Chapter 3

Transformative Orientation in Learning to Teach Physics and Chemistry

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Additional information is available at the end of the chapter

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Abstract

Initial teacher training (ITT) involves different perspectives regarding the role of theoretical versus practical knowledge in teaching and requires an answer to how students integrate theory and practice and how learning environments contribute to this integration. Many authors have been advocating the idea of teachers as researchers of their own practice as a way to establish connections between theoretical knowledge and the knowledge gained from their practice. The ITT program of the University of Lisbon is based on a conceptual framework that proposes that student-teachers construct professional knowledge from researching their own practice in a context of supervised practice. This paper aims at describing the interpretations that student-teachers make about the Portuguese science curriculum, as well as describe the research questions and methods that they used for collecting data concerning students learning, and their evaluation of the learning process. For that, 31 written reports were analyzed. While involved in the design of the didactic proposals, student-teachers were encouraged to interpret the formal curriculum and turn it into a teaching curriculum, and to critically reflect on the curriculum. By researching their own practice, they developed new understanding regarding students' difficulties, promoting students' conceptual change and managing classroom and students' behavior.

Keywords: initial teacher training, research of own practice, reflection, professional knowledge construction

1. Introduction

Initial teacher training (ITT) is a matter of debate among scientists, educators and educational researchers. Scientists advocate for greater scientific training with explicit criteria about scientific competence based on scientific disciplines, while educators and educational researchers call for greater pedagogical and didactic expertise based on educational research.

Notwithstanding, both sides defend professional practice based on theoretical knowledge. They both acknowledge that through practice, one can acquire professional knowledge, while also recognizing that the dominant influence of the practice may prevent the use of more innovative strategies [1]. Adding to the debate and from a different perspective, students consider the teacher training programs to be too theoretical and are calling for a greater practical component [2]. So ITT involves different perspectives and debate regarding the role of theoretical versus practical knowledge in teaching and requires an answer for how students integrate theory and practice, and how learning environments contribute to this integration.

According to recent perspectives, teaching involves a process of knowing and acting, while simultaneously presupposes the unity of thought and action and the rejection of the duality of knower and the object known [3]. Teaching requires the use of specialized forms of knowledge for promptly responding to the problems arising from teaching practice. Indeed, teachers engage in a process of dialogue with their practice that provides either the construction or the reconstruction of their knowledge concerning practice. Teachers do not just find a solution to a problem; they have to start by equating the problem by understanding a problematic and uncertain situation, and then, they have to go through a specific process of decision making considering the purposes to be achieved and the means to be achieved. So the deliberation process involves thinking about the consequences of the actions outlined, using the knowledge already gained through teaching, and it provides increased knowledge that can change future actions and decisions.

One important point is that problems are reconstructed and interpreted from real situations. Indeed, according to several authors [4, 5], teacher experience is an important source of teachers' learning. However, learning from experience is only made possible if teachers are able to reflect on their own practice, looking at it from different angles and building new meanings from it. This involves a process of personal reconstruction of professional practice, which escapes the *"canons"* of technical rationality. Indeed, the resolution of the problem depends on how it is equated, the meanings attributed to the different aspects that are involved in the problematic situation and the application of knowledge already gained from the professional activity in which teachers have been involved [6, 7].

Many authors have been advocating the idea of teacher as a researcher of his/her own practice, on the base that it is this dimension that allows teacher to go further away in his/her reflections and in exploring new possibilities for action [8]. Research about their own practices begins with an authentic question rooted on teachers' practice [9]. By researching their own practices, teachers are challenged to establish connections between theoretical knowledge and the knowledge gained from their practice [10]; also, it allows teachers to develop a different perspective about their own reality, as they become a participant observer of their own actions and decisions and the consequences of it [11].

Thus, researching own practices is a powerful tool in the teachers' lives, as it helps teachers learn about their students, about school and about themselves as teachers. It should also be noted that researching their own practices can go beyond the resolution of concrete problems and overcome the classroom boundaries, giving voice to teachers and making them constructers of educational knowledge [12].

