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Contribution of the research component in internship reports to the development of didactic knowledge of mathematics

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Abstract

In Portugal, the training of educators and teachers of the early years includes various components, requiring the conclusion of an internship report on the supervised teaching practice. In the Escola Superior de Educação de Santarém this report includes a research component. This qualitative study analyzes the role of research conducted by future teachers and educators in mathematics with regard to their professional development, aiming to identify aspects of didactical knowledge concerning the tasks, which are evident in these reports. The data are collected by documentary analysis of the reports made in the courses that enable to teach Childhood Education to the 2nd cycle of basic education, school years 2010-2011 to 2014-2015. The studies conducted involving various mathematical topics and the use of different kinds of tasks that rely essentially on the use of manipulatives and the promotion of various representations. The study evidence shows that the investigative component, focused on teaching and learning of mathematics, allows them to develop research skills and deepen their knowledge of tasks, in particular, the analysis and reflection of its implementation with students, their productions and work in the classroom. Future teachers and educators identify gains and suggest future action strategies.

Key words

Internship report; research; preservice education; didactical knowledge in mathematics.

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Contribución de la componente de investigación de los informes de prácticas en el desarrollo del conocimiento didáctico de las matemáticas

Resumen

En Portugal, la formación de educadores y maestros de los primeros años incluye diversos componentes, uno de ellos requiere la realización de un informe de etapa en la práctica docente supervisada. En la Escola Superior de Educação de Santarém este informe incluye un componente de investigación. Este estudio cualitativo analiza el papel de la investigación llevada a cabo por los futuros maestros y educadores en matemáticas con respecto a su desarrollo profesional, con el objetivo de identificar los aspectos del conocimiento didáctico relativos a las tareas, que son evidentes en estos informes. Los datos se recogieron mediante análisis documental de los informes realizados en los cursos que permiten enseñar de Educación Infantil a 2º ciclo de educación. Los estudios realizados implican varios hilos matemáticos y el uso de diferentes tipos de tareas que se basan esencialmente en el uso de manipulativos y promoción de diversas representaciones. El estudio muestra que el componente de investigación le permite desarrollar habilidades de investigación y profundizar su conocimiento de las tareas, en particular, el análisis y la reflexión de su aplicación con los estudiantes, sus producciones y espacio para trabajar clase. Futuros maestros y educadores identifican las ganancias y sugieren futuras líneas de actuación.

Palabras clave

Informe de prácticas; investigación; formación inicial; conocimiento didáctico de matemáticas.

Introduction

The preservice teacher education in mathematics should promote the development of the ability, of these future professionals, to integrate the content knowledge and mathematical processes, and the knowledge of the students to teach, according to their education and curriculum guidelines. It is important that this integration provides the opportunity to develop their pedagogical content knowledge in mathematics, mainly, on the tasks proposed, the classroom work and the students' learning processes. In Portugal, the preservice teacher education of the early years includes various components, requiring the writing of a final report on the supervised teaching practice. In the Escola Superior de Educação do Instituto Politécnico de Santarém this report includes a research component. In this exploratory study we analyze the role of this research, conducted by future teachers in mathematics, in their professional development, aiming to identify aspects of teaching knowledge that are evident in these reports. In particular, this article focus on teaching practice knowledge regarding the tasks, seeking to identify the key findings of its studies on how to teach, depending on the level of education, from pre-school to the 2nd cycle of basic education and highlight contributions of the investigative process.

Didactical knowledge in mathematics

Ponte e Oliveira (2002) presents four dimensions that make up the didactical knowledge: i) knowledge of mathematics, that includes the knowledge of the fundamental concepts and procedures of mathematics teaching, types of representation of these concepts and, connections between mathematical topics or between mathematical and non-mathematical topics; ii) knowledge of students and their learning processes, regarding the knowledge of how students learn, their difficulties and the strategies they use; iii) knowledge of the curriculum, and iv) knowledge of instructional processes, ie, knowledge about the lesson preparation (planning and building tasks), on the conduct of the teaching-learning situations (dynamic class) and the after-class reflection. Ponte (2012) identifies the instructional knowledge as "the fundamental core of teaching knowledge" (p. 88), as it is in this context that the teacher performs the main options, relying on the other three dimensions. Thus, in the didactical knowledge, future teachers develop new knowledge of mathematics that allow them to relate key concepts to situations, representations and diversified models especially important in the teaching and learning process. Planning classes also requires mathematical knowledge (Gómez & Rico, 2004), as well as curriculum knowledge. The development/selection of tasks and resources, and the organization of the students' work, as well as the evaluation of their learning, also require in-depth knowledge of the learning processes of students, specific to the various mathematical topics.

