International Journal for Lesson and Learning Studies

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Article information:

To cite this document:

Teresa Conceição, Mónica Baptista, João Pedro da Ponte, (2019) "Lesson study as a trigger for preservice physics and chemistry teachers' learning about inquiry tasks and classroom communication", International Journal for Lesson and Learning Studies, <https://doi.org/10.1108/IJLLS-11-2018-0081>

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Lesson study as a trigger for preservice physics and chemistry teachers' learning about inquiry tasks and classroom communication

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Received 2 November 2018
Accepted 6 November 2018

Abstract

Purpose – The purpose of this paper is to understand what physics and chemistry preservice teachers learn on the nature of the inquiry tasks and about classroom communication in an inquiry task when they take part in a lesson study.

Design/methodology/approach – This is a qualitative and interpretive research which was carried out within a master's degree course in physics and chemistry teaching with three preservice teachers. Data were collected from participant observation with video recording, interviews, written reflections and group report by the preservice teachers. This two-cycle lesson study was conducted over 12 sessions. The data analysis took place through asking questions and using the constant comparison method, which allowed the identification of the most relevant issues about the preservice teachers learning according to the categories nature of the inquiry tasks and communication promoted by the teacher.

Findings – The results show that the preservice teachers learnt to identify the characteristics of inquiry tasks, how to develop an inquiry task when planning the research lesson and acknowledged its potential for student learning. Moreover, the preservice teachers acknowledged the fact that the classroom communication promoted by the teacher fostered student participation, negotiation of meanings about scientific concepts and construction of new learning that can be shared within the class.

Research limitations/implications – Research is needed as regards how initial teacher education providers may contribute to the learning of preservice teachers in lesson study in initial teacher education programmes.

Originality/value – This research contributes to show potentialities of lesson study in the initial teacher education of preservice physics and chemistry teachers.

Keywords Lesson study, Initial teacher education, Classroom communication, Inquiry tasks, Speed of sound

Paper type Research paper

Introduction

Inquiry-based science education (IBSE) increases student interest in science (Swarat, 2008), stimulates the development of their in-depth knowledge (NRC, 2012), critical thinking and argumentative skills (Lederman *et al.*, 2013). Many research studies point to the benefits of IBSE in learning of science concepts, notably because it allows students to learn more meaningfully (Minner *et al.*, 2010). IBSE has beneficial consequences as regards to more participatory, critical and informed citizenship (Hodson, 2011). According to Marshall *et al.* (2017), IBSE is an “intentional student-centred pedagogy that challenges the learner to explore concepts, ideas and/or phenomena before formal explanations are provided by the teacher and/or other students” (p. 779). This understanding of IBSE is necessary for the teacher to create and adapt inquiry tasks that allow students to learn science in the classroom in line with current recommendations for science teaching (e.g. BSCS, 2017; NGSS, 2013).

Teresa Conceição is supported in her doctoral work by a PhD grant awarded by the University of Lisbon (Application Code, C0885p since 2016).

Nonetheless, teachers rarely use inquiry in their lessons (Prenzel *et al.*, 2009; S-TEAM, 2010). The literature shows that this approach poses challenges for preservice teachers (Anderson, 2002), new teachers (Roehrig and Luft, 2004) and more experienced teachers (Capps and Crawford, 2013). For example, in the study by Krämer *et al.* (2015), most of the 32 participating teachers admitted that they did not understand the nature of inquiry and indicated that they use a “teacher-centred approach and do not establish open inquiry” (p. 336). Therefore, there is a need to use initial teacher education processes that allow future science teachers to learn how to organize teaching in an IBSE perspective, developing and using inquiry tasks and understanding how to communicate in the classroom. Lesson studies are a possibility pointed out in the literature as they entail a collaborative, reflexive and student-centered process that promotes learning opportunities that allow preservice teachers to devise a task on a curriculum topic, plan a lesson based on this task, observe the lesson and make a deep discussion of the topic based on student outcomes (Fujii, 2016). Research in lesson study as a teacher education process of future science teachers shows promising results (e.g. Juhler, 2017; Sims and Walsh, 2009; Zhou *et al.*, 2016). Nevertheless, there is little research in lesson study in science teaching using inquiry tasks and addressing how the teacher conducts classroom communication. The present research aims to understand what physics and chemistry preservice teachers learn about the nature of the inquiry tasks and classroom communication when they participate in a lesson study on the speed of sound. The research questions are the following:

- RQ1. What physics and chemistry preservice teachers regard as their own learning on the nature of inquiry tasks during a lesson study?
- RQ2. What physics and chemistry preservice teachers regard as their own learning on classroom communication promoted by the cooperating teacher in a research lesson based on an inquiry task?

The lesson study topic, speed of sound, is part of the K-8 physics and chemistry curriculum. Few studies have dealt with students’ preconceptions of sound (e.g. Eshach and Schwartz, 2006). If one goal of science education is advancing students’ learning about their own world and about “useful knowledge” (Layton, 1973, cap. 5), then the subject of sound should be an essential component of science curricula. Therefore, identifying students’ preconceptions is a necessary stage in increasing teachers’ awareness of the difficulties and barriers faced by their students in understanding scientific phenomena. This awareness, in turn, will enable teachers to design better and more effective learning environments (Galili and Hazan, 2000).