For this reason, recently, many educational training models are based on the idea of teacher as a research of his/her own practice. Research in practice as a component of ITT has been advocated by several Portuguese researchers [12, 13]. Main arguments are: the investigative dimension allows teachers to become constructors of professional knowledge and not only users of knowledge produced by others [14]. In addition, it facilitates the development of questioning competencies of teaching practice and the contexts of practice, helping student-teachers learn from their own teaching practice, and throughout their professional career [15]. According to an ITT perspective, in the process of learning to teach it is necessary that student-teachers learn to consider the thoughts and actions of other teachers, while simultaneously they begin the process of researching their own practice. This process requires strategies for promoting critical reflection of the teaching practices as well as a learning context where they can communicate the results of their research. These two training processes—research and professional communication—contribute to student-teachers' professional development.

The ITT program of the University of Lisbon is based on a conceptual framework that proposes that student-teachers construct professional knowledge from their teaching supervised practice. According to this model, students design a didactic proposal taking into account the suggestions of the curriculum that they discuss in collaboration with the school teacher and the educational researcher; afterwards, they put the plan into action in the classroom (intervention). Simultaneously, student-teachers plan a research for studying their intervention. They collect data on students' learning that will be the subject of analysis and reflection. Afterwards, student-teachers write a report where they present the research questions, the theoretical rational, the description of the didactic proposal with justification of the chosen tasks, methods of data collection and analysis, the responses to the initial research questions and a reflection concerning the intervention and the research process as well as about their own learning. Finally, they publicly discuss the results of their intervention and research about the intervention.

Considering the importance of the ITT for professional knowledge and also educational research suggesting the importance of the process of researching their own practice for facilitating professional knowledge, it is important to know the student-teachers' perspective regarding this ITT model. This paper aims to describe the interpretations that student-teachers make about the Portuguese science curriculum as they are expressed in their options regarding the didactic proposal, as well as to describe the research questions and methods they used to collect data concerning students learning, and their evaluation of the learning process in which they were involved when they research their own practice.

2. Researching own practice for professional development

Over the last 100 years, many new ideas have been proposed, but few have made significant impact on the way that science is taught or learned [16]. Science education guidelines have been calling for an increase in inquiry-based instruction that situates the learning within the

context of scientific process and the nature of science [17]. These curricular documents are grounded in contemporary theories of learning as an active process centered on students. Accordingly, traditional expository teaching is now regarded as inadequate and less than satisfactory for every lesson, while at the same time, a greater emphasis has been put on the role of inquiry in science teaching [17]. This requires a change of teachers' knowledge, competencies, and attitudes. Although some of these ideas have been embedded in past reform efforts, it has proven difficult for teachers to create and sustain these roles in the classroom. Many reasons have been singled out as why innovation tends to be a difficult task.

Learning to teach effectively requires strategies that haven't usually been used by teachers in their classrooms. Through their own educational experiences, and by observing good and bad teachers, student-teachers have constructed models concerning how to teach, often without reflecting on the quality of teaching, and assuming all to be equally good. Thus, personal experience issues may contribute to the conservative character of their concepts and to the development of mechanisms of resistance to change [18].

In fact, student-teachers enter ITT programs with explicit as well as implicit conceptions about their future role as teachers [19–21]. These conceptions reflect and structure the ways in which they intend to behave and interact with their students, how they assess students' learning, and how they organize and manage classrooms. Student-teachers have varying conceptions of teaching and learning, which have a profound impact on their approaches to teaching and may result in resistance to change during the process of learning to teach in ITT programs. So, in the process of learning to teach science, it is necessary to facilitate the (re)construction of conceptions about teaching and help student-teachers to change their science teaching conceptions. Feeling competent and comfortable with the new strategies will be central to involve teachers (and student-teachers) with the required changes. In addition, teachers (and student-teachers) have to construct new content knowledge and a new understanding about the curricular innovations, which is often not an easy task [22].

As it is now widely accepted in the literature on student-teacher learning, new information and knowledge presented to student-teachers in teacher education programs needs to relate to their existing conceptions in order to enable learning [5, 23]. Student-teachers are encouraged to adopt a critical perspective toward the context of their teaching and to question themselves about their didactic conceptions so as to become open to innovation and change. However, often teacher (and student-teachers) are not familiar with basic methods of research and are reluctant to be researchers. Thus, it is important that ITT training provides situations that allow for reflection about actions and the development of research competences.