Serrazina (2012) points out that "in teacher training don't think only on what should be taught, you must also equate as teaching" (p. 267-268). Thus, initial training should enhance the discussion of the importance of how the teacher organizes the learning of mathematics. The teacher must be aware of the choice and use of teaching materials, namely, tasks, manipulatives, computer resources, tools and teaching techniques that provide challenging learning environments for students (NCTM, 2000). As for student learning, the teacher must meet several aspects in their teaching practice; particular consideration must be given to the type of tasks. Ponte (2005) organizes the kind of tasks according to two dimensions, the structure (open or closed) and the degree of difficulty (low or high), thus identifying four key tasks: exercises, problems, exploration and investigations and, games and projects. Ponte e Serrazina (2004) identifies that for a long time the predominant task in teacher practice was the exercise, and that the others gained more expression since the 80s of last century. The study by APM (1998) identifies that, exercise is the task that teachers say they use always or on many classes; problems arise as the second most frequent task. Situations of work of a more "open" nature, as exploring tasks or research, or projects (these develop over a longer period of time and that may involve several classes), are rarely used by teachers. This study also shows that the main resource used by teachers is the manual, which in turn, is the main source of tasks. The nature of the tasks can also be analyzed by their cognitive level (Stein & Smith, 1998) including the factors associated with maintenance of high level cognitive demands, and also in relation to the representations that they promote: active, iconic and symbolic, identified by Bruner (1997) and cited by Boavida, Paiva, Cebola, Vale e Pimentel (2008). Ponte (2014) argues that the tasks selected by the teacher have great influence on student learning. Also according to the NCTM (2000) "students learn mathematics through the experiences that teachers provide" (p. 17), so the teacher has the responsibility to select tasks that provide diverse learning experiences to students, taking into account the learning objectives. Combined to the tasks are the representations. Students have to know how to interpret the representations of statements and also to select the representations that allow them to express their way of solving a given situation. In addition, Ponte (2014) states that students have to learn to make representations. The teacher has, thus, several components to

consider when selecting a task, and that "in addition to providing an opportunity to work certain mathematical concepts and procedures, have to meet the fundamental aspects of related learning with the way the student builds their knowledge working in different contexts " (Ponte, 2014, p. 26).

The role of research in preservice education

Preservice education should, as much as possible, involve the future teachers and educators in research practices of their own practice. In one hand, it can be aimed at changing some aspect of practice, after it is identified the need for this change and, in the other to improve the understanding of specific situations in practice (Ponte, 2002; Serrazina & Oliveira, 2002), aiming to the "definition, at a later stage, of an action strategy" (Ponte 2002, p. 7). Serrazina and Oliveira (2002) identifies the importance of the design and conduct of research in promoting reflection on the students, the change and the actual practice of teaching and learning, thus contributing to the development of professional knowledge of the teacher. The study Esteves (2004) in research and training strategy, in the initial training of teachers for the 3rd basic cycle and secondary education, identifies positive aspects in the implementation of this training strategy for research related to:(i) the process as it relates to the choice of work issues, their preparation, the definition of objectives, the relationships established, data collection; (ii) the products obtained, in particular concerning the development of knowledge and skills in the research and pedagogical relationship dimensions and "the balanced consideration of the role of theory, scientific research and research on the teachers practice" (Esteves, 2004, p. 222). Vieira and her colleagues (2013) found that integrated research on supervised educative intervention projects can contribute to reflective practice, "where research is at the service of understanding and transforming the educational experience and where this is the axis of the (dis / re) construction of the thought and action of future educators and teachers "(p. 2653). In addition, there are referred some limitations, particularly with regard to knowledge about research and to the ability to establish a link between, data collection and, analysis and pedagogical decisions.

