriculum of the Pair 20, which was developed in the context of "Heat transfer and Thermal insulation materials," is an indicative example. We present in Table 7 the activity sequence mapping of the reconstructed unit of Pair 20 to showcase the degree and type of reconstruction followed for their curriculum development.

According to Table 7, the corresponding lesson of the national curriculum begins with a discussion about the possible variables that may affect the thermal insulation properties of different materials. The teachers of Pair 20 explained in their reflective journals that they considered this introduction as irrelevant to students' everyday lives and thus they proceeded on modifying the introduction by adding a case-based problem to be make the orientation phase more authentic and relevant to students' lives. Furthermore, a small modification was also performed in activity 4 (Table 7 for details), as teachers substituted the use of a table for making records of the values of the variables that relate to the experimental design with the use of the Experimental Design Tool, an app that is available for use in the Go-Lab platform and facilitates the design of valid experiments for answering the investigative questions that are previously followed.

Level 2 - Partial reconstruction of the national curriculum unit – design of extra inquiry activities

The curriculum designs that were clustered in PDC Level 2 concern the case of national curriculum materials that were modified and enriched by the addition of extra inquiry activities that were incorporated effectively into the existing activity sequence. The curriculum materials of Pair 1, which were built in the context of "Friction" is an indicative example of curriculum designs that were categorized in Level 2. As illustrated in Table 8, the existing activities of the national curriculum unit are an inquiry-oriented as they engage students in several scientific practices such as formulation of investigative questions, designing and conduction of valid experiments, and reporting of findings. In looking at the activity sequence developed and implemented by Pair 1, it is noticeable that the teachers enriched the national curriculum materials with more inquiry activities that offer extended learning opportunities to their student. In particular, the teachers chose to change the problem to make it more authentic and compatible to student's everyday life, and they also added an extra activity that pertained on asking the student to define the problem to verify that the problem at hand was comprehended by the student and that the student appreciated the need for finding a solution to the problem. Furthermore, they embedded activities through which the student would be introduced to new concepts and terminology, such as smooth and rough surfaces. These new concepts served as facilitators in helping the student to identify possible variables that might affect the friction exerted on a surface when an object is rubbed on it, and integrate them, at a later stage, in investigative questions, and hypotheses that could be tested through the design and conduction of valid experiments. Furthermore, this pair of teachers integrated some activities through which student's active role in the implementation of the inquiry activities is highlighted and promoted. For instance, during the experimentation phase they prompted their student not only to merely stating the variables that should be altered, measured, and controlled but also to decide how to alter the independent variable (e.g., I would use three different carpets that differ in roughness), how to measure the depended variable (e.g., by

Table 7: Activity sequence of Pair 20 clustered in Level 1

National curriculum activity sequence	Activity sequence of Pair 20
The teacher asks the students: Which factors affect the thermal insulation properties of different materials?	The teacher asks the students: "Mr. Brown uses a coffee pot to prepare coffee for his customers every day. What type of material the handle of the coffee pot should be made of to prevent his hand from burning?
The students discuss and write down possible factors	The students discuss and write down possible factors
The students formulate investigation questions. The teacher gives them the general form of it	The students discuss and write down possible factors. The teacher gives them the general form of it
The students design and perform their experiments and record their measurements. They are provided with a table on which they have to define the variable that should be tested, the variables that should be kept constant, and the variable that should be measured	The students design and perform their experiments and record their measurements. They are provided with the Experimental Design Tool on which they have to define the variable that should be tested, the variables that should be kept constant, and the variable that should be measured
The students draw their conclusions	The students draw their conclusions

The activities in gray-colored boxes corresponds to the new activities that the Pair 20 designed and incorporated in its curriculum material. The activities in white colored boxes represent the activities that were replicated from the national curriculum unit without any changes

Table 8: Activity sequence of Pair 1 clustered in Level 2

National curriculum activity sequence	Activity sequence of Pair 1
Introduction to a scenario to stimulate students' curiosity and to orientate to the problem. "Aris enjoying slipping on snow. He wants to make a board to be able to move as far as possible after he get off the slope	Introduction to a scenario to stimulate students' curiosity and to orientate to the problem. "In recent months, a housewife has been complaining that her new shoes do not help her at all when she is mopping the floor, because she slips"
	Students state the problem situation
	Students are introduced in concepts and terminology (e.g., smooth, rough surface)
Students formulate an investigative question	Students formulate investigative questions, hypotheses, and predictions
Students complete a table to design their experiment	Students use the Experimental Design Tool to design their experiment
Students choose among a given list of variables of the variable that is going to be altered, the variable that is going to be measured, and the variables that will be kept constant	
	Decide about which variables are going to be altered, kept constant, and measured
	Students decide about the materials they are needed for performing their experiment
	Students make a graph to plot the data collected and reflect on the relationship that is revealed between the variables
Students make a presentation to share their findings	Students report their findings of their experiments in a table
	Students write the conclusion and reflect on the inquiry process

The activities in dark gray boxes correspond to the new activities that Pair 1 designed and incorporated in their curriculum materials. The activities in light gray color relate to these which were partially reconstructed from the national curriculum unit

measuring the friction exerted on an object that rolls on each carpet; the more the object rolls on a particular carpet the less the friction is), and how to control (keep them constant) the rest of the variables that are involved in the experiment (e.g., I would use the same object in each trial, the starting point when the object rolls in each carpet would be the same, etc.) (Note: The statements in parentheses pertain to student's quotes, as these were captured and integrated in teachers' reflective journals). In addition, they engaged their student in creating a graph with the use of the data collected during experimentation. Through this activity, their student was expected to identify the relationship between the depended and independent variables based on the type of graph that would emerge after the plotting of the data, and thus to draw conclusions about how the variables under study are related.

