RESEARCH DESIGN IN SCIENCE EDUCATION

CONCEPÇÃO SOBRE A INVESTIGAÇÃO NO ENSINO DE CIÊNCIAS

DISEÑO DE LA INVESTIGACIÓN EN LA ENSEÑANZA DE LAS CIENCIAS

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ABSTRACT: The scientific literature has emphasized the importance of research experiences for students in initial teacher formation. Trying to better understand this scenario, the objective of this work was to investigate the perception of teaching degree students in Biological Sciences in a practical activity in research-based Science Teaching. To achieve this objective the students were accompanied in two practical disciplines during five semesters. During the development of the discipline's students were encouraged to keep notes about the whole process. At the end of the course an account of the activities developed was requested. This information was used as analysis material in this work. The data obtained suggest that the students' conceptions about the research and investigation process in education were related to the practice and interpretation of their own research project and that the experience of the project modified their conceptions about the research. This work presents that the experiences lived in the initial teacher formation instigate a greater reflection on the nature of research. In this way, I believe that the results presented here can contribute to the initial formation of these students.

KEYWORDS: Initial teacher formation. Pedagogical practices. Teaching by research.

***RESUMO**: A literatura científica tem enfatizado a importância das experiências de investigação para os estudantes na formação inicial de professores. Tentando melhor compreender este cenário, o objetivo deste trabalho foi investigar a percepção dos estudantes de Licenciatura em Ciências Biológicas em uma atividade prática no Ensino de Ciências baseado em investigação. Para alcançar este objetivo os estudantes foram acompanhados em duas disciplinas práticas durante cinco semestre. Durante o desenvolvimento das disciplinas os estudantes foram estimulados a manterem anotações sobre todo o processo. Ao final da disciplina foi solicitado um relato das atividades desenvolvidas. Estas informações foram utilizadas como material de análise neste trabalho. Os dados obtidos sugerem que as concepções dos estudantes sobre o processo de pesquisa e investigação na educação estavam relacionadas à prática e interpretação de seu próprio projeto de investigação e que a vivência do projeto modificou as concepções que os mesmos possuíam sobre a pesquisa. Este trabalho apresenta que as experiências vivenciadas na formação inicial docente instigam uma maior reflexão sobre a natureza da investigação. Desta forma, acredito que os resultados aqui apresentados podem contribuir na formação inicial destes estudantes.*

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PALAVRAS-CHAVE: *Formação inicial de professores. Práticas pedagógicas. Ensino por investigação.*

RESUMEN: *La literatura científica ha destacado la importancia de las experiencias de investigación para los estudiantes en la formación inicial del profesorado. Tratando de comprender mejor este escenario, el objetivo de este trabajo fue investigar la percepción de los estudiantes de grado en una actividad práctica en la enseñanza de las ciencias basada en la investigación. Para lograr este objetivo se acompañó a los estudiantes en dos disciplinas prácticas durante cinco semestres. Durante el desarrollo de las disciplinas se animó a los estudiantes a tomar notas sobre todo el proceso. Al final de la disciplina se solicitó un informe de las actividades desarrolladas. Esta información se utilizó como material de análisis en este trabajo. Los datos obtenidos sugieren que las concepciones de los estudiantes sobre el proceso de investigación e indagación en educación estaban relacionadas con la práctica e interpretación de su propio proyecto de investigación y que la experiencia del proyecto modificó sus concepciones sobre la investigación. Este trabajo presenta que las experiencias vividas en la formación docente inicial instigan una mayor reflexión sobre la naturaleza de la investigación. De este modo, creo que los resultados presentados aquí pueden contribuir a la formación inicial de estos alumnos.*

PALABRAS CLAVE: *Formación inicial del profesorado. Prácticas pedagógicas. Enseñar por la investigación.*

Introduction

The current reforms in Science Education in Brazil increasingly require changes in the way students learn. For most teachers, this requires reflecting on their own practice and developing new roles for both themselves, as a teacher, and for students (DARLING-HAMMOND; MCLAUGHLIN, 1995). In this perspective, Predebon and Pino (2016) highlight the importance of including in the initial formation of teachers practices that have an investigative character. According to this approach, investigation can serve as a means of involving students in the ideas, concepts, processes and practices of science (ADLER *et al.*, 2018). Although it is not the only way to teach science, inquiry-based teaching is believed to have a powerful influence on student learning (NRC, 2000).