Metodology

The study, of a qualitative and exploratory nature, focuses on the research component of final reports of, future educators and 1st cycle and 2nd cycle of teachers of basic education, whose problematic focuses on the teaching and learning of mathematics. The study aims to identify the role of research in their professional development, particularly regarding the didactical knowledge in mathematics that emerges from that research. All reports are analysed according to the subject of mathematics teaching and learning, in courses that enable the teachers from pre-school education up to the 2nd cycle of basic education, and were thus performed by students of these Masters Educational Programs at the Escola Superior de Educação do Instituto Politécnicos de Santarém, in the school years 2010-2011 to 2014-2015, as presented in table 1:

Table 1.

Final reports by Educational Program

Educational Program	**No. of reports**
Master in Preschool Education (MPE)	2
Master in Preschool Education and Teaching of the 1st cycle of Basic Education (MPE1C) (year 1 to 4)	5
Master in Education of 1st and 2nd cycle of basic education (ME12C) (year 5 to 6)	5

A documentary analysis, of the internship reports that focuses on the chosen topic, the keywords, the summary, the findings of the study and the final reflection, is performed. It is carried out a content analysis which is based on i) subject and fundamental topics of research; ii) nature of research and study design; iii) Data collection; iv) knowledge about the tasks for the Mathematics teaching (type of task, cognitive level, representations and resources); v) reflection on the importance of the research process. Each dimension consists of subcategories for which we identify what final reports to include and the respective evidence in the mentioned reports. Thus, the data analysis focuses on the themes, the nature of the tasks, the resources used and the contribution of the investigative component identified by the future teachers and educators.

Results

The research component of the final reports include a theoretical deepening of the theme selected by the future teacher and educator and the definition of an appropriate methodology to the study's objective. Following is a summary of the distribution of reports by course and subject of mathematics teaching and learning, as well as evidence of the internship reports regarding to the knowledge of the tasks and the reflection of the future teachers regarding the research process of developing this knowledge.

Themes and methodological options of the studies

Of the 12 internship reports whose research component has focus (Table 2) in the field of mathematics, 2 are performed by preservice educators in Preschool Education, 5 by the preservice educators and teacher in Preschool Education and Teaching of the 1st cycle of Basic Education and 5 by the preservice teachers in Education of 1st and 2nd cycle of basic education (Table 2). The mathematical topics covered are diverse: data collection, organizing and analysis (pre-school and 1st Cycle); geometry and measurement (1st and 2nd Cycle); algebraic thinking (1st Cycle); numbers and operations, in particular rational numbers, multiplication and division (1st and 2nd Cycle). Some of the reports focus also in educational resources (manual, games, tasks, manipulatives) and in the dynamics of math classes, particularly in exploratory teaching and in the investigative cycle of collection, organizing and analysis of data.

Table 2.

Research focus on internship reports progress

Educational Program	**Research focus**	**Years involved**
MPE	Data collection, organizing and analysis (AF)	Preschool
	Didactic games for classification and sets (AA)	Preschool
MPE1C	External representations in mathematical problem solving (AM)	2nd and 3rd years
	Promoting understanding of multiplication (PS)	2nd and 3rd years
	Analysis and generalization of growing pictorial sequences (FC)	4th year
	Difficulties in the construction and interpretation of graphs during collecting, organizing and analysing tasks (DA)	2nd year
	Use of manipulatives in conjunction with the textbook might promote further / consolidation of mathematical concepts (division and rational numbers) (CD)	4th year
ME12C	Teaching and learning of rational numbers and use of manipulatives (AC)	3rd and 5th years
	Use of games in the development of spatial sense (SM)	3rd and 6th years
	Problem solving in exploratory teaching of mathematics (JG)	6th year
	Problem solving in exploratory teaching of mathematics. Determination of perimeter and area figures in the plan in situations involving manipulatives (ID)	6th year
	Geometric solids models in learning geometry (AL)	5th year

All studies are qualitative, with a strong descriptive nature. They involve working with students of different levels and concern aspects related to the practice. Two of the studies assume a design research-action, nine with a case study design and one of the study does not identify the design research. The option for a case study design is related to the time available for the studies on the practice aspect, that is identified as difficult to manage and limitative by the future teachers, whose studies follow a methodology of action-research.

Preservice teachers support their studies in documents produced by the students, which is the most widely used data collection instrument between the 12 reports (Table 3). The audio and/or visual recordings: the recording of the interactions in the classroom, the picture of the final work or activity of the students and the video of the class, are also important means of data collection. Five studies also involve data collection by means of an inquiry to the students. Observation also plays an important role in these studies. However, this does not appear in a structured manner, not being clear about the objectives of the observation, its focus and how to register it.