Overall, the activity sequence presented above indicates that the teachers who were clustered in Level 2 performed a partial reconstruction of the activities of the national curriculum unit to make the existing activities more authentic and more student-centered, and enrich them with activities that fostered their students' engagement in fundamental scientific practices centered on inquiry.

Level 3 - Total reconstruction of the national curriculum unit with strong priority to IBL

PDC Level 3 encompasses the curriculum materials whose designers followed a total reconstruction of the national curriculum unit they chose to work with. To showcase the type of reconstruction that has been applied to these curriculum materials, we selected the curriculum materials of Pair 19 as a representative example.

Pair 19 reconstructed the unit "Forces and Motion" from the national curriculum. As these teachers explained in the documentation provided in their reflective journals, the purpose behind proceeding in a total redesign of the existing curriculum materials departed after examining the existing curriculum materials and concluding that inquiry was almost absent from the entire unit. Hence, through their proposal of how this particular unit should look like, they stated that they would seek to assist their student in formulating operational definitions about the concept of force through a constructivist and inquiry-oriented approach. This would be accomplished through investigating the factors that would affect the relocation of an object. Table 9 summarizes the structure and the content of the activities of the national curriculum unit in conjunction with the activities of teachers' curriculum materials.

According to the Table 9, it appears that in the activity sequence of the national curriculum the students neither are engaged in developing hypotheses or investigative questions about the phenomena under study nor are encouraged to design and perform any controlled experiments and, as a result, they do not experience inquiry learning at all. On the contrary, the activity sequence proposed by Pair 19 illustrates a total reconstruction of the existing curriculum materials and most importantly, the inquiry activities that were designed aim to help the student develop inquiry skills and conceptual understanding of the phenomenon under study. The teachers focused not only on aimed to help the student define the concept of force in the context of the activities he engaged with but also to integrate the developed concept into the inquiry cycle.

Table 9: Activity sequence of Pair 19 clustered in Level 3

National curriculum activity sequence	Activity sequence of Pair 19
Students are asked to relocate an object on their desk to identify how this task can be accomplished	Orientation phase: Presentation of the scenario concerning two kids who are playing tug of war. They are exerting force on the rope in opposite directions. The winner is the kid who will push the other toward him. The students are prompted to state what the kids should do to win
Students explain the different ways they followed in solving the task using the words: Push, pull, force, location	Conceptualization phase: Students are asked to define the concept of force based on their experiences. They formulate investigative questions and hypotheses
Students observe a set of images that show kids pushing or pulling or both different objects. They discuss how the force is acting on the objects in each case	Investigation phase: Students decide the materials that will be used. They use the Experimental Design Tool to design their experiment (they identify the variables that will be altered, kept constant, and measured and propose how these will be manipulated in the context of their experiments)
Students are provided with a definition of force	Students perform their experiments
Students are introduced in a problem: The capacity of the school bin is very law, so there is not enough space for the plastic bottles of water. What the school students could do?	Students plot the data collected in graphs with the use of the Graph tool and formulate conclusions about the relationship between the variables that have been tested
They conduct an experiment in which they apply force on a plastic bottle and note their observations	Students revisit their investigative questions to pose answers and confirm/reject the associated hypotheses
Students formulate a conclusion based on the experimental data collected	Students transfer the newly acquired knowledge in new contexts
They read the following scenario: Two kids saw a very heavy box of books at the entrance of the class. They thought that it has to be moved, but it's so heavy!	
They conduct an experiment and conclude that a force can change the direction of an object	

Types of the designed activities

With regard to the third dimension of curriculum materials analysis, the analysis of teachers' ILSs revealed that the type of activities that were incorporated within their ILSs were mainly inquiry-oriented, conceptually driven, and were interconnected in some cases with scaffolds that were used to foster students' inquiry competence and conceptual understanding. However, the level of learners' autonomy when following the designed inquiry activities, the format of the conceptually driven activities, in conjunction with the presence and location of scaffolds along the activity sequence, enabled the classification of teachers' activities into three distinct PDC levels that are presented below.

Level 1 – Very structured inquiry activities - Conceptual understanding development is either missing or accomplished through delivery of ready-made statements - Partial scaffolding

PDC Level 1 entails teachers' curriculum materials that entailed very structured inquiry activities. Whenever teachers attempted to involve their students in inquiry-oriented activities, this was accomplished through a cookbook-like procedure (e.g., first do this, then do that …). Furthermore, the lack of activities that intend to foster students' development of conceptual understanding across the curriculum designates that teachers of Level 1 did not give emphasis to this particular learning dimension. The description of the activity sequence of Pair 22 in the context of electromagnetism is particularly revealing in documenting the abovementioned findings.

In the orientation phase, the students construct an electromagnet with the guidance of the teachers. Afterward, the teachers provide to students a text that explains what an electromagnet is and where electromagnets are used. In the conceptualization phase, the investigative questions "Does the size of the magnet affect the magnetic attraction force?" and "Do the number of turns in the coil affect the magnetic attraction force?" are delivered as ready-made to the student. In addition, the corresponding hypotheses are also delivered in a ready-made manner, and the student is asked to change the given hypothesis in case she disagrees with the relationship of the variables that were assumed and integrated into a specific hypothesis. In the next phase, the teachers do not prompt their student to propose an experimental design of how to test the hypotheses or respond to the investigative questions. Instead, the experimental design is given as a narrative to the student (e.g., in our experiment we need to vary the number of turns in the coil variable; hence we need to decide how many turns are needed in each experimental trial…), and the student is asked to use the experimental design tool to define the values of the variable that had to be altered and the values of the variables that should be controlled (Figure 1). After conducting a specific experiment with the use of an Online Lab, the student is asked to fill in a table with the conclusions derive from the data collected. This activity, albeit important for facilitating student's conceptual understanding, it is "served" to a student without any conceptual scaffolding (e.g., What do the data collected tell us about the relationship between the tested variable and its impact on electromagnetic force?).