Inquiry-based teaching encompasses a broad spectrum of approaches, ranging from structured, teacher-led research to student-led open research (NRC, 2000; MUNFORD; LIMA, 2007; SASSERON, 2018). In the structured investigation, students investigate a question presented by the teacher through a prescribed procedure, leading to a predetermined result, similar to following a prescription (KABERMAN; DORI, 2009). Unlike structured research, in guided research, students investigate questions and procedures that teachers

present to them, but the students themselves decide on the processes to be followed and can reach unpredictable but well-conceived conclusions (BLANCHARD *et al.,* 2010).

Inquiry-based learning can facilitate the acquisition of conceptual and procedural knowledge and understanding by promoting flexible thinking skills and epistemic practices (HMELO-SILVER; DUNCAN; CHINN, 2007; MUNFORD; LIMA, 2007; SASSERON, 2018). However, inquiry-based learning also presents numerous challenges for students, with teachers playing a key role in facilitating this process (HMELO-SILVER; DUNCAN; CHINN, 2007). Crawford (2000) expanded this scope and stated that the teacher in an inquiry-based classroom should assume a multitude of roles, such as motivator, diagnoser, guide, innovator, experimenter, researcher, modeler, mentor and collaborator.

Despite the central role of investigation in the teaching-learning process, teaching based on this process is rarely implemented in the classroom (WINDSCHITL, 2003; MUNFORD; LIMA, 2007; CAPPS; CRAWFORD; CONSTAS, 2012). Thus, many teachers end up using the traditional teaching model, reflecting the way they were taught, however there may be other reasons for the absence of these activities, such as: traditional beliefs about the teaching-learning process (SAAD; BOUJAOUDE, 2012), lack pedagogical skills (SHULMAN, 2013), lack of time (LOUGHRAN, 1994), inadequate knowledge of practice (SAAD; BOUJAOUDE, 2012) and inadequate formation. In light of these findings, one of the most difficult tasks that Teaching Degree courses face is developing the capacity of faculty to support their students during these activities. In order to overcome these difficulties in teacher training Harres *et al.* (2005, p. 2, our translation) states that:

> [...] researchers in the area, coming from different contexts, and even the new guidelines for teacher education in Brazil indicate the need to implement an investigative perspective in initial education. However, these innovations are not ready anywhere.

The learning related to investigative activities that teaching degree students have comes from the experiences of undergraduate courses. As in pre-school education, the higher-level teacher not only teaches the content of their courses, but also models teaching practices and strategies for future teachers in their classes (GROSSMAN; WILSON; SHULMAN, 1989). Thus, students need more explicit instructions on Science Teaching by investigation, including how to create knowledge through arguments based on exploration and evidence (ROGERS, 2009). Thus, the construction of these skills in teachers is essential to increase scientific literacy in students, consisting of a significant understanding of scientific concepts and skills (MUNFORD; LIMA, 2007; BHATTACHARYYA; VOLK; LUMPE, 2009;

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SASSERON, 2018), such as also in the interest for science (LEE *et al.*, 2008). To avoid the continuous cycle of negative or inaccurate portrayal of science in elementary and high school classrooms, it is imperative that teacher education programs prepare students more effectively, incorporating authentic research experiences into teaching degree courses, so that do not be superficially introduced into the investigation. (BAXTER *et al.,* 2004)

In this way, subjects that provide research experiences in the pedagogical formation of teaching degree students are extremely important in teacher formation so that they can build their own professional identity and develop such activities in the classroom (BREDA *et al.,* 2016; CUNHA *et al.,* 2016; STAFFORD, 2016; DATTEIN; GÜLLICH; ZANON, 2018). Teachers of teaching practices disciplines, for example, can offer opportunities for teaching degree students to conduct their own investigative activities in teaching and link their experiences in the classroom (e.g., OLIVEIRA; SCHNEIDER, 2016). These disciplines are configured in an important locus of research on the pedagogical practices of the teaching degree students. Combining the actions proposed by the aforementioned disciplines with investigative practices seems to be an important path.

Based on the topics covered, the aim of this work was to investigate the perception of teaching degree students in Biological Sciences in a practical activity in Science Teaching based on investigation. This work also analyzed how these experiences can contribute to classroom practice. Therefore, I intend to answer the following questions: i) What is the point of view of Teaching degreee students regarding research in the classroom?; ii) What is the contribution of research experiences in changing the conceptions of teaching degree students? iii) Teaching Practices disciplines help teaching degree students acquire skills in inquiry-based Science Teaching?