Table 3.

Data collection tools

Tools	**No. of reports**
Not structured observation	8
Structured observation	0
Documents produced by students	11
Questionnaire to students	2
Questionnaire to teachers / educators	0
Interview to students	3
Interview to teachers	3
Records audio and / or visual classroom	8
Field notes or logbook	2

Emerging knowledge of tasks

The reports focus on tasks of different nature and include the study of diverse mathematical topics and transversal capabilities. Table 4 presents a summary of the nature of the tasks that were used for data collection in the twelve reports.

There is a predominance of problem solving and exercise tasks, but there is also the use of exploratory nature and game tasks. In some cases the students recognize the importance of the use of certain tasks with regard to the learning opportunities they promote in their pupils “As a future teacher I intend to continue to adopt this kind of work because I found that the students, when solving problems often in the classroom and having the opportunity to use different representations, have a better understanding of the concepts and mathematical relationships, and also acquire pleasure in learning of mathematics" (PM).

Several studies use problem solving as a promoter of learning, namely, AC, AM, JG and PS. PS identifies the development in students from the 2nd year for 3rd year in relation to their ability to understand the problems and application of an appropriate strategy. The results of this study allow to point out "the importance of the incidence of work in the development of mental calculation strategies and writing and the gradual understanding of

the operations and their meaning in the context of problem solving, in particular, multiplication"(PS). JG also uses problem solving, highlighting the importance of the exploratory nature of the educational approach in the classroom. The results show that "the resolution of problems, both in the introduction of concepts and in the mobilization of knowledge allows various strategies and various representations and can promote the connection to mathematical and not mathematical topics" (JG). Thus, concludes that the study reinforces the perspective "on the importance of problem solving in mathematics learning and the sharing of strategies, representations and the discussion in the classroom, as part of an exploratory learning environment" (JG). Two of the reports involve working with games, one in preschool and one in 1st and 2nd cycles of basic education. With preschool children, AA verifies the importance of working games with first ages children, "because with the realization of this game was notable the acquisition and consolidation of knowledge on the subject of classification, specifically in the formation of sets and the observation of similarities and differences between the parts, by children" (AA). For his part, SM offers students a game with manipulatives, under the geometry and measurement context. The study concludes that the realization of the experience in the classroom was "important to recognize the skills that the students have developed and that can be exploited through the game, using structured manipulatives geometry, as Geoboard and tangram" (SM). Performing a task of this nature allows to conclude that students need further experience with the structured manipulatives involved in the study." In addition, SM was able to check the contribution to the development of the knowledge and skills of the students, considering supporting their learning and allowing "to promote a discussion of the results, as students observe their constructions, represent them and describe them" (MS).

Table 4.

Task type

Task type	**No. of reports**
Exercise	4
Problem	5
Exploration	3
Investigation	2
Project	0
Game	3

As for the cognitive level of tasks, the references to the factors mentioned by Stein & Smith (1998) are still limited, as associated to the maintenance of cognitive demands of high level tasks, as shown in Table 5. These factors include: (1) the teacher encourages justifications, explanations and meanings through questions, comments and feedback and 2) the tasks are based on the students' prior knowledge, both with 6 related references (3) the teacher often establishes conceptual connections, and (4) to have ample time for the task (not too much nor too little) appears with 4 references.

Table 5.

Factors for maintaining the cognitive level of tasks

Factors	**No. of reports**
The teacher encourages justifications, explanations and meanings through questions, comments and feedback	6
The tasks are based on the students' previous knowledge	6
The teacher often establishes conceptual connections	4
It is allowed enough time to explore task (or more or less)	4

For example, AF identifies in his study the promotion of the children's learning within the organization and the processing of data by the articulation between the topics that the tasks promote: "There is care in carrying out tasks involving different mathematical concepts, encouraging the involvement of children" (AF). Also in this issue, but in the 1st cycle of basic education, DA highlights the importance of the teacher meeting the students' prior knowledge in the development or selection of a task. In his study, this lack of knowledge hampers the activity: "the fact that the students do not have prior knowledge of the graphic, makes its reading more complex. This occurred in several cases." (AD). Moreover, the study concludes that, like other authors mention, "the students have difficulties in filling a chart, partially constructed, associated with a given set of data" (DA).