Research of their practices can be an opportunity to reflect about practice in a guided and sustained way. Research of their practice can be an opportunity to reflect about practice. The idea of teachers as researchers arose from a long process of contestation; presently, there are several conceptual models [1].

Teachers as researchers of their own practice involve developing a systematic and intentional research focused on their classes and school, with the goal to professionally develop as a teacher.

Research of own practice aims to solve professional problems and to increase the professional knowledge concerning those problems; and its main reference is the professional community instead the scientific community [12]. Sagor defines research of own practice as a study conducted by the teachers about their own work or about any aspect that will be a part of their work [24].

Zeichner and Nofke propose a four stage process for conduct a research of own practice. The first stage consists of the formulation of a research problem. The problem arises for any situation of the teacher's practice. The problem has to be clear and has to make an authentic contribution to the practice. During the second stage, the teacher as a researcher collects data. This requires a previous phase of planning the research, considering the research questions, available instruments and other resources. The third stage involves interpretation of the results and reaching conclusions. Finally, teacher as a researcher has to communicate his/her results and conclusions. This can be made formally or informally; nevertheless, this is a very important stage of the research as it allows sharing ideas, discussion different perspectives and evaluation of the research [1].

According to Sagor, there is no unique method to do this kind of research, but several. And he proposes a process consisting of four phases. The first one consists of clarifying goals of the research; at this point, the teacher as a researcher also defines validity criteria. The second phase involves theoretical articulation. At this moment, teacher develops a plan of a lesson (or a sequence of lessons), identifying key factors. Also he/she also plans the research, in order to assure that the research goals will be achieved. During the third phase, teacher implements the intervention and collects data. Finally, the fourth phase involves communication and reflection about the results of the research and also about the research itself [24].

Sagor proposes two types of researches: quasi-experimental research and descriptive research. Teachers are often involved in quasi-experimental research. Daily teachers use diverse teaching strategies. However, seldom students can achieve all defined learning goals. So teachers have to reflect on students' difficulties, raising questions such as: "What would happen if I change my teaching practice or strategy? Would students' difficulties be overcome?" These questions can be researched by means of a quasi-experimental research [24].

Descriptive research starts differently. Sometimes teachers feel that something have happened in their classes with their students or at their school, and they know that they need to do something to solve the problem. However, they do not understand the problem in the context of the school, and so they face difficulties with outlining possible strategies to solve it. Descriptive research aims at providing teacher with a rich description of the context, using operative theories for understanding it. So while in quasi-experimental research, the teacher as a researcher focuses on the efficacy of a new teaching strategy and its impact on students' learning, in a descriptive research, the teacher uses a theory to make sense of the context or a specific situation.

No matter the type of research developed, one important point is that research of own practice has always to follow quality criteria [12], such as the following ones:

(1) Research has to have a liaison with the teacher's practice [25].

(2) Research has to be authentic, by containing the perspective of the teacher and its connection to the social, cultural, economic and politic contexts.

(3) Research has to include a new element, whether in the research questions, in the methods or interpretation of data [26].

(4) Research has to have methodological quality, implying that the research has to be guided by a research question, it has to involve a detailed description of data collection methods and analysis, it has to involve data triangulation, and conclusions have to be supported in evidences [10, 27–29].

(5) Research has to involve a moment of sharing and communicating the results, which will be evaluated by the peers; it is the phase that confers legitimacy and relevance to the study performed [10, 12, 25, 28].

3. Methodology

A qualitative and interpretative approach was used for analyzing student-teachers' didactic proposal, the research of own practice and professional learning.

3.1. Data sources

Data sources were the student-teachers' reports about the didactic proposal and their own research, which were publicly presented and discussed with two experts in Science Education, one expert in Physics and one expert in Chemistry. All the reports were publicly discussed between 2010 and 2016. These are personal and also public documents. Many researchers use written documents to access teachers' thoughts. For instance, Bolin used written diaries to access teachers' thoughts about teaching. This researcher required the teachers to write down their daily lessons plan and to justify their curricular decisions [30, 31].

The reports about the didactic proposal and their own research represent student-teachers decisions concerning didactic proposal and students' tasks. In this study, we analyzed 31 reports, of which 71% were written by female student-teachers.