Inquiry tasks and communication

Inquiry tasks that the teacher can use in science lessons have an open nature, i.e., they accept more than one solution or several ways to find a solution (Rocard, 2007), allowing students to develop and use their own strategies. In addition, inquiry tasks are highly challenging, i.e., they enable students to observe and explain phenomena, plan research, make predictions, draw conclusions, make generalizations and solve problems (BSCS, 2017). Inquiry tasks can also be developed following different models, as the one developed by Bybee (1997). This model is based on a constructivist vision of science and suggests the development of inquiry tasks in a five phase cycle: engage, explore, explain, elaborate and evaluate. The cycle begins with engagement, which aims at motivating the students for studying a certain issue. So this stage seeks raising students’ interest and curiosity and as such it begins with a problematic situation. During the exploration phase, students have the opportunity to develop group work. They make questions, make previsions, raise hypothesis, make plans to test their hypothesis, register observations and discuss with peers the results obtained, comparing results and possible explanations and organize the information collected. Next, explaining, aims at

articulating observations, ideas, questions and hypothesis. So students are stimulated to use their own words to explain the concepts that emerged from the learning situation, to use the results to sustain their explanations, and to critically argue with their peers and the teacher. During the elaboration phase, students make connections with other concepts and mobilize learnt concepts and competencies in a new situation. Finally, on the evaluation phase, students reflect on the work that they have developed (Bybee, 1997). The benefits of IBSE in student learning are widely acknowledged in the literature (e.g. Furtak *et al.*, 2012). In an inquiry-based lesson, students play an active role in interpreting questions, in representing information and in creating problem-solving and planning strategies. In these lessons, students carry out the task in small groups and share results with the whole class. Therefore, in IBSE, classroom communication is key (NGSS, 2013).

One way for the teacher to set up the work on an inquiry task is to structure the lesson into three stages: introduction of the task, student autonomous work, and whole class discussion and final synthesis (Chapman, 1997). In the first stage, the teacher presents the task, gives the students instructions of how they will be organized during the lesson and asks questions in order to clarify any issues that can prevent the students from performing the task. In the second stage, student autonomous work, the teacher fosters the discussion of ideas in the group, thus allowing rich and productive interactions, and collects information of their individual participation (Stein *et al.*, 2008). In the third stage, whole class discussion, the teacher values the students' contributions, negotiates meanings and promotes shared learning in the classroom (NGSS, 2013). To end the lesson, the teacher summarizes the main points of the discussion and reinforces the language and symbols used. With this approach, i.e., in a lesson where students develop knowledge by discussing ideas and negotiating meanings (Cakir, 2008), the way communication flows is very important (Sierpinska, 1998).

However, research shows that preservice teachers have difficulty using communication in IBSE lessons (e.g. Davis *et al.*, 2006). For example, in Hayes' (2002) study, preservice teachers found it difficult to develop a way of questioning which would facilitate students' learning of scientific concepts. In a study by McNally *et al.* (2005), teacher communication was restricted to questions on student behavior. In another study, preservice teachers admitted that it was difficult to foster student inquiry, support them to draw conclusions and teach a lesson in which they worked in groups (Krämer *et al.*, 2015).

Lesson study

Lesson study (*jyugyoukenkyuu*) is a collaborative, reflexive, student-centered process that teachers use to research learning based on what students have learnt (Isoda, 2010). In a lesson study, participants begin by identifying a topic that will be taught and in which students have difficulties. Then, they deepen their knowledge about the topic, analyze how it is explored in the curriculum, analyze scientific articles on the difficulties and misconceptions of students in learning it, discuss the tasks that can be used to teach the topic, devise the task that they will present to the students and develop a very detailed and structured lesson plan, in order to help the students learn the topic. This stage, the planning of a research lesson (*kyouzai-kenkyuu*), is the longest in the lesson study and plays a very important role in professional development (Chichibu, 2016). Subsequently, there is the research lesson (*kenkyu jugyou*), taught by one of the participants according to the joint lesson plan, while the remaining participants observe and take notes. Afterwards, there is a post-lesson reflection (*kenkyuu kyougikai*) focusing on in-depth discussion of the students work in the task, based on the evidence gathered during the research lesson. The results of the teaching decisions made together are evaluated. The planning stage, the research lesson and the post-lesson reflection form the lesson study cycle. Should there be interest from the participants, a second or more cycles may be conducted (Fernandez *et al.*, 2003). In that case, the completion of new cycles involve new research lessons and their respective post-lesson reflections.