In summary, the curriculum materials that were clustered in Level 1 share a teacher-directed teaching approach, as the teacher is the one who defines the steps for when and how inquiry activities should be implemented. As far as the conceptual understanding and scaffolding are concerned, this is also accomplished either through lecturing or through content delivery statements, since students are seldom prompted to

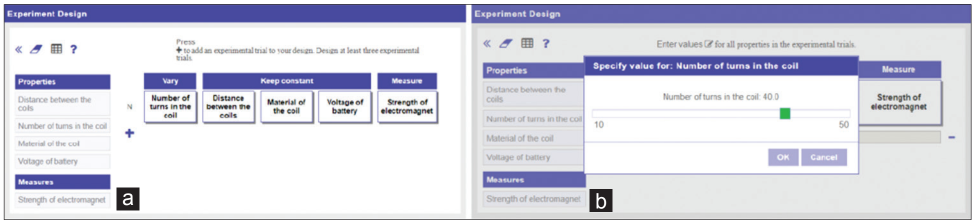

Figure 1: (a) Illustrates how the experimental design was prepared by the teachers, (b) illustrates how the student altered the number of turns in the coil

appreciate the need for articulating operational definitions for the concepts involved in the context of their investigation.

Level 2 – Structured and guided inquiry activities - Introduction of concepts through examples from everyday life – Conceptual and procedural scaffolding

Teachers' curriculum materials that were clustered in PDC Level 2 involve structured and guided inquiry activities, as well as activities that promote the familiarization with concepts through examples from everyday life. However, the teacher still remains in the forefront and the student act as a follower of his/her predefined learning pathways, since whatever students are expected to learn or do in the context of the lesson is prescribed by the teacher, either directly or through the curriculum materials s/he designed. The curriculum design of teachers of Pair 4 in the context of Light and Shadows is an indicative example that falls in Level 2. We briefly describe below the format and structure of their activity sequence for documenting the clustering of their curriculum materials in Level 2.

First, the teachers introduce a problem regarding the factors that affect the size of a shadow. This was as follows: "It's 8 o'clock in the evening and Petros is waiting at the bus stop to catch the bus for home. On the left side of the bus stop there is a floor lamp. Petros noticed that his shadow is formed on the opposite wall, and was surprised to notice that his shadow increased or decreased whenever he approached or moved backward to the wall. Why is this happening? Can you help him understand this phenomenon?" Next, the teachers prompt the students to go out, observe their shadow, and explain why and how a shadow is formed. After stating their thoughts, the teacher presents the following piece of text "A shadow is formed when light from a source is blocked by a solid object. The shadow is the dark area formed behind the object. The object should be opaque or translucent for shadow formation because light cannot travel through such material. A transparent object cannot create any shadow because the light will pass straight through it." After introducing the shadow concept, the teacher provides guidance to the student to formulate investigative questions and hypotheses and subsequently proceeds in designing a controlled experiment to test each hypothesis. The teachers through the curriculum provide all the variables involved in each experimental design and the student is prompted to decide the variables that will be altered, measured, and kept constant according to the investigative questions and hypotheses. Then, he performs the experiments with the use of the Online Lab, organizes the data in a predefined table, and following the teachers' guidelines (e.g., Which variable should be placed in the horizontal axis? Which on the vertical axis?) he creates a graph with the use of the Graphing Tool to study the relationship between the variables under study. At the end of the activity, the student is asked to answer the investigative questions and reject or confirm the hypotheses developed during the orientation phase through writing a report. The aforementioned scaffolds are provided during both investigations and do not gradually faint out as the student moves from the first inquiry cycle to the second.

To sum up, the designed activities were mostly guided inquiry-oriented. The student, on the one hand, receives support from the teachers either through prompts for reflection or through text that entailed ready-made knowledge (e.g., the definition of a shadow), and on the other hand, the student is given the opportunity to investigate himself the impact of two independent variables on a dependent variable, collect and analyze data, and make reports about the yielded findings.

Level 3 – Guided and open inquiry activities - Conceptually oriented activities interconnected with the inquiry activities - Conceptual and procedural scaffolding that faints out gradually

PDC Level 3 includes the case of curriculum materials that were developed on the tenets of a combination of guided and open inquiry perspective. A balance of both inquiry and conceptually oriented activities was evidenced, and most importantly, these activities were well interconnected as the inquiry activities complemented the conceptually oriented activities and vice versa. To foster learners' engagement in both types of activities, several conceptual and procedural scaffolds were designed and embedded at several instances in the activity sequence, and these scaffolds appear to faint out gradually as learners move from the initial inquiry cycle to the later one. The curriculum materials of Pair 8 that was designed in the context of "Sinking and Floating" is a representative example of a curriculum clustered in Level 3 and is briefly presented below.

In the beginning of the lesson, the teachers introduce an authentic scenario to their student, in the context of which a problem emerges. In the conceptualization phase, they engage their student in the development of an operational definition for the concepts "sinking" and "floating." Specifically, they provide a piece of aluminum foil to the student and prompt her to place it first on the surface of the water of a water basin and record her observation (the aluminum foil floats this time). Next, the student is prompted to place the aluminum foil inside the water basin and observe what would happen (the aluminum foil sinks this time). Based on these contradictory observations, the teachers highlight the importance of deciding how and where to place an object inside a water basin to decide if it will float or sink. They decide mutually with their student that the best way is to place the object inside the water basin and observe what would happen. In case the object moves to the bottom of the basin, this means that the object sinks. On the contrary, if the object moves toward the water surface, this means that the object floats. Through this constructivist approach, the student is guided to formulate an operational definition of sinking and floating that is going to systematically use it during the investigations that follow.