3.2. Data analysis

Accessing meaning contained in data is a task of the researcher; in this study, meaning was explored after data collection [32]. According to Miles and Huberman, the process of analysis involves the interaction of three types of activities: reduction, representation and organization. In order to reduce all the information, we started with previously defined categories of analysis (research questions, didactic proposal, methods and procedures, and professional learning) [32], and after an initial categorization, we re-read the reports and through a method

of constant questioning and comparison, we inductively created sub-categories [33]. These methods are appropriate to the goals of the study, that is, to understand the interpretations that student-teachers make about the curriculum, when they develop and put into action a didactic proposal, and to evaluate student-teachers' professional learning.

4. Results

In this section, we present our results concerning: (1) research question, (2) didactic proposal (3) methods of data collection and analysis and (4) professional learning.

4.1. Research questions

Research questions made by student-teachers as a starting point for their research were presented in the introduction chapter of their report, while the research methods and procedures were presented on the chapter IV, concerning the methodology. The research questions are answered when student-teachers implement their didactic proposal. Answers were presented on chapter III of their report, where they scientifically support their didactic proposal and students' tasks and assessment.

Most research questions are related to students' difficulties (84% of the research questions raised by the student-teachers). In addition, 48% of the research developed by the student- teachers aimed at identifying what students learned by being involved in the didactic proposal (e.g., specific scientific concepts—10% of the research questions, or specific competencies—10% of the research questions) and 19% of the researches focused on the potentialities of specific strategies for facilitating students' learning. In addition, most student-teachers (84%) asked their students to evaluate the didactic proposals (**Table 1**).

One of the student-teacher started with the question: "How does using a story for presenting a problem facilitate students learning of scientific concepts?" In order to answer this question, all

Type of research question	
Students difficulties (i.e., difficulties faced by the students when involved in a learning task)	84%
Students learning (i.e., what have students learnt after being involved in the learning task?)	48%
Specific competencies	
Conceptual change	
Concept learning	
Students' perception of potentialities of specific strategies for improving learning	18%
Other	18%

Table 1. Student-teachers' research questions.

the tasks proposed by this particular student involved reading—they all started with reading a story as a way to engage students with the topic studied. The topic studied was the sound and high and low pitches. After using the stories for engaging students with the topic, and according to the 5 E's model [34], students were then required to distinguish high from low pitches, based on daily sounds and objects.

This research question illustrates a focus on concept learning. Other students reveal similar, though more undefined, interests, such as learning in general. These students wonder how learning can be facilitated using specific teaching strategies. For instance, one student-teacher used a cartoon for engaging students with the task. This cartoon is about a young man who is playing piano and then starts wondering about the different sound produced by the instrument. This student-teacher asked his students to identify the characteristics of the sounds, by selecting a musical instrument that was constructed on the first lesson. Then, they had to design a plan in order to characterize the sound produced by the instrument.

Both didactic proposals have the same goal: to facilitate students learning considering the properties of the sound and to distinguish high and low pitches. Although they have the same didactic focus—concept learning, they started with differing research questions: one wanted to know how involving students in reading activities could facilitate concept learning and the other one, how engaging students by using cartoons would facilitate their involvement with the activities and then students concept learning.

Other student-teachers researched more specific issues, such as the potential associated to the use of wikis or to STS-E tasks. Two student-teachers aimed at identifying the potential that students attribute to learning through using wikis in the classroom. One of this student-teacher used a wiki with ninth-grade students for teaching Periodical Table of Elements, while the other student-teachers used a wiki for teaching a didactic sequence of Physics to 10th grade students. Students from 9th and 10th grades evaluated wikis very positively, identifying some shared positive elements; but also differing in some other issues. For instance, 9th grade students mention that wiki facilitated their learning as they were required to assume a more positive stance toward science classes and increased their motivation for science learning. As students state, they had to ask questions, to do internet search, to organize collected information, to collaborate with peers, and to report by writing. Another mentioned positive issue was improving their competencies and knowledge regarding ICT and group work. Tenth-grade students pointed: easy use, facility of accessing its contents from wherever and whenever, the possibility to upload interesting texts, videos, and/or links and relevant internet pages. Sharing information with peers was seen as very important as they were able to learn from their peers' questions and doubts. Another interesting mentioned point was the fact that as work is registered in the wiki, it is easy for them to monitor work progress and improvement, and also their own learning.