Lesson study is a teacher education process that allows preservice teachers to develop high quality teaching materials and to improve the teaching of a topic through the planning, delivery and observation of a lesson, as well as through in-depth discussion of students' results (Lewis *et al.*, 2006). Given the specificities of initial teacher education programmes, lesson study has to undergo several adaptations, notably as to how the research lesson is planned, how it is carried out as well as the post-lesson reflection (Larssen *et al.*, 2018; Ponte, 2017). Since the beginning of the twenty-first century, there has been increasing interest in the use of lesson study in initial teacher education, with encouraging results (Chichibu, 2016). For example, Zhou and Xu (2017) investigated the effects of microteaching lesson study on the learning of future physics and chemistry teachers in IBSE. The study was carried out in the scope of two courses of an initial teacher education program, involving 73 preservice teachers. The research lesson was taught by some preservice teachers to their peers. The results showed that those preservice teachers recognized that the lesson study allowed them to learn important aspects of IBSE. In addition, they valued the experience of planning an inquiry lesson and teaching that lesson. In the post-lesson reflection, they also valued the discussion of the lesson, in particular what was achieved and what needed improvement. In this study, the results also showed that the questioning conducted by the future teacher who taught the lesson and time management were a challenge for the participants. In a three-cycle lesson study in IBSE involving 24 future primary science teachers, Marble (2007) showed that, from cycle to cycle, participants paid more attention to student characteristics, managed time more effectively and learned to anticipate classroom questions. In the post-lesson reflection sessions, those preservice teachers provided valuable feedback that could improve the inquiry task, by fostering students' active involvement in classroom activities. Likewise, Hamzeh (2014) conducted a study involving 48 future science teachers, whereby 12 participated in a lesson study and 36 were a control group. In this lesson study, the research lessons were taught to K-10 and K-12 grade classes by three preservice teachers. The results showed that, when involved in a lesson study, the preservice teachers developed more positive attitudes toward IBSE. In addition, many of the preservice teachers admitted that the lesson study helped them understand what IBSE is, realize their potential in science learning and teaching, devise their own inquiry-based learning materials and feel more confident about using them in the classroom. Nonetheless, many have feared this approach to teaching as it represents something new and because classroom questioning requires the building of confidence. With different adaptations to initial teacher education programmes, the studies presented showed that, when involved in a lesson study, preservice teachers may become familiar with IBSE and value the approach.

Methodology

Participants

This research involved all preservice teachers (Carmo, Henrique and Sofia) who were attending a master in physics and chemistry teaching degree. In addition to the preservice teachers, the three authors of this article and the cooperating teacher of the classes involved took part in the sessions. The topic of this lesson study was the speed of sound, taught at grade 8 (ages between 14 and 15 years old) in the Portuguese public schools. The topic was chosen according to the cooperating teacher's school planning. The school was situated in Lisbon (Portugal) and students belonged to a medium-low social extract. In general, these students had difficulties in many physics and chemistry concepts and constituted an heterogenous class regarding achievement in these subjects, as assessed by the cooperating teacher.

Organization and structure of the lesson study

This two-cycle lesson study was conducted over 12 sessions involving 36 h. The first cycle consisted of ten sessions: in the first eight sessions were the planning stage, guided by the

instructor of the course (Sessions 1–8), this was followed by the first research lesson, taught by the cooperating teacher (Session 9) and the post-lesson reflection (Session 10). Then, there was a second cycle consisting of two sessions, namely the second research lesson, once again taught by the cooperating teacher (Session 11) and its post-lesson reflection (Session 12) (Figure 1).

During the two years of the master in physics and chemistry teaching program, the preservice teachers develop activities in school with the support of cooperating teachers. These activities are carried out in curricular units, with an increasing involvement of the preservice teachers in the schools. This research took place in one of these curricular units, more specifically in the second semester of the first year of the program. The cooperating teacher had 20 years of teaching experience and prior experience as cooperating teacher. She played an important role as the preservice teachers' model and had influence over their learning. The cooperating teacher participated in all sessions of the lesson study, as well as the authors of this paper. This was due to the fact that literature shows the importance of cooperating teacher and university supervisor in the learning to teach process (e.g. Zeichner, 2010). The two research lessons were taught by the cooperating teacher and the remaining participants in the lesson study were observers. The decision of the cooperating teacher to serve as a model, by teaching the research lessons and discussing them with the preservice teachers, is widely advised in the literature as it fosters the professional development of preservice teachers (e.g. Anderson and Stillman, 2010; Grossman, 2010). The following list shows a detailed description of the lesson study sessions:

(1) Planning (Session 1–8):

- Identification of the topic (i.e. speed of sound) and how this is explored in the curriculum reference documents and textbooks (Session 1).
- Student conceptions about the topic (analysis of scientific articles) (Session 2).
- Discussion of the level of challenge and openness of tasks in IBSE (the nature of tasks) (Session 2).