In the subsequent activities, the student is involved in two inquiry cycles. During the first inquiry cycle, the student is guided on how to formulate an investigative question and a hypothesis. To scaffold these tasks, the teachers provide her with the general form of an investigative question (e.g., Does variable A affect variable B?) and the student is prompted to use this syntax for formulating the investigative question in the context under study. In the case of hypothesis generation, the teachers explain that hypothesis should entail a relationship of how two variables are assumed to be associated with (e.g., the more the… the more (or the less) the …) and ask student to use the investigative question as the basis for defining how variable A will affect variable B and through this a hypothesis would be formulated. Next, the student proceeds with the design of the first experiment and asked about how to manipulate the variables involved in the experimental design (e.g., what variable should be altered and how is going to be altered, and so on). After finishing with the experimental design, the student uses an Online Lab in the context of sinking and floating to conduct the experiment she previously designed, collects data, and record them on a table. The teachers act as facilitators of the data collection and organization on the table through prompts and scaffolds (e.g., in the first column you need to enter the values of the independent variable, in the second column the values of the dependent variable, etc.).

As soon as the student finalizes the data collection, analysis, and reporting the findings (first inquiry cycle), she proceeds with the second inquiry cycle. It is important to note at this stage that during the entire second inquiry cycle, the teachers let the student alone to formulate an investigative question and a hypothesis, and decide about the variables that should change, measure, and keep constant. Then, the student decides on her own the procedure for conducting the experiment, what data should be collected, how the data would be analyzed and reported, and so on. Although no scaffold is provided, the only guidance that is offered to the student is a reminder; if she does not recall how to perform a specific practice, she needs to revisit the first inquiry cycle and refresh of how this was done. Hence, it appears that the scaffolds faint out as the student transitions from the first inquiry cycle to the second, in case there is enough evidence that the student can take over the process of the inquiry learning.

Integration of the inquiry learning cycle within the curriculum designs

One of the requirements that were included among the guidelines provided to teachers when designing their curriculum materials points to the learning objectives that should be promoted through the learning activities they were expected to design and implement with their student. Specifically, the teachers were expected to design inquiry activities through which they would help their student develop inquiry competence (e.g., inquiry skills and epistemic understanding about the nature and purpose of inquiry). To address this learning requirement into their curriculum designs, they had to exploit the principles of IBL and follow the phases of inquiry learning framework they went through as learners in Phase 1 and built on its tenets that were inductively identified during Phase 2 of the PDP (see Methods section for more details).

Three levels of increased sophistication yielded from the examination of their curriculum designs in terms of how the inquiry was articulated into their curriculum designs and approached afterward during their practice.

Level 1 – Inquiry as a linear process

PDC Level 1 relates to curriculum designs that approached the inquiry components in a linear fashion. An indicative example that is briefly described below is the curriculum design of Pair 2.

The teachers followed a linear process while designing and implementing their inquiry activities that were compatible with the process found in many science textbooks (i.e., question, hypothesis, experiment, results, and conclusion). The teachers begin with a video that presents four primary students performing an experiment to confirm or reject the Aristotle's hypothesis "Heavier objects fall down more quickly than light objects in a vacuum." The students at the video present the process of how to conduct the related experiment, mention their findings, reject the Aristotle's hypothesis, and formulate a new hypothesis as follows "All objects reach the ground at the same time when left to free fall from the same height in a vacuum." This hypothesis is used by the student as the starting point for the investigation that follows. Specifically, the teachers ask the student to decide about the object that will be used, what variables should be kept constant, and how to measure the time of flight of the objects. As soon as the experiment is conducted and the student has already collected enough data, he proceeds in drawing the main conclusion.

The activity sequence example shows that the student followed a straightforward process where the phases of inquiry appear in a series manner. For instance, in the investigation phase, the student could be asked to move back to the orientation phase to compare his findings with the findings that were presented in the video. Furthermore, at the end of the process, the student could go back the conceptualization phase to retrieve the initial hypothesis and decide of whether it could be confirmed or rejected based on the collected data. Overall, it seems that these teachers believe that scientific knowledge is generated in a single, fixed manner, and that inquiry is carried out in linear and sequential steps.

Level 2 – Inquiry as a linear process but sometimes students are prompted to back to recall what has been done or learnt

PDC Level 2 pertains to teachers' curriculum materials that again inquiry was assumed to be a linear and straightforward process. The difference between this level and the previous one lies in the fact that in Level 2 there was evidence of instances where teachers prompted the students to go back to recall what has been done or learnt. A representative example of Level 2 curriculum designs is the one developed by Pair 7 in the context of hydrostatic pressure.

The activity sequence begins with the orientation phase during which the student watched a video about a diver who wondered what will happen if a sealed plastic bottle full of air dives at 10-meter depth in the sea. The video illustrated a plastic sealed bottle that was compressed at the 10-meter depth in sea water because of the hydrostatic pressure exerted on it. When the diver released it to the surface of the water, the bottle was decompressed and returned to its normal shape. After this introduction, the student identified possible variables that might affect hydrostatic pressure. In the next phase, the student chose two of the identified variables and prompted to formulate investigative questions and the corresponding hypotheses. At the beginning of the investigation phase, the teachers informed the student that he would use the hydrostatic pressure virtual laboratory for conducting the experiments to collect experimental data to confirm or reject his hypotheses. The curriculum proceeds with an illustration of the virtual lab and its capabilities. When it was time for conducting the experiments to test the previously developed hypotheses, the student was asked to go back to the conceptualization phase to recall the hypotheses developed to choose the appropriate variables for conducting the related experiment. In the conclusion phase, the student drew conclusions based on the data collected during the preceding phase. At this point, the teachers asked the student to recall the video that was presented during the orientation phase and provide an explanation to account for the plastic bottle decompression under the water.