Other students who have also used wikis mention that it is a very important tool for communicating, easily and fast, with the teacher when they have difficulties or any doubt. Student-teachers who have used this resource do share the same perspective. All of them recognized that this type of resources facilitates collaboration with their students and monitoring of students' progress and so it facilitates students' learning.

4.2. Didactic proposal

Didactic proposals were analyzed considering chosen curricular theme, grade level taught, duration of the intervention, tasks presented to the students. Didactic proposals concerned themes from Physics as well as themes from Chemistry. All the interventions have to be put into action from January to May, depending on the schools and school teachers, and aligned with school calendar. So student-teachers are constrained to choose one of the thematic that will hold during a specific period of the school calendar. Also, the proposals were put into action to students varying from 7th grade to 12th grade (**Table 2**).

As proposals are aligned with the Portuguese Physics and Chemistry curriculum, there are some constrains of the themes chosen by the student-teachers. As such, most didactic proposals for seventh grade involve the themes: materials, energy and earth planet—solar system. In what concerns 8th grade, didactic proposals focus on the sound (Physics) and chemical reactions (Chemistry). On ninth grade, didactic proposals involved Periodical Table of Elements (Chemistry) and electric chain and electric circuits (Physics). As all student-teachers taught a class of Physics in 10th and 12th grades, all the didactic proposals focused on Physics. And as all student-teachers taught a class of Chemistry in 11th grade, all of the proposals focused on Chemistry.

Duration of each intervention varied from 450 min (i.e., 10 lessons of 45 min each) to 945 min (i.e., 21 lessons of 45 min). This difference in the duration of the intervention is mainly related to the curricular theme chosen as well as the period of the school calendar when it was implemented.

About 65% of the student-teachers used investigative tasks, according the 5 E's model. According to Bybee et al., investigative tasks allow students to experience learning situations that facilitate questioning, argumentation, and knowledge construction. This model proposes five stages for developing the tasks: engagement, exploration, explanation, elaboration and evaluation [34].

One of the tasks proposed by a student-teacher aimed at studying the characteristics of the sound, by starting with the presentation of a cartoon and some initial questions. Then, students were required to plan a research in order to study sound and high and low pitches, to

School subject		**School grade**	
Physics	55%	7th	26%
Chemistry	45%	8th	13%
		9th	16%
		10th	26%
		11th	13%
		12th	6%

Table 2. Interventions by school subject and school grade.

make and to report observations and to draw conclusions. Afterwards, students were challenged to develop the initial cartoon. Finally, students had to reflect on the task, stating what they have learnt by being involved in the task, the difficulties they faced, the process of group work and what they liked the most.

Another student-teacher presented a problematic question: students were challenged to choose a detergent for a washing machine in a situation where the public water has a high value of pH. In order to answer this question, students in group had to analyze the label of different detergents and to make some questions. Students found the answers for these questions by reading a text provided by the student-teacher. Afterwards, each group presented its ideas to the other groups. In the second part of the task, students had to plan a laboratory activity with the goal to compare hardness of samples of different waters. They then enacted their plan and shared their conclusions with the class. Finally, students were directed to explore a site with information about care of washing machines. The tasks ended up by challenging students to reflect, individually and written, about what they have learnt, their difficulties and the interest they had in the task.

About 16% of student-teachers mentioned solving problems as a teaching strategy. All of these student-teachers started from a problem which solution could only be found after students were involved in a laboratory activity. In general, students involved in the problem resolution task were required to search for specific information either in text books or via the internet, to get involved in group discussion, to prepare replies and presentations to colleagues with debate involving the whole class.

Reading texts is one more teaching strategy, which was used by 16% of the student-teachers; generally, this teaching strategy was used with secondary school students (10th, 11th and 12th grades). In some learning tasks, reading texts is used within a STS-E approach. In all the learning situations, students were required to read alone in order to answer a set of questions; reading was followed by a discussion in small group and exposure of the group ideas to the whole class. In some of the learning tasks, students were required to write questions about the text and then to search for an answer either by reading their text books or searching in the internet.

About 54% of student-teachers used questioning and debates as teaching strategies, mostly used with secondary school students. Student-teachers questioned their students during the lesson, after exposing the theme or after students concluding a learning task.