Figure 1.
Organization of the
lesson study

- Completion of different tasks on various topics, focusing on learning objectives, possible student reasonings and difficulties. Discussion of everyday contexts (Session 3-4).
- Development of the diagnostic task on the concepts of distance, time interval and speed (Session 5).
- Analysis of the students' results in the diagnostic task. Identification of the students' learning progress and difficulties (Session 6).
- Analysis of the transcription of a lesson in three stages and of the communication promoted by the teacher during these stages (questioning and whole class discussion) (Session 6).
- Completion of a set of tasks in IBSE on the topic. Discussion of contexts, learning objectives, possible reasonings and difficulties of the students (Session 7).
- Development of the research lesson task (i.e. topic task) and context selection. Focusing on the IBSE, the task allows students to interpret and represent information, to build and use problem-solving strategies, to explain a phenomenon, to make predictions, to generalise and to communicate the results to the class. The inquiry task is applied in a 45 min lesson. Students work in groups and are encouraged to solve the task autonomously. The task context is the thunderstorm phenomenon (Session 7-8).
- Development of the research lesson plan based on previous work (Session 8).

(2) Research lesson one (Session 9):

- The cooperating teacher teaches the lesson and the preservice teachers observe the students and take notes of their learning progress and difficulties. The preservice teachers use the research lesson plan to guide them.

(3) Post-lesson reflection (Session 10):

- Analysis of task achievement (difficulties and learning progress). Reflection on task achievement based on the lesson plan
- Adjustment of teaching strategies, task and lesson plan improvement.

(4) Research lesson two (Session 11):

- The cooperating teacher teaches the second research lesson to a different class. The preservice teachers observe the lesson and take notes of the learning progress and difficulties of the students, using the improved lesson plan to guide them.

(5) Post-lesson reflection (Session 12):

- Analysis of task achievement and adjustment of the task and the lesson plan.
- Reflection on the learning progress and the difficulties of the students.
- Reflection on the collaborative learning progress made after teaching the topic.

In this study, the lesson plan included the five dimensions to be used in a lesson study proposed by Roback *et al.* (2006) (Figure 2).

These five domains were developed in great detail and in close connection to each other (Harris and Rooks, 2010). So, at the beginning of the research lesson the task was introduced with the reading of a short statement of the problem to investigate (column 1), the duration of this activity was estimated (column 2), students' questions and difficulties in understanding the task and in devising a strategy were anticipated (column 3), the answers

of the cooperating teacher and their questioning were anticipated (column 4), and finally, the students' learning and the evidence of their learning which enables assessment was taken into account (column 5). Both research lessons were organized in three stages: introduction of the task; student autonomous work; and whole class discussion and final synthesis (Chapman, 1997). The communication to be promoted in the lesson by the cooperating teacher in each of these stages was planned as shown in the following list.

Questioning of the cooperating teacher and aspects to keep in mind:

- (1) Task introduction: to ask a student to read aloud the text introducing the task. To question students about the meaning of thunder and lightning (the task context is thunder). To question students about the speed of light when compared to that of sound [...].
- (2) Student autonomous learning through group work: to encourage students to reread the text of the task and collaboratively analyze the information provided. If students raise questions about the interpretation of the task graph, encourage students to engage in group discussion [...].
- (3) Whole class discussion and final synthesis: to ask a student to go to the board to present the group's results and explain the decisions made. To encourage the discussion of the results with the other groups, starting with those who experienced more difficulty. To question the meaning of variable 1,020 m (this is the distance traveled by thunder] and the meaning of variable 3 s (this is the time of thunder propagation):
 - About distance: to encourage in-class group discussion: How many meters does thunder take to travel in a second? (340 m approx.) And in 3 s? (1,020 m approx.) And how fast does it take in each situation? (340 m/s):
 - About time: how long does it take for the thunder to be heard if you cover a distance of 680 m? (2 s approx.), etc. And how fast does it take in each situation? (340 m/s).
 - Extending the topic of thunder speed. Compare the speed of thunder in the situations discussed (it is the same).
 - To apply what was learned about the speed of sound. How far away do thunderstorms develop if the sound takes 0.5 s to be received? (170 m), etc [...].

Data sources and analysis

This is a qualitative and interpretive research (Erickson, 1986). Data were collected from participant observation with video recording (VR); individual interviews (I), carried out at the end of the lesson study; individual written reflections (IWR), done at the end of the planning stage; and a group written report made at the end of the lesson study (GWR). For analyzing data, we used an inductive strategy of content analysis, recurrently examining the data to uncover salient patterns and themes associated with the research

1. Learning tasks and activities	2. Expected duration	3. Student performances and possible difficulties	4. Teacher questioning and aspects to keep in mind	5. Learning objectives and student assessment

Note: Adapted from Roback *et al.* (2006)

Inquiry tasks and classroom communication

Figure 2.
Domains of the lesson plan

aims (Miles and Huberman, 1994). We begun by transcribing the video records of all sessions and interviews. After that, all documents from the different sources of data were read and the targeted text was segmented. Each segment was assigned a code according to the categories and subcategories listed in Table I. These categories and subcategories are formulated taking into account theoretical considerations on the nature of tasks and the usual stages in an inquiry lesson.