The abovementioned activity sequence designates that the teachers assumed that inquiry is organized into a set of consecutive phases that are linked in a linear manner. The purpose behind prompting the student to revisit a previous phase was to help the student recall something that was previously stated and not because the inquiry was assumed as a cyclical and iterative process.

Level 3 –Inquiry as a cyclical and iterative process

The curriculum materials that fall into PDC Level 3 were designed according to the IBL framework suggested by Pedaste et al. (2015). More specifically, the inquiry activities that were incorporated in the curriculum materials were organized in a cyclical and iterative manner. To present how an activity sequence clustered in Level 3 looked like, a description of the curriculum materials of Pair 12 is provided below.

In the orientation phase, teachers, the teachers provided the following scenario: "George visited his grandmother and forgot his glasses at home. He wanted to watch his favorite TV series, but it was impossible to watch it without his glasses. Hence, he thought of using his grandmother's glasses. When he tried to watch on TV, everything was blurred! He started wondering why the glasses of his grandmother caused such an effect." In the conceptualization phase, the student became familiar with the different types of lenses. Furthermore, the student formulated the first investigative question and the hypothesis concerning the impact of "type of the lens" on the "clarity of an image." In the investigation phase, the student performed a controlled experiment, collected evidence to answer the research question, and represented the data in a table and a graph. After the first investigation, the student returned to the conceptualization phase to formulate a second investigative question and an associated hypothesis that both related to the impact of the "thickness of a lens" on the "clarity of an image." As a follow-up activity, he was asked to design and conduct a valid experiment, record the data, and create a graph. In the conclusion phase, the learner revisited the investigative questions and the hypotheses and drew conclusions based on the data collected. Specifically, he utilized the data to respond to the investigative questions and rejected or confirmed the hypotheses. Furthermore, at this stage, the learner returned to the initial problem (why he could not see clearly when used his grandmother's glasses) and tried to solve it through applying the newly acquired knowledge.

Organizing the activity sequence in two consecutive inquiry cycles, as illustrated in the abovementioned extract, designates that teachers whose curriculum materials were clustered in Level 3 conceptualized inquiry as an iterative process that involves several phases that are interconnected in a cyclical manner. This conceptualization is totally different compared to the conceptualizations of teachers in Levels 1 and 2, as these conceptualized inquiry as a prescribed, uniformed and linear process.

Evaluation of students' learning gains

The last dimension that was used to analyze teachers' curriculum materials were examined concerned the assessment tasks they developed to evaluate their students' learning gains. Specifically, the type, the format, the content, and the time of administration of the assessment tasks were taken into consideration while looking at the means of evaluation of students' learning gains. Three levels of increased sophistication emerged from the analysis and are presented below.

Level 1 – Pre- or post-evaluation of students' rote learning through closed-ended questions

This PDC level concerns teachers who designed only pre- or post-evaluation tasks for assessing students' declarative knowledge related to the subject domain of their ILS. The assessment was carried out before or after the implementation of their ILS and the format of the tasks they designed were in the form of multiple choice questions or/and true/false questions or/and closed-ended questions. It is important to note that no tasks were designed to assess students' inquiry skills. The assessment task designed by Pair 6 is an indicative example and is presented in Figure 2.

According to Figure 2, this pair of teachers chose to evaluate students' understanding of the concept of Friction in the format of a multiple-choice question. Furthermore, this assessment task was administered only at the end of the curriculum's implementation. It should be pointed out that this assessment task measures if the students were able to recall something that was already been discussed during their engagement with the ILS. Specifically, right after they finished investigating factors that relate with the context of friction, the teachers introduced some scenarios from individuals' everyday activities that friction is involved, and students were asked to study the scenarios and tell whether friction facilitated or impeded the task performed by individuals. The case of using chains on a car's wheels on a slippery road was among the scenarios administered to students. Given that teachers chose a context that their students had already been introduced in the context of the ILS implementation to assess their conceptual understanding status, it was concluded that the emphasis of the assessment related to rote learning.

Level 2 – Pre- and post-evaluation of students' understandings about concepts relevant to the topic engaged with open-ended tasks

Level 2 relates to the case of students' assessment in the beginning and ends of the ILS implementation and focused on students' understandings about concepts relevant to the topic engaged. Open-ended tasks were designed that prompted students' to provide the reasoning behind their responses. An example of two assessment tasks developed by Pair 16 is provided in Figure 3 and elaborated afterward.

The assessment tasks presented in Figure 3 concern two assessment tasks that were administered at the beginning (pre-test) and end (post-test) of ILS implementation. Through the pre-test, the teachers aimed to evaluate their student's prior ideas whether a specific factor (e.g., mass of object attached to a vertical spring) affects the elongation of a spring. In their reflective journals, the teachers explained that it was important for them to know their student's initial ideas to design the intervention in the context of "forces and springs" in a way that it would be meaningful to their student. As a post-test assessment task, the teachers designed a different task to assess the same learning objective as the pre-test (e.g., whether the mass of an object attached to a vertical spring affects its elongation, see post-test in Figure 3 for more information). The rationale behind designing this task was based on the assumption (according to teachers' explanation found in their reflective journals) that post-test assessment should be accomplished through tasks that welcome students' ability to transfer their developed understandings and knowledge in contexts near or far of the context of instruction.

Level 3 – Pre- ongoing and post-evaluation of students' inquiry skills and understandings about concepts relevant to the topic engaged with open-ended tasks

PDC Level 3 resembles PDC Level 2 in that it entails the case of assessment tasks that focused on evaluating students' conceptual understanding, but it also encompasses assessment tasks that pertain in evaluating students' inquiry skills. This was accomplished through several tasks they designed and administered throughout their intervention. A noteworthy feature of these assessment tasks relates to the context chosen for designing these tasks. Specifically, the teachers chose not only the context of their ILS but also different contexts, because (according to their own words) "It is important to see if students are able to transfer these skills in new domains. If they can do this effectively, then we can be sure that they truly developed the inquiry skills we helped them to develop" (extract from Pair 14 reflective journal).