In the promotion of algebraic thinking, HR study with growing pictorial sequences allows to conclude that "there are factors inherent to the structure of the sequence and the questions that can influence the strategies used by the students." It identifies factors as the type of sequence, noting that in crescent ones there is a change in structure from term to term, the order of the term, may be near or far, as well as the visual component provided by pictorial terms. Regarding the latter aspect, concludes that "students can interpret unexpectedly situations and activities and it is up to the teacher to manage the event and direct the student to what is intended" (FC).

In several reports analyzed it is evident the work with different types of representations (Table 6) and in some cases the students refer to connections between them.

Table 6.

Representations promoted by the tasks

Representations	**No. of reports**
Active	6
Symbolic	8
Iconic	6

The AM study has a particular focus on the analysis of representations in problem solving involving multiplication and division. It concluded that "the representations used in comparing different types of problems, protrudes the fact that there are some problems where the use of a representation is more evident over others, both in the 2nd year and in the 3rd year" (AM). The study notes that the use of pictorial representation prevails in the 2nd year, and that in the 3rd year the symbolic representation is more expressive, though more in some types of problems than in others. AM verifies the importance of using problem solving in promoting the understanding of the two transactions involved: "By the analysis of the representations used by the students, it was found an evolution relating to mathematical knowledge, for example, in the 3rd year the identification of division and relating it with the multiplication, with the addition by repeating parcels with the subtraction by subtracting successive parcels, showing an understanding of the relationship between the various operations" (AM).

Several of the situations studied are tasks that integrate the use of manipulatives. CA uses structured and unstructured materials aimed at the approach to rational numbers. In the study identifying the contribution of these materials for understanding the meaning of the fraction and the part-whole concept and of the concept of unit with continuous quantities, using the circular template and the rectangular model. It also found that the use of manipulatives contributes to the establishment of relations, "the students were able to identify and establish various relationships, especially equivalence relations. By manipulating the materials they found that there were several symbolic ways of representing the same amount, a number of equivalent fractions, making also various comparisons and ordinances" (AC).

In the study of another mathematical theme, geometry, ID concludes that "carrying out the tasks with the use of Geoboard and Pentominoes was positive and promoted the development of the students' skills and expanded their knowledge regarding the concepts of area and perimeter" (ID). In particular, it notes that the use of these materials allows to place" confronting the perimeter and area concepts, in order to clarify the same" (ID). It also identifies its contribution in the development of visualization skills, being for students as a "significant experience with regard to the display with the representation of figures in stippling, built in Geoboard and representation of figures in the graph built with Pentominoes" (ID). Also in this theme, AL notes the importance of working with geometric solids models in learning: "models of geometric solids contributed to the development of the ability to identify the properties of solids and classify (polyhedral and not polyhedral, prisms and pyramids)" (AL). Also, regards its contribution in identifying curved surfaces and flat surfaces and identifying prisms and pyramids as "with its exploration and analysis the students were able to deduce that the pyramids have only a base as the prisms have two congruent bases" (AL). In turn, CD identifies in his study the relevance of the implementation of different nature and resources to different teaching materials tasks, noting that the "combination becomes conducive to teaching and learning mathematics process. So with this study, I do not intend to compare these two textbooks, but to show a way you can use them in a complementary perspective on math class" (CD). Reinforces also that this study aims to "highlight the potential of educational materials, namely, the wielding materials and the textbook, when inserted in a structure/dynamic class that consisted of an initial phase with manipulation of the materials for the introduction of mathematical content articulating it with the resolution of the textbook exercises to consolidate the contents apprehended in a final stage" (CD). Still the same trainee relates working with materials (active representations) in order to promote the emergence of iconic representations. "In the evaluation forms it was found that a large proportion of

students resorted to pictorial representation of manipulatives, which appears to have been significant for them to use" (CD).