Results

Nature of inquiry tasks

In this lesson study, inquiry tasks that can be used in science lessons were widely discussed. For example, in the planning stage, it was discussed a paper about the level of challenge and openness of inquiry tasks. Then, a set of tasks of different nature on different topics was solved, paying attention to their level of challenge and openness. The level of challenge and openness of the tasks was varied. These tasks were focused in various topics, such as properties of sound, buoyancy, density of solids and liquids, weight and mass, gravitational acceleration, forces and movements. Most of the tasks were selected by the authors and the cooperating teacher but the preservice teachers also selected two tasks from textbooks, one about the properties of the sound and the other about the speed of sound. The tasks brought by preservice teachers had a closed nature, i.e. admitted a single strategy to reach a single answer or solution. In addition, for each question of the task, the learning objectives and possible students' reasoning and difficulties were identified. The potential of these tasks for student learning was much discussed with the preservice teachers. Later, in the planning stage, and in order to develop the task for the research lesson, several inquiry tasks on the topic were solved. In the discussion of these tasks, the same procedure was followed, again, focusing on the level of challenge and openness and the potential for the students' learning. With regard to the paper that supported this work, in her individual written reflection, Sofia mentioned:

The analysis of this paper on the nature of inquiry tasks allowed us to understand the difference between inquiry tasks and exercises [...]. [This] distinction helped me select the type of task to use in the research lesson and this is of utmost importance for my future teaching activity.

What Sofia learnt about the nature of the inquiry tasks was the starting point for further learning. She referred to this, for example, in her individual written reflection:

In inquiry tasks which are [of a] more open [nature] at first, the students do not have a method for solving the problem. When completing an inquiry task, the students need to understand the rubrics (or instructions) and define a problem-solving strategy, which implies greater involvement from them.

Category	Subcategory	Description
Nature of inquiry tasks	Open nature	Preservice teachers' views about the nature of tasks (open tasks have more than a strategy of solution and/or multiple solutions) and their potential for students' learning
	Challenging nature	Preservice teachers' views about the nature of challenging tasks and their potential for students' learning
Communication in a three-stage lesson	Introduction of the task	Preservice teachers' views about the communication promoted by the cooperating teacher during the introduction of the task
	Student autonomous work	Preservice teachers' views about the communication promoted by cooperating teacher during students' autonomous work
	Whole class discussion and synthesis	Preservice teachers' views about the communication promoted by the cooperating teacher during the whole class discussion and synthesis of the lesson

Table I.
Categories and subcategories of analysis

Thus, for Sofia, given the fact that inquiry tasks include problems that the students do not know how to solve at first encourage them to interpret the information and to develop problem-solving strategies. As such, in her opinion, the students become more actively involved in the learning of science. In fact, some of the inquiry tasks (discussed in planning stage) had the characteristics mentioned by Sofia. For example, in a task the students classified the instruments of an orchestra, using criteria defined by them. In another task, the students searched information about the factors that influence the height of sound on a stringed instrument. Afterwards, they planned and carried out an activity to support their answers. So, each student used his/her own strategies for solving the problem. According to Henrique, through inquiry tasks that have been previously prepared at the planning stage, "the students have different ways to reach a solution and this should be valued by the teacher. The students should not be given only one way of solving a problem" (IWR). By valuing more open-ended tasks in science teaching, Henrique, just like his colleague, showed deeper understanding of the role of tasks that allow students to have a more active role in their learning.

In addition to open-ended nature of inquiry tasks, the preservice teachers were also sensitive to their high level of challenge. This was evidenced, for example, in Henrique's individual written reflection:

The teacher should favour more challenging tasks in order to foster students' research skills [...]. With these tasks, not only do students learn [science] concepts and procedures, but also develop reasoning and communication skills.

Henrique valued inquiry tasks, which were widely discussed in the present lesson study, as they allow students to carry out a set of activities that favour the development of their reasoning, the understanding of scientific concepts and processes and the communication of their ideas within the class. The learning progress from inquiry tasks is an important step toward the use of more challenging tasks in the classroom in the future.

At the later part of the planning stage, the task for the research lesson was developed. Among other aspects, the task was developed based on the nature of the topic, the learning objectives, the length of the lesson and classroom interaction patterns. Accordingly, the preservice teachers said: "The task of the research lesson was designed to be carried out by the students in small groups [...]. The students are expected to work autonomously while they are on task, [i.e.,] to calculate the speed of sound without prior explanation on the part of the cooperating teacher" (GWR). For the preservice teachers, the fact that the students could carry out the task of the topic autonomously in small groups, i.e., without prior input by the cooperating teacher, was rather new. Such learning was an important contribution to teaching their lessons according to IBSE.

The characteristics of the task for the research lesson were also discussed by the preservice teachers in the planning stage. In their group written report, they mentioned some of these characteristics. For example:

The task [for the research lesson] included a graph and it was necessary for [the students] to interpret it in order to calculate the speed of sound [in this case, of thunder] [...]. Afterwards, [the cooperating teacher] discussed the speed of sound for different distances [of the thunderstorm] [with the students]. [At the end of the task] the students would have to conclude that the speed of sound remained constant. The goal was to lead the students to extend what they had learnt on the topic drawing on various concrete situations.