Another significant characteristic of Level 3 that differentiates from Level 2 concerns the chronological order of assessment implementation that was accomplished not only through pre- and post-tests but also through ongoing assessment tasks. A representative example of an evaluation task designed by Pair 14 to assess students' inquiry skills is provided in Figure 4.

As illustrated in Figure 4, the teachers designed an assessment task in the context of pendulums, through which they aimed at examining whether their student is able to identify flaws in a given experimental design and resolving these issues through proposing a controlled experiment. The teachers

Read the following statement and choose the correct answer. Put a tick in the appropriate box:

When we drive on ice, we place chains on the wheels of the car to:

a) increase the friction
b) decrease the friction
c) the friction remains constant
d) none of the above

Figure 2: Excerpt of the assessment tasks of Pair 6 in the context of friction

Pre-test
1.Michael argues that a vertical spring elongates the same whenever objects of different mass are attached to it.Do you agree with Michael's argument ? Explain your response.

Post-test
2. Imagine you are going to participate in a Science Fair and the challenge is to design a device to measure the mass of different objects. You are given the following materials:

- a plastic tube that contains inside a spring. There is a hook at one of the ends of the spring,
- a pen marker,
- a ruler,
- a set of 10 metallic nuts each of which weighs 100 gr

Make a drawing of the proposed device, describe how you constructed it, and how one can use it to measure the mass of an object.

Figure 3: Excerpt of the assessment tasks of Pair 16 in the context of springs

> Myrto wants to study if the mass of a weight influences the time it takes to cover the distance A to B and vice versa (in the context of a simple pendulum). The first time she placed a weight of 30g in the shape of a wooden sphere and the second time she placed a weight of 40g in the shape of a plastic cube. Is the experiment valid? How would you correct the design of this experiment in order to be valid?
>
> Justify your answer.

Figure 4: Excerpt of the assessment tasks of Pair 14 in the context of simple pendulum

did not focus on the assessment of student's knowledge of what a "controlled" experiment is, but instead, they aimed at giving the opportunity to their student to apply the skills and knowledge he developed in the context of ILS implementation in a new context.

Classification of pairs of teachers' curriculum designs in the emerged levels across the five PCK for IBL dimensions

The distribution of the 22 pairs of teachers along the five dimensions of analysis of their curriculum materials and across the emerged PDC levels are presented in Table 3. According to the findings of Table 3, it appears that the majority of the pairs of teachers (17 out of 22) revealed a consistency in the degree of sophistication of their curriculum designs. These pairs were classified as follows; six in Level 1, seven in Level 2, and nine in Level 3.

The five remaining pairs of teachers' curriculum designs were not classified in the same emerged level across the five dimensions of analysis. Specifically, the curriculum materials of Pair 1, Pair 7, and Pair 18 were classified in Level 2 in all dimensions except for the Evaluation of students' learning gains (pair 1), the Types of the designed activities (pair 7), and the Degree and type of reconstruction of the national curriculum unit (pair 18). Pairs 17 and 12 were categorized in Level 3 except for the dimensions integration of the inquiry learning cycle within their curriculum designs (Pair 17) and teachers' curriculum design orientation and types of the designed activities (pair 12).

Nevertheless, the frequency of teachers' classification along the three levels of increased sophistication resulted from the analysis of their curriculum materials, in conjunction with the degree of consistency within each emerged level; suggest that teachers who engaged in the same PDP for IBL have conceptualized in diverse ways the underlying principles of the IBL approach.

What Information Do The Characteristics of Preservice Teachers' IBL Curriculum Materials Provide Concerning Their PCK for IBL?

Looking closely at the characteristics that emerged for every level and for each of the five dimensions of analysis, we gain insights not only of the status of teachers' PDC for IBL but also the amalgamation of these aspects helps in portraying teachers' PCK for IBL. An examination of the characteristics within each of the emerged levels revealed three different profiles of teachers' PCK for IBL which are elaborated below.

Profile A

The teachers with profile A choose to take up a teacher-directed orientation in their curriculum designs. The activities they designed are characterized by strong transmissive pedagogies; they seem to entirely control students' learning and expect that the pieces of knowledge they diffuse through their lessons will be "absorbed" and "recycled" by their students when in need. This claim is enhanced through the absence of activities that would help their students develop inquiry skills that are necessary to be applied for the study of future scientific phenomena. In addition, these teachers show a strong attachment to the textbooks used at schools, since the teaching materials they develop do not deviate much from the activities included in the national curriculum units. As a result, they keep intact the format, the structure, and the content of the national curriculum activities.

As far as the types of the designed activities are concerned, they design or select from the textbooks very structured inquiry activities, as these resemble a cookbook-like procedure. This particular perspective they adopt can be attributed to how these teachers conceptualized inquiry in terms of its format and its purpose. The way they structured the inquiry activities they designed, designates that they assume inquiry to be carried out in linear and sequential steps, and, also, scientific knowledge is produced in a single, predetermined approach.

Similarly, when it comes to conceptual understanding and its associated scaffolding, this is also accomplished either through lecturing or through content delivery statements, since students seldom are prompted to appreciate the need for articulating operational definitions for the concepts involved in the context of their investigation. Given that their curriculum materials do not entail activities that intend to foster and monitor students' development of conceptual understanding, it appears that teachers with profile A do not attend to this particular learning need of their students.

Finally, the type and format of assessment tasks they propose to use for capturing students' learning gains reveal a favor to rote learning, since they do not attempt to challenge their students in transferring the newly acquired knowledge into new domains.