Methodology

This work features a multiple case study approach in order to make sense of the relationships between the subjects' conceptions and actions in relation to the investigation of their actions (HUBERMAN; MILES, 1994). The research participants for the development of activities correspond to students enrolled in the disciplines of Education Practices in Biology 1 and Education Practices in Biology 2 arranged over the years 2017 to 2019 (five semesters, 8 classes) of the Teaching Degree in Biological Sciences at the University of Brasília. The subjects of Teaching Practices in Biology 1 and 2 constitute subjects with practical activities developed in groups in which students propose and prepare an education research project to

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be implemented in the classroom with an investigative character, which can be completed in up to six months. Students at the beginning of the course are informed that the work culminates in a final presentation for the whole class and that the objective is to defend the elaborated proposal (theme, problem, methodology, result and conclusions).

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Data analysis was performed based on the theoretical assumptions of Bardin (2011) for content analysis. It is noted that, in summary, in this type of analysis, initially all the material produced is read and then, it is searched for words, themes, expressions that can be configured in analysis categories, which are later discussed and interpreted in confrontation with literature (BARDIN, 2011). The research categories emerged from the data contained in the reports, based on the students' reflections on the vision of research in Science Teaching and its relations with the disciplines of practice. The analysis resulted in 3 categories: i) the first section describes the reflections of the teaching degree students and their respective interpretations of the experience accumulated during research work in Science Teaching, ii) the second presents the understandings of research in Science Teaching, iii) and finally, the third reports the associations of practical disciplines with the exercise of an investigative activity. In order to preserve the anonymity of the students, the reports were named by the letter “EST” (referring to student) followed by numbering.

Results and discussions

Regarding experiences throughout the process of teacher education, most undergraduates (37, 82%) reported having three types of experiences related to the use of

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research in the classroom. However, the other teaching degree students (5, 18%) had misconceptions and opinions about this methodology. These students presented reflections relating the investigation process to other teaching methods (such as practical, experimental activities), suggesting that there is confusion with the term. These ideas relate to many of the misconceptions and myths that educators have about research (NRC, 2000).

The experiences mentioned regarding the experiences were: i) initial difficulties in proposing an investigation; ii) overcoming difficulties; and iii) experience a feeling of carrying out the activity. However, the reports presented varied in terms of the intensity with which the feelings were described.

In the initial phase of project implementation, the undergraduates described predominantly pessimistic experiences associated with their feeling of difficulty in implementing the activity, due to the inexistence between real applied practice and theoretical knowledge. These experiences can fill the gap between pedagogical theory (content) and teaching practice (ADLER; ZION; RIMERMAN-SHMUELI, 2019). The teaching degree students also faced a lack of practical preparation to manage a classroom, as can be seen:

> *[...] when we started working on the theme in the classroom, the students were very anxious, which generated a lot of conversation and discussion during the development of the activity. ...* (EST 14)
> *There was a lot of discussion about group formation, exchanging colleagues, choosing places [...] the lack of discipline ended up causing a lot of wasted time in the classroom to reach a consensus...* (EST 23)
> *[...] the students' lack of discipline hindered class performance. The organization of the space ended up taking more time than the proposed activity and, therefore, we had losses in the implementation on the first day...* (EST 27, our translation)

From the analysis of individual reflections, it was possible to verify that this feeling is closely linked to the stage of formulating hypotheses, in which, in addition, there is a lower perception of learning. In these moments of the discipline, it seems logical to find a certain "insecurity", which may be related to the lack of confidence in their teaching skills. For this reason, it is necessary to explicitly address research activities in teacher formation programs, as was done in this study. As for the perception exercised by the teaching degree students in this initial stage, their reflections indicated a lack of preparation to manage the classroom.

> *I feel like I went through the activity quite directly, but I made a lot of adjustments at the beginning of the activity and ended up asking more questions. At the beginning of the activity I ended up choosing a few questions, ... questioning and observing the students, but it didn't work....* (EST 4)

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> *I thought working a question with students would be difficult, but getting feedback from them was even worse....* (EST 27)
> *I thought a lot about how exactly I would describe the construction of the hypothesis with the students... I thought about the experiences I had at university the possibilities emphasize the need for an answer that was not answered with "yes or no"* (EST 31, our translation)

The student EST 27 also suggested that, although high school students have difficulty in creating hypotheses, the questions generated by them should be taken advantage of and tried to lead to the thought of a "hypothesis", without characterizing it, emphasizing the importance of working science based on inquiry, “you can't just know if it's a good hypothesis…it's expected to be tested” (EST 27). Another point highlighted at this time was that such activities required more intense initial planning, different from the way they planned traditional classes in the internship “[...] working in this way is much more complicated than working with traditional classes...” (EST 31, our translation).