For the preservice teachers, the task for the research lesson had characteristics that allowed the students to interpret information from a graph, to develop problem-solving strategies, to draw conclusions and to make generalizations. In a teaching situation, these aspects are important for the learning of physics and chemistry. By being aware of them in the task of the research lesson, the preservice teachers showed they were well informed of how to develop and use inquiry tasks in the future when teaching this topic and

possibly other topics. Moreover, in their perspective, the duration of the research lesson affected the structure of the task. For example, in her individual written reflection, Sofia mentioned that “the inquiry task devised for the research lesson seemed more appropriate given the short duration of the lesson [...]”. The tasks following the 5E model require more lesson time.” Time constraints in reference to this teaching model were also mentioned in the preservice teachers’ group written report:

Due to time constraints, a question that could go much further, which would correspond to the Elaborate of the 5E model developed by Bybee, was not introduced [in the task for the research lesson]. The purpose of the question was that the students would be able to extend the speed of sound in the air to a learning context other than a thunderstorm. This question would have increased the level of challenge of the task.

For the preservice teachers, the task of the research lesson, which was developed in the present lesson study, could be more challenging if the lesson were longer. This example shows that they acknowledged the potential of using inquiry tasks in science teaching.

In short, the preservice teachers recognized that the inquiry tasks, which were widely discussed during the lesson study sessions, allow students to play a more active role, as such tasks entail situations that the students do not know how to solve. Furthermore, in their perspective, inquiry tasks provide opportunities for the development of student reasoning, the understanding of the concepts and processes of science and the communication of students in the class. The preservice teachers also recognized that, in the research lessons taught by the cooperating teacher, the students carried out the task on their own and in groups. They also admitted that doing the task allowed the students to interpret graphs, develop and use problem-solving strategies, draw conclusions and make generalizations. In their view, the duration of the 45 min research lesson was an obstacle to raising the level of challenge of the task.

Communication in a three-stage lesson

The communication promoted by the cooperating teacher in the research lesson in which the inquiry task was carried out was widely discussed in the lesson study. Previously, in one of the planning sessions, the transcription of a three-stage lesson was analyzed: introduction of the task; students’ autonomous work; and whole class discussion and final synthesis. For each stage, much attention was paid to how the teacher conducts communication (questioning, feedback and whole class discussion). Subsequently, in planning the research lesson, the way the cooperating teacher fostered communication in each stage of the research lesson was discussed. In every case, communication was discussed as a strategy to help students to carry out the task autonomously. Therefore, in the observation of the research lesson, communication was one of the aspects that the preservice teachers focused on.

With regard to the introduction, the preservice teachers stated that: “This is a key stage to involve the students and to make them feel motivated” (GWR). In addition to the motivation that the task provides to the students, particularly contributing to their involvement, the preservice teachers also acknowledged that:

This stage of the lesson, namely the introduction of the task, is extremely important because the teacher has the opportunity to contextualise the topic of the task and the key aspects that they want to emphasise, in more detail, without indicating what in fact the students are going to do during their autonomous work (GWR).

Consequently, for the preservice teachers, the communication promoted by the cooperating teacher in the introduction of the research lessons provided opportunities for contextualizing the topic and answering students’ questions, without providing immediate solutions to the task. Moreover, this lesson stage enabled the preservice teachers to value communication as a means for the teacher to know the students’

conceptions regarding the topic, as they stated in their group written report: “Regarding the task introduction stage, in the first research lesson, the [cooperating] teacher decided to question the students about the meaning of lightning and thunder and obtained very interesting answers.” In their opinion, the questioning conducted by the cooperating teacher in the introduction of the task fostered the individual participation of the students, allowing for creative responses. Furthermore, classroom questioning is actually a very useful way for the teacher to understand students’ conceptions.

The communication conducted by the cooperating teacher in the research lessons during students’ autonomous group work was also object of reflection by the preservice teachers. For example, in his individual written reflection, Henrique commented that:

In the development of student work, the teacher should know how to conduct teacher-student interaction, but without providing the answers in advance and to lead them in their reasoning so that they can get to what is intended. [Also], the teacher can guide the students into developing communication strategies that can help them overcome their difficulties. This can be done, for example, by referring to the discussion of group work using positive reinforcement.

In this example, Henrique acknowledged that the positive reinforcement from the cooperating teacher during the students’ autonomous work was a means of encouraging them to discuss their ideas in the group, and it helped them overcome difficulties and seek for their own solutions.

In the third stage of the lesson, i.e. during the whole class discussion, the preservice teachers also showed they had made progress in their professional development. For example, this is the case of Sofia, who said in her individual written reflection:

The third stage in the lesson is perhaps the most interesting one, as students present their answers and not only compare them with those of their peers, but also justify their reasoning and discuss how they could improve their answers. This is a very rich stage for the [cooperating] teacher as it informs [classroom] teaching.

Sofia valued the communication promoted by the cooperating teacher as this encouraged the students to communicate and to justify their results to the class and helped them to go further. In doing so, she recognized making important progress when it comes to her knowledge about communication taking place in science lessons. Accordingly, Sofia feels more prepared to lead her students into taking on more responsibility for their learning in the future.