Profile B

The teachers who adopt this PCK profile implement both transmissive and transactive curriculum design orientations in their curriculum materials. Although they show an interest in engaging their students in inquiry-oriented and conceptually driven activities, and thus to provide them with necessary space for active knowledge construction, at some point they reduce students' autonomy in IBL, as they intervene to illustrate "what needs to be learnt" or/and how a procedure should be accomplished.

During working with their inquiry designs, they proceed in the partial reconstruction of the format, the structure, and the content of the unit from the national curriculum. Through their designs, they aim at making the activity sequence more authentic and student-centered, foster students' familiarization with concepts through introducing examples from everyday life, and give substantial emphasis to students' engagement with fundamental scientific practices centered on inquiry. However, because they still do not feel confident enough to let their students follow their own learning pathways when practicing inquiry, they remain in the forefront to ensure that their students will not decline from what they have already planned to be learnt and how to be learnt. Since they feel insecure to "mess up" when having their students working in an autonomous manner, they organize the inquiry activity sequence into a set of consecutive phases that are linked in a linear manner. They might allow their students to move back and forth while progressing from one inquiry phase to another, only if the students need to recall something that was previously stated or learnt. Hence, they appear to have conceptualized inquiry not as a cyclical and iterative process, but instead as a linear one.

When it comes to assessing their students' learning gains, they do not seek to explore whether their students have developed any inquiry skills. Instead, the emphasis of their assessment concerns only students' development of conceptual understanding. Their evaluation is implemented both at the beginning and end of their instruction, and it is accomplished through open-ended tasks that welcome students' expressing the reasoning behind their responses.

Profile C

The teachers who correspond to this PCK profile integrate a combination of transactive and transformative orientations when designing their IBL curriculum materials. Given that they consider their students and themselves as actors in leading and supportive roles, respectively, they systematically scaffold their students to actively constructing their own learning through activities that promote self-reflection and self-awareness. In doing so, they prompt their students to express their ideas about a topic under study, then they challenge them to confront these ideas with the knowledge that emerges through inquiry-oriented activities and at the end, they scaffold them in enriching, revising, or reconstructing their existing knowledge.

Their curriculum materials are developed on the grounds of a combination of guided and open inquiry perspective and give strong priority in helping their students to develop inquiry skills and conceptual understanding of the phenomenon under study. To succeed in this direction, a well balance of both inquiry and conceptually oriented activities exists within their curriculum designs that are interconnected in a way that the inquiry activities complement the conceptually oriented ones and vice versa. To facilitate their students' meaningful engagement in both types of activities, they integrate several conceptual and procedural scaffolds in the activity sequence, and they choose to faint them out once they feel that their students have mastered what is expected to be learnt to transit through inquiry cycles. As a result, these teachers appear to have conceptualized inquiry as an iterative process that involves several phases that are interconnected in a cyclical manner.

As far as the evaluation of students' learning gains is concerned, this is accomplished through several assessment tasks that are used as an initial, ongoing, and final evaluation of students' status of inquiry skills and conceptual understanding. To ensure that their students have comprehended the anticipated concepts or developed the inquiry skills that are fostered throughout the IBL activity sequence, they design assessment tasks that require students to meaningfully apply the concepts and skills they might have mastered in new domains.

DISCUSSION AND CONCLUSIONS

The study aimed at examining preservice elementary teachers' inquiry-oriented curriculum materials in an attempt to unravel their PDC and PCK for IBL, after attending our specially designed PDP, and centered around inquiry-based teaching and learning. The analysis of teachers' curriculum materials revealed that they were developed along five PCK for IBL dimensions. In terms of the characteristics of the teachers' IBL curriculum materials, our analysis revealed three levels of increased sophistication along each of the five dimensions. Each of these levels corresponded to a different teacher PDC. Moreover, through our data analyses, we managed to identify three different PCK for IBL profiles.

The combination of all these findings provides an interesting background which might prove valuable in understanding how an effective PDP must be designed. First, we should highlight the contribution of the teachers' curriculum materials as means for studying teachers' PDC and PCK for IBL. In prior research, the types of teachers' knowledge transformations were elicited either through written questionnaires, clinical interviews or class observations (e.g., Elster et al., 2014; Seraphin et al., 2013). In this study, we made use of teachers' curriculum materials as a lens to examine these transformations and managed to collect considerable evidence about the status of their PCK and PDC. This approach is in line with the stance of Beyer and Davis (2012), who argue that looking into teachers' curricular planning practices we can gain insight on the types of knowledge that teachers employ in their planning and the ways in which they apply the different types of knowledge in their own practice.

Second, the findings of the study showed that our preservice teachers entered our PDP with all sorts of background differences, which resulted in having the teachers perceiving the content of the PDP in a different manner. We inferred this from the different characteristics of their IBL curriculum materials, the different levels of their PDC and the different profiles of their PCK. Therefore, the question that is raised at this point is whether the same PDP should be offered to all preservice teachers. Could it be that tailoring a PDP according to preservice teachers initial PDC and PCK for IBL be more effective in training them for understanding and implementing the IBL approach? This remains to be seen in future research since our design did not involve an initial screening of the teachers in terms of their PDC and PCK for IBL. It might be the case that teachers with similar PDC and PCK for IBL perceive the content of a PDP in the same manner, which will enable the PDP instructors to better adapt the PDP to their needs (e.g., have focused discussions which are beneficial to all attendees of the PDP).