Despite numerous publications that support the advantages of an investigative approach (CHEN *et al.*, 2014; MARSHALL *et al*., 2016), its teaching practice still remains a challenge. The lack of experiences that allow for an implementation in the classroom is still striking, considering the emphasis that research teaching has received in educational reforms in recent decades (NRC, 2000). Furthermore, in the few cases where this approach is applied, the misunderstanding of research teaching and the nature of science culminates in poor implementation (MCLAUGHLIN; MACFADDEN, 2014). Other factors identified as difficulties in using this approach are also highlighted, such as the planning and evaluation processes, the management of the classroom or the resources and restrictions of the educational system (ROMERO-ARIZA *et al*., 2020), as portrayed above.

After the initial stage of the project, the teaching degree students reported a greater amount of time spent to be able to deal with the difficulties they were facing in relation to the application of your activities in the classroom. As the project developed, the licensors understood the need for greater organization and planning to carry out the activity. Teaching degree students, with the help of the regent professor, intervened in the students' lack of discipline, mediated issues of conflicts that arose during the application and appropriated the idea of the fundamental role they played at that time.

> *I noticed that, despite being a graduate student, primary school students see us as the activity's conductors, and I'm responsible for organizing the class...the students are of a low age, which implies the need for a person to coordinate their actions...* (EST 4, our translation)

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At that point, the negative reflections of the teaching degree students were gradually reduced and replaced by positive experiences. In short, the experience of overcoming difficulties can be seen as a turning point in the perception of teaching degree students. Thus, we can infer that they begin to understand that the success of the application was basically their responsibility, being achieved with efforts, knowledge and acquired skills. At this stage, your doubts have been replaced by greater confidence.

In the middle of the development of activities, most undergraduates perceived a greater resourcefulness in the activities, understanding some advantages of working with research in Science Teaching. At this time, teaching degree students started to feel confident about the application. One of the aspects observed in this development phase of the activity was the opportunity to establish personal relationships with students.

> *Working with investigative activities in high school was very interesting and pleasant, through the discussions generated to create and answer the raised hypotheses, it was possible for me to help students individually. I was able to conduct the work of scientific thinking in the same way as my advisor does for me...* (EST 14, our translation)

These results seem cohesive, considering that perhaps the participants did not have the time/opportunity to carry out research activities during their mandatory internships, considering that this approach is not yet widespread in educational practice (VÁZQUEZ; MANASSERO, 2015). Different from what was observed by Adler; Zion and Rimerman-Shmueli (2019), the results show that the reflections of the teaching degree students on procedural understanding, on learning as a process and on the affective point of view, ranged from moderate to high. These observations suggest the capacity of the teaching degree students to effectively support these aspects while guiding the activity.

In the final phase of the work, it was observed that almost all teaching degree students had a feeling of "duty accomplished" after the changes that took place in their classes. The discipline of students, which was previously considered an obstacle to the performance of the activity, was changed. According to the reflections presented, with the development of the activity, the teaching degree students managed to manage the class more effectively, thus conducting the work. In this way, it is possible to deduce that teaching degree students have become more aware of the process of scientific investigation, also contributing to better classroom management.

Another emerging category was "understanding research in Science Teaching". In this category, it was possible to infer that there is a greater understanding of the activity during the

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experience. Teaching degree students reflected on the impact of investigative activities on their own knowledge and attitudes towards Science Teaching. Although they simulated different activities in the classroom, this understanding occurred mainly at the end of the activities, at which time they began to develop a greater understanding of the process, as can be seen in the following report:

> *Since the beginning of the activity I have had autonomy for my project. The ability to choose a topic in which I was interested to work with the students motivated me to commit to my observations, but it was only at the end that I was able to better understand what I was developing.* (EST 22)
> *[...] different from the class format experiences I had from elementary school to higher education, in which there were only expository classes, a class with investigation was a challenge. A challenge because I had never had anything like it, but it revealed to me an effective method of dealing with topics that are not always pleasant for students..., it was at the end of my project that I managed to become the leader of the class and I was able to understand the skills that are developed in this kind of practice* (EST 40, our translation)

These reflections are in line with other authors (KAZEMPOUR, 2013), indicating that the immersion of academics in classroom experiences can be a way to increase their knowledge and skills in scientific investigation, as well as their confidence and motivation to deal with an investigative activity in Science Teaching. Although the teaching degree students may have initial problems with the activities, upon completion a sense of satisfaction with successful activities is observable, followed by criticism about the projects.