Still on the third stage of the lesson, in the interview, Carmo commented:

The teacher checked the answers within each group and then she moved on exploring the topic from that point. When there was consensus, she moved on [to other questions]. When there was no consensus, the teacher kept on questioning the students until the expected answer was given.

Thus, for Carmo, the communication promoted by the cooperating teacher during the whole class discussion was useful to gather contributions from all students, to negotiate meanings and to build shared learning. What this preservice teacher learnt from the way the cooperating teacher used communication in whole class discussions will be fruitful for her teaching career as it will enable her to support her students in understanding science in the classroom in the future.

Regarding this stage of the lesson, in his individual written reflection, Henrique highlighted another key aspect of the communication promoted by the cooperating teacher:

Whole class discussion is undoubtedly the turning point of the lesson [...]. They should guide the sharing of students’ answers, by gradually supporting students completing their reasoning and getting their point across as they provide constructive input, by discussing with the students what they have achieved (positive reinforcement) and by informing them what is not correct or what was not reached.

According to Henrique, the way the cooperating teacher communicates in the classroom allows students to participate in the construction of shared learning. In fact, suitable classroom management can make it possible for all students to contribute to science learning.

The final synthesis is the culminating point of a lesson which required specific (cooperating) teacher-student interaction which the preservice teachers were sensitive to. For example, in her individual written reflection, Sofia commented that the “final synthesis is very important in the sense that it will be the stage where the concepts addressed throughout the task are summarized and it is at this stage that students are expected to make sense from the task.” In her opinion, the cooperating teacher ended the lesson by summarising the most important shared ideas and this was a very helpful way to help students make sense from what they learned from their work.

In short, in introducing the task, the preservice teachers valued the role of the cooperating teacher in conducting communication as a means of contextualizing the topic, in answering students’ questions and in understanding their concepts, without taking away the students’ curiosity about solving the inquiry task. During the students’ autonomous work, the preservice teachers valued the questioning of the cooperating teacher as this encouraged the students to discuss their ideas in the group. They also acknowledged that this enabled them to overcome difficulties and to develop reasoning skills. In the whole class discussion, the preservice teachers valued the communication promoted by the cooperating teacher as a means to encourage all students to communicate and account for their results and to build shared learning. And they valued the final synthesis which summarized the key learning issues, helping the students to understand the purpose of the task they had carried out.

Discussion

The results show that, in this lesson study, the preservice teachers learned to identify the characteristics of inquiry tasks that can be used in science lessons. This was noticeable, for example, when they recognized that learning the topic from an inquiry task enabled the students to interpret graphs, develop and use problem-solving strategies, in their groups and on their own, draw conclusions and make generalizations. The results also show that the preservice teachers acknowledged the potential of using these tasks in science learning. In this vein, they recognized that the open nature and the high level of challenge of inquiry tasks allowed students to develop their autonomy, their reasoning skills, their understanding of scientific concepts and processes, and how to communicate their ideas in the classroom. These results were largely due to an extended planning stage (two-thirds of the sessions) which enabled in-depth discussions on the nature of inquiry tasks and their development. The inquiry task selected for teaching the topic was widely discussed with the preservice teachers and it aimed to actively involve the students as they carried it out. The observation of two research lessons involving an inquiry task, and the in-depth analysis of the students’ work contributed to the preservice teachers’ learning about the use of tasks in IBSE.

Research in teacher education shows that preservice teachers have difficulty in understanding the nature of inquiry (e.g. Krämer *et al.*, 2015). In the present study, the preservice teachers learned to identify the characteristics of inquiry and understood its importance for student learning. They developed an inquiry task on the topic, in detail, observed how it was carried out in the classroom and improved it based on student achievement. Undergoing a second cycle in a different class allowed them to observe the specificity of teaching and improve teaching materials (task and lesson plan). In fact, the development of teaching materials in a lesson study (Lewis *et al.*, 2006) is an opportunity for preservice teachers to learn how to devise those resources and to develop a more student-centered approach to science education (e.g. Juhler, 2017). Furthermore, the materials developed in a lesson study can be used later when teaching a topic in line with IBSE, thus addressing the problem of the scarcity of teaching materials (Fitzgerald *et al.*, 2017).

Other studies, using other teacher education models, showed that the involvement of cooperating teachers in the planning lessons, giving feedback and supporting the preservice teachers is crucial for their learning (e.g. Zanting *et al.*, 1998; Zeichner, 2010).

As to the communication promoted by the teacher in a three-stage inquiry lesson, the results show that, in several situations, the preservice teachers recognized the way in which the cooperating teacher attempted to guide the students to learn the topic. For example, in the first stage of the lesson, they valued the way the teacher contextualized the topic and analyzed the students' conceptions. During students' autonomous work, the preservice teachers valued questioning as a way to encourage them to discuss their ideas in groups and to create their own problem-solving strategies. In the final stage, namely, whole class discussion and final synthesis, the preservice teachers recognized that the questioning conducted by the cooperating teacher encouraged the students to communicate and to account for their achievements with the rest of the class. They also considered that the communication conducted by the cooperating teacher enabled the construction of shared learning and summarized the most important concepts addressed in the lesson. According to the preservice teachers, this procedure allowed the students to make sense of the task that they carried out.