Third, the IBL curriculum characteristics that emerged provided in-depth insights about teachers' curriculum design orientations, instructional knowledge and curricular knowledge for IBL, knowledge about students' competence for engaging in inquiry and how to assess their IBL competence, which in turn enabled us to understand aspects of teachers' PCK for IBL. It has been claimed that teachers' PCK for IBL can be developed and enhanced through research-based activities, such as action research and lesson study, employment of classroom practice, use of computer-supported tools, and collaborative learning (Juang et al., 2008). In our study, a considerable emphasis was placed on supporting teachers to develop through a specially designed PDP the necessary PCK for IBL. Following the recommendations of Blanchard et al. (2009), which state that teachers develop their PCK for IBL through applying a model of inquiry they engaged with (probably as learners) to their own lesson designs and implementations, in conjunction with the stance of Kielborn and Gilmer (1999) that teachers' active participation in inquiry science experiences helps them to develop more robust conceptualizations of inquiry and how to teach it to their own students, as well as Irakleous (2015) argument about having the teachers to experience IBL through different angles/perspectives (e.g., teacher as a learner, thinker, curriculum designer, and reflective practitioner), we developed a PDP with four consecutive phases. Each phase was assigned to a different role, to maximize their learning, reflective, and teaching opportunities about IBL. Engaging teachers as curriculum designers, along with other participatory roles (e.g., teachers as learners, thinkers, and reflective practitioners) within the context of a PDP, can create a significant shift in their philosophy and their PDC of how they approach and implement the national curriculum within their practice. This argument concurs with others scholars' recommendations (e.g., Forbes and Davis, 2010) who underlined the importance of engaging preservice teachers to learn to use or revise science curriculum materials to promote IBL. This is because novice teachers tend to rely heavily on the available curricular resources they have access to Grossman and Thompson, 2004, which quite often integrate IBL in a superficial manner (Beyer et al., 2009; Kesidou and Roseman, 2002).

Fourth, the description of the characteristics of teachers' IBL curriculum materials across the levels that emerged enabled us to draw essential inferences about their understandings of the design principles that are important to be followed during developing IBL curriculum materials, their PDC for IBL (Brown, 2009), the types of knowledge transformations applied in the development of these teaching materials, as well as their alternative ideas about how IBL is fostered and assessed within specially designed instructional settings. Expanding on other studies that have identified limitations in preservice and new teachers' PCK for IBL (e.g., Beyer and Davis, 2009; van Driel et al., 1998; Zembal-Saul et al., 2002), the findings of the present study revealed previously identified or new alternative ideas that novice teachers possess while applying their knowledge of science assessment, science curriculum materials, and science instructional strategies.

For instance, in terms of the degree and type of reconstruction of the national curriculum materials, about one-fourth of the pairs of teachers (6 out of 22) let intact the activity sequence of the national curriculum materials. One explanation to account for this decision, which concurs with other reports, is that novice teachers might have assumed that there is no need to revise or reconstruct existing curriculum materials either because it has been developed by experts in the field (Ben-Peretz, 1990; Schwarz et al., 2008) or because they have been published, they are of high quality (Ball and Feiman-Nemser, 1988; Ben-Peretz, 1990).

In addition, teachers' tendency to focus on assessing students' conceptual understanding and neglecting their inquiry competence concerns a finding that was also found in previous research (e.g., Beyer and Davis, 2009). Teachers' preference to design assessment tasks to capture their students' conceptual understanding status might be attributed to either their traditional views of what the purpose of assessment should be (e.g., priority to factual and not to procedural knowledge) (NRC, 1996), or to the limited knowledge about their students' learning needs, or both. Consequently, Beyer and Davis's (2009) claim that preservice teachers tend to engage "…in more thoughtful planning about what they would teach rather than about what they wanted their students to learn and how they would measure it" (p. 151) can be used to explain this finding.

Moreover, the PCK for IBL dimensions through which teachers' characteristics of curriculum designs were elicited from, in conjunction with the description of the emerged levels for every dimension (Table 2 for more details) can be approached as a framework that provides the basis for examining teacher designed and developed curriculum materials from different perspectives, while at the same time inferences about the status of their PDC and PCK for IBL can be extracted. The findings of the present study point to three different profiles of teachers in regard to their PCK for IBL, each of which indicates that the teachers who engaged in the same PDP have conceptualized in diverse ways the underlying principles of the IBL approach as this was reflected through their PDC and PCK. Similar profiles have been elicited in a study conducted by Kazempour and Amirshokoohi (2014), which focused on exploring the impact of science teachers' professional development experiences into their practice. For instance, profile A in their study, which refers to the case of teachers whose emphasis was on the coverage of terminology of background information, resembles profile A of the present study in terms of their curriculum orientations, designed activities, and assessment of students' learning gains. Similarly, profile C (e.g., teachers who are in favor of a more guided inquiry approach) and profile D (e.g., teachers who design more open and student-driven activities) of the Kazempour and Amirshokoohi (2014) study resemble profile B and profile C of the present study, respectively.

In summary, the findings of the present study provide insight into the extent to which preservice elementary teachers develop their PDC and PCK for IBL, as a result of their participation in a specially designed PDP, and apply them for the purposes of curriculum design, adaptation, and implementation. In addition, examining teachers' planning and enactment practices through the use of a five dimension framework, like the one emerged and used in this study, may shed light on the strengths, struggles, and constraints they encounter during applying particular aspects of their PCK into their curriculum designs. Of course, further research, with wider samples and longer exposure to a PDP, is needed before reaching to general conclusions. Another limitation of this study was the fact that we could not study or measure the effect of each of the roles undertaken by the teachers during the PDP (i.e., learners, thinkers, designers, and reflective practitioners) on their PDC and PCK for IBL. To do so, a different research design should be in place. Thus, we encourage future researchers to examine this issue, since understanding the effect of each role would enable us to optimize the effectiveness of the way such a PDP is delivered to the teachers. Finally, a longitudinal study, in which teachers are followed from their preservice years to their in-service ones, is needed to examine how a teacher's PDC and PCK for IBL are evolved. The idea is to collect as much information and evidence as possible for developing a framework that portrays how effective PDPs for IBL should be developed. The ultimate goal is to improve teachers preparation for enacting IBL effectively within their science classrooms.

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