Lab work was used by 39% of student-teachers, mostly with secondary grade students and in lab-classes. Some of the student-teachers used tasks as proposed in the textbook, which had some investigative characteristics but did not follow 5 Es' model.

Only 9% of the student-teacher used visualizations in their classes. One of the student-teacher started the lesson about the "Role of fossil fuels in World's Development", by asking the students the watch a set of videos available on YouTube ©. After this initial moment, students were then asked to make a list of all the topics and to write down relevant information. Students then had to choose one role and to pretend that they would have to present their

position in the Parliament about Exploration of fuel in Alentejo's cost. So watching a video was a starting point for involving students in a role-playing activity.

Finally, many student-teachers (39%) used distinct ICT tools for implementing different proposals, such as YouTube, wikis, internet for searching information or for presenting simulations, *Popplet* platform. These tools were used with students from all grades. In particular, wikis were used as a resource for helping students in the construction of a research plan: Students were challenged to share their plan, how they would put it into action, the observations made and the conclusions reached. All groups were urged to compare their results with the results of other groups.

4.3. Methods and procedures

Developing research competencies is a central goal of the ITT. Indeed, it is intended that the student-teachers will develop this type of competencies, so that when they become teachers, they will keep on researching their own practices, in a systematic and rigorous way. Thus, it is important to describe the kind of methods and procedures that the student-teachers used for collecting and analyzing data concerning the implementation of didactic proposal (**Table 3**). All the student-teachers used participant observation and document analysis of documents produced by the students during the didactic sequence. Only one of the student-teachers did not carry on focus group interview for collecting students' evaluation of the didactic proposal; instead, this student-teacher has used written responses from the students. Audio record of the lessons was used by 29% of the student-teachers, who placed an audio recorder in each of the working groups, while they were working on the assigned tasks.

Two of the student-teachers also videotaped their own lessons besides using students' documents and focus group interviews. Pre- and post-questionnaire was applied by 21% of the student-teachers, before and after their didactic intervention.

All data collected by means of interviews, and audio and video records were totally transcribed for content analysis.

Methods	
Participant observation with field notes after the lesson	100%
Written documents produced by the students	100%
Focus group interview	98%
Audio record of work group	29%
Video record of the lessons	6%
Questionnaire before and after the intervention	21%

Table 3. Methods and procedures.

4.4. Professional learning

The written reports end up with student-teachers' reflections about their own learning during the process of designing and the implementation of the didactic proposal and from the discussions held both with the school teacher and the educational researcher. Student-teachers assigned great importance to the moments of reflection and to the possibility of researching their own practice. They considered that all the process was very important for learning about teaching. Mainly mentioned issues were: students' learning, designing learning tasks, classroom management and teacher's role.

Student-teachers considered that their involvement with this educational program contributed to change how they understand the role of teacher: from a perspective of teacher as a transmitter of knowledge to a perspective of teacher as guiding students' learning. For instance, one of the student-teachers wrote in the report:

"Research on my own practice contributed to develop a critical and reflective attitude about my own performance as a teacher and also to develop specific research tools, which will be useful when in the future I come across problems. On that time, I will be able to design a research and to find out solutions which are sourced on evidences" (Student-teacher 1).

Another student-teacher focused on classroom management, stating that he acquired a better understanding of the dynamics of the classroom which will allow him to improve students' engagement with the learning tasks and a better management of classroom discussions in order to take up the maximum of each individual contribution.

Another important issue mentioned by most of the student-teachers was that they learnt how to design and put into action investigative tasks. In addition, they recognized that these types of tasks create engaging learning contexts; also by being involved in these types of tasks, students are required to engage actively with learning, which is beneficial for their learning. Nevertheless, designing as well as implementing, this type of learning tasks was not difficult-free. For instance, one of the student-teacher mentioned that:

"Initially, I had difficulties in managing class behavior and time. Indeed, in the first classes, challenged by the nature of the task, students constantly cried for my help. As the class had so many students, I had a hard time in helping all the students simultaneously" (Student-teacher 15).

The difficulty that student-teachers experienced in the management of students' behavior led them to test different strategies and roles within the classroom, which reflects professional learning (**Table 4**).

Finally, student-teachers mentioned also the opportunity that they were been provided for improving and developing scientific and didactic knowledge.