These results show that, in a lesson study, it is possible for preservice teachers to acknowledge that the way how classroom communication occurs is critical for student learning (Sierpinska, 1998). Indeed, the literature points out the fact that having the cooperating teacher as a model in the teaching process is a key factor impacting the efficacy of the professional development of preservice teachers (Grossman, 2010; Zanting *et al.*, 1998). Two factors that contributed to the obtained results were highlighted: the planning of the lesson included the communication to be promoted by the cooperating teacher and the fact that she served as a model for teaching the research lesson. The detailed planning of the research lesson, valuing the questioning of the cooperating teacher in all stages of the lesson allowed the preservice teachers to recognize that the way the teacher conducts communication in the classroom is very important to help students learn. In fact, in Harris and Rooks (2010) model, classroom communication, combined with other elements of the educational process (task and student), is at the heart of science education which is in line with international recommendations (e.g. NGSS, 2013). Moreover, the fact that the cooperating teacher taught the research lesson, communicating according to well-defined learning objectives, allowed the preservice teachers to value classroom interactions and negotiation of meanings, as emphasized by Cakir (2008).

The literature shows that it is necessary to support preservice teachers to value multiple classroom interactions (Magnusson and Palincsar, 2005) and to develop a more integrative perspective of communication in the educational process (Woolfolk Hoy and Weinstein, 2011). In this research, the results show that these preservice teachers understood the role of the cooperating teacher in conducting communication to promote student learning, thus catering for the needs highlighted in other studies regarding the role of the teacher in conducting classroom communication (e.g. Magnusson and Palincsar, 2005).

Conclusion

Future teachers need to learn how to create teaching opportunities that enable students to learn science through inquiry (NGSS, 2013). In this research, the preservice teachers learned to identify the characteristics of inquiry tasks, developed an inquiry task to teach the topic and acknowledged its potential to foster student learning. In addition, they understood the role of the cooperating teacher in conducting communication in an IBSE lesson and in student learning during the different stages of the research lesson.

In this lesson study, eight sessions were dedicated to planning, during which the nature of inquiry was widely discussed. At this stage, the preservice teachers became familiar with inquiry tasks that can be used in science lessons and developed a task that would allow students to learn a physics topic through inquiry. These activities had an impact on the learning of the preservice teachers regarding the characteristics of the inquiry tasks. As in previous lesson study research (e.g. Chichibu, 2016), during the planning stage, the preservice teachers learned important aspects of their profession from more experienced teachers. In this lesson study, an experienced IBSE teacher taught the research lesson, allowing the preservice teachers to observe students' learning from an inquiry task. After the lesson, the preservice teachers were encouraged to reflect in depth on the students' work on the task and to suggest strategies that could help them improve the task and the lesson plan. A second research lesson and post-lesson reflection was held, enabling the preservice teachers to observe the results of the teaching strategies used, some of which were suggested by them, based on the students' previous results. This enabled the preservice teachers to participate in a lesson in which the way of conducting communication was decisive in supporting students to learn the topic through an inquiry task. As Isozaki and Isozaki (2011) pointed out, observing experienced teachers in a lesson study is a very useful way for preservice teachers to learn to act as teachers.

It is well documented in the literature that a good connection between university courses and school activities in initial teacher education programmes contributes for the professional development of preservice teachers (e.g. Darling-Hammond, 2006; EC, 2015; Grossman, 2010; NCATE, 2010), which is also underscored in this research. As such, the adjustments made to the lesson study process to fit initial the teacher education program seemed suitable. In fact, the support of the cooperating teacher and of the university supervisors during the planning phase and setting up the cooperating teacher as a model in the research lessons were crucial arrangements of this lesson study. Therefore, the results of this research can contribute to a better understanding of lesson study in the initial teacher education of physics and chemistry teachers. Conducting lesson study in initial teacher education programmes also contributes to a smoother transition into the induction period (EC, 2015). In addition, it contributes to reconceptualising teacher professional development as a journey rather than an end (McMahon *et al.*, 2015), thus mitigating the idea that preservice teachers at the end of their internship are able to exercise their professional activity similarly to experienced teachers. In this research, the cooperating teacher and the team members have substantially supported the preservice teachers to deepen issues related to their courses, in the context of teaching practice. This was done within an ethos where everyone felt confident and in which the participation of the preservice teachers was highly encouraged and valued, as recommended in literature (e.g. Sykes *et al.*, 2010). However, little is yet known about the role of teacher educators in the development of preservice teachers in initial teacher education programmes using lesson study. In order to turn this teacher education process into a well-grounded empirical practice, research is needed as regards how initial teacher education providers may contribute to the learning of preservice teachers in lesson study in initial teacher education programmes.

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