Reflection on the value of the research process

The research contribution is focused specifically with regard to the reflection on the value of the investigative process in the knowledge of the tasks. To this end, two dimensions are analyzed: (i) knowledge gained on the tasks and recommendations related to them, and (ii) limitations imposed by this particular research aspects. The twelve students identify in their reflections gains of knowledge of the tasks that the studies that they performed provided them, pointing aspects for their future practice. FC clearly identifies some factors that should be considered in selecting or building tasks aimed at work with growing pictorial sequences for its possible influence on the strategies that the students use: "For example, the fact that the sequence is increasing causes students to reveal more difficulties in their operation than in repeating sequences. . . Another important aspect is the order of the word order, near or far. . . the visual pictorial component provided by the terms of the sequence may also hinder or not the exploration and the generalization of the sequence" (FC). AA points integration conducting games in his future practice due to the results obtained in his study: "it will always be present to host several games in the most diverse areas for children to get new knowledge and better understand the content covered". Future teachers and educators also identify the relevance of promotional work involving children and students in enriching mathematical activity, assuming such a central role, as pointed AF: "The role of the child during these tasks was undoubtedly a very participatory and argumentative role".

The use of manipulatives is very relevant in some of this research and is also its relationship with the tasks subject of reflection by trainees: “Using the manipulatives I intend to create challenging tasks, enriching, dynamic and motivating in order to take the students to get involved in learning through active and concrete experiences” (AL).

Another aspect highlighted in the reflection on the research work refers to the selection and preparation of the completion of tasks by students, providing a significant activity of students. ID highlights her perception that “these must be well planned, so that during the same does not occur unexpected situations and that in the end the goals are achieved”. In addition, the research in some situations promote reflection on the students' knowledge arising from proposed tasks, particularly with regard to difficulties: “effectively contributed to the understanding of the difficulties that students show in the application of mathematical concepts and content, in particular by solving problems as well as proved essential in developing skills that students must mobilize day-to-day tasks” (JG); “After the task analysis can conclude that students showed difficulties regarding the reading of the charts in the categories read between data and read beyond the data (Curcio, 1989) and in graphics that are not complete by end also manifest difficulties in the category read data” (DA). These gains are articulated, explicitly in most reports, with statements relating to future practices, where preservice teachers presenting recommendations concerning the tasks and the need for its adaptation to the pupil group.

In internships reports is also evident the reflection of some preservice teachers regarding the limitations imposed by the research concerning the development of tasks. These limitations are related to the period of time that elapses, the management capacity of the data collection process, pointing the strategy of using more diversified data collection tools that facilitates and enhances the relationship between research and teaching practice. This path of research into practice in initial teacher education still needs further analysis to

identify contributions in other components of professional knowledge and a better understanding of how learners experience this process.

Discussion and conclusions

The research within the mathematics teaching and learning performed by the preservice teacher and educators involved in this study include the different levels of education, from pre-school to the 2nd cycle of basic education (up to year 6) and include various mathematical topics, transversal skills and performing tasks of different natures which are based essentially on the use of manipulatives and promotion of various representations. Thus, the focus of research in teaching practice shows contributions to the knowledge of the teaching and learning of specific subjects, the nature of the tasks and the importance of each type of task in learning, particularly problem solving and games, as well as manipulative material associated. Furthermore, the analysis of aspects of knowledge of teaching practice reveals the relationship with other aspects of the didactic knowledge that Ponte (2012) identifies. In particular, from the various works emerges a reflection on the knowledge of the learning process, the students' knowledge, their difficulties and strategies, on selection of tasks and during the conduct of classes, reflecting as teaching, evidenced by Serrazina (2012) as essential in the training education.

The research component present in the reports allows to develop research skills and deepen their knowledge of tasks, namely by the analysis and reflection of its implementation with students, their productions and work in the classroom. Preservice teachers and educators identify gains and suggest future action strategies. The preparation of data collection instruments that are relate mainly to the work in the classroom, in particular the preparation of tasks aimed at the collection of student written productions and the analysis of this work is a central elements of the research work carried out. Preservice educators and teachers recognize contributions to a better understanding of the teaching and learning of mathematics that are realized by both the process and the product achieved, as identified Esteves (2004). Nevertheless, some difficulties emerge during the investigation process concerning the implementation of the teaching and learning situations in the classroom and their simultaneity with data collection as part of an investigation of their own practice. This challenge of research on their own practice should play an important role in the teacher educational programs, considering the difficulties that you may underlie, but mainly focusing on their contributions to the reflective practice, identified by Vieira et al. (2013), and development of professional knowledge.

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