	Description
Focused on students	Considering alternative conceptions of students
	Identifying students' difficulties with proposed tasks
	Recognizing learning strategies used by students
	Developing critical reasoning
Focused on teacher	Playing another role in the classroom: from knowledge transmitter to guiding learning
	Researching own practice as a strategy for learning to teach
	Promoting enthusiasm, and motivation for science learning
	Using scientific language carefully in order to avoid the formation of alternative conceptions
	Questioning the students to get them to make predictions, generalizations and formulation of questions
Scientific domain	Deepening Physics and Chemistry scientific knowledge
	Recognizing that in the evolution of science there are contradictory ideas that raise controversy
	Enhancing the role of science in society
	Relating the effects of society on the development of science
Didactic domain	Developing investigative tasks
	Developing open tasks using stories, visualizations, digital resources
	Learning how to assess students
	Selecting tasks that promote conceptual change
Teaching context	Managing different working groups
	Developing behavior-control strategies in the classroom
	Managing time allocated to the different moments of class

Table 4. Professional learning.

5. Discussion and conclusion

Since 2010, the ITT model of the University of Lisbon has intended to create conditions for the student-teachers investigate their own practice. By doing this, this model makes the student-teachers not just consumers of educational knowledge, but also producers of knowledge derived from their own practice.

The acquisition of professional knowledge is influenced by the experiences and conceptions of teaching [21]. Teachers hold different conceptions of teaching, namely traditional experimentalist, constructivist and social [35]. Thus, it is essential to identify student-teachers' conceptions of teaching, to bring it to awareness and to discuss how these conceptions influence their curricular decisions. Within this ITT model, while involved in the design of the didactic

proposals, student-teachers were encouraged to interpret the formal curriculum and turn it into a teaching curriculum. And so, they were led to critically reflect on the curriculum, considering such elements as what, how and why to teach this particular subject, and to consider the relevance of the subject taught for students and for society. In addition, student-teachers researched the implementation of the didactic proposal within the classroom. This moment required them to identify a previous research problem, to collect and analyze data and to reflect on students' learning and difficulties, as well as on conceptions affecting their decisions and actions. So by developing and implementing a didactic proposal and by researching their own practice, student-teachers were not only developing theoretical knowledge, but also they were using it to make sense of their teaching experience. In this process, they were confronted with tacit conceptions, which were analyzed and changed.

These experiences facilitated the development of professional knowledge. Indeed, student-teachers developed didactic proposals sourced on educational literature and deeply explored and discuss it in collaboration with the university teacher and the school teacher. The relationship between the university teachers and the school teacher, as recommended by educational research [36], encourages the connection between theory and practice, as student-teacher bring to the classroom "fresh" theoretical knowledge which will be put into action and tested in straight collaboration with the school teacher and his/her insights from the practice. In addition, the reflection about their practices and its impacts on students' experiences, supported with educational knowledge, assists them in building new meanings regarding practices and facilitates critical analysis of previous conceptions at the light of evidences that they collected during their practices.

Student-teachers evaluated positively this ITT model as they had the chance to experience different situations: (1) Discussions held with the educational researcher and school teacher, (2) Designing investigative learning tasks, which improved their didactic knowledge, reasoning and communication competencies, and (3) Researching their own practice, in order to reflect on the impact of their practice on their students' learning and to understand the influence of tactical conceptions on their practice.

However, despite the importance attributed to the reflection and to the construction of professional knowledge by the teachers as a way to break with non-reflected practices and conceptions, research show that teachers' practices remain more or less unchanged [37]. Even beginning teachers involved in recent innovative practices in contexts of ITT tend to adopt more traditional ones when they are placed in contexts of professional practice [38]. So despite the positive evaluation made by the student-teachers about the ITT model presented in this paper, it is important to have in mind that this was a sole experience and to wonder about the durability of its impacts on student-teachers. Indeed, one thing is being involved in a context of teacher training, and another thing is the deliberate will to keep on changing and implementing innovative practices that require effort, confidence and also a supportive school. Considering this, two questions emerge from this study. How do student-teachers transpose knowledge constructed during an ITT experience to contexts of professional practice? How to make the impact of ITT experiences last when student-teachers are involved in contexts of professional practice?

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