In the field of inquiry-based teaching and learning, some authors suggest that professional development in the initial formation phase provides teachers with research experiences. This is because students who go through these challenges can develop better teaching practices that effectively guide their students through the investigation process (KAZEMPOUR, 2009). In addition, Sadeh and Zion (2009) suggest that teaching degree students who practice research activities exhibit a greater domain in the performance of research dynamics and processes.

According to the results, it was possible to observe that the involvement of teaching degree students in an investigation activity in Science Teaching focused more on the uncertainties of the scientific activity than on other aspects of the investigation process. According to Adler; Zion and Rimerman-Shmueli (2019), focusing attention on the uncertainty involved in the inquiry process is an important step towards enabling them to implement inquiry-based activities in the classroom and effectively guide their students through uncertain and unpredictable learning processes.

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The teaching degree students who participated in the activities and presented the reflection discussed the ongoing process of an investigative activity. They stressed that this activity does not end when the project ends, as the context of each student brings questions that still need to be explored. They also mention the need for continuity of activity: “It would be interesting to continue the activity to be able to see the results over time” (EST 8, our translation). In this way, it is important that teachers approach the questions as a continuous process throughout the investigation process, while trying to find a solution to the scientific problem to be worked on (ADLER; ZION; RIMERMAN-SHMUELI, 2019). Based on these results, we propose that, in teaching degree courses, the continuous thinking underlying the research process is purposeful and explicitly structured in the pedagogical disciplines. The participants' reflections suggested an understanding of the scientific investigation process and a greater willingness and sense of preparation to incorporate research experiences in Science Teaching in their future classrooms.

Considering the reflections developed by the teaching degree students, the next category relates “the associations of practical disciplines with the exercise of an investigation activity”. According to Freitas and Villani (2016), undergraduates are apprentices who are actively building visions about teaching and learning based on personal experiences developed during lived experiences. In this way, the experiences lived in schools, through research, allow for greater reflection on pedagogical practices, as portrayed in the following reports:

> *Having contact with the proposed activity in the discipline contributed to better professional formation. Even if we do not continue in this area, this experience changes our look inside the classroom, as we learn to observe and try to understand what we are observing... becoming better teachers* (EST 25)
> *The research experience is an active way of producing knowledge, not just reproducing it. This is very valuable, and I feel it should be encouraged more within educational institutions as it takes us out of the passive position in the realm of education and learning.* (EST 36, our translation).

Some authors (DRESNER; WORLEY, 2006; MORRISON, 2008; ZION *et al*., 2018) suggest that teachers in formation can develop a greater understanding of investigative science through individual achievements in their teaching degree courses. Therefore, courses that provide such hands-on investigative experiences can provide powerful tools to guide the ability of prospective teachers to guide their students in investigative work. (ZION *et al.,* 2018).

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In this scenario, Menezes (2017) states that the experience of research practice, assisted by reflections on teaching, can offer a possibility for the student to reflect on their professional training even in the face of difficulties. It is noteworthy that, "not every teacher, being reflective, is also a researcher, although the reverse is, by force, true" (LÜDKE, 2001, p. 31, our translation). The research activities suggest that the researcher exercises a reflective posture, developing a critical sense (LÜDKE, 2001).

The perception that students have about their activities evidences the lived experience, corroborating the considerations made in other studies (TARDIF; LESSARD; LAHAYE1991; THERRIEN, 1997). Tardif, Lessard and Lahaye (1991) emphasize that teachers confer an individual status to knowledge from experience, in which, through this knowledge, they develop parameters to judge what they consider important as professional competence for teaching.

About the associations of the exercise of research with the disciplines of practices, some students reported:

> *The practice of a research activity awakened my interest in education even more....* (EST 2).
> *The discipline allowed me to have a close contact with the investigation, where I had to work on all the steps involved in the research process involved. I was also able to learn a lot in contact with the discussions produced by my students*. (EST 16).
> *With a more critical look at the activities, I can understand that education is very complex. The empowerment of knowledge is the junction of theory, practice, field, among others, with fixed objectives that have been previously researched and analyzed so that real learning takes place* (EST 19, our translation).

The practice of research developed as one of the pedagogical disciplines of the Teaching Degree in Biological Sciences course allows the student to professionally improve with the insertion of research in the Teaching of Biology. Thinking about how to contribute to the expansion of research spaces and reduce the space between the institution and the school, I consider Orso's (2000) statement:

> There is a gap between what is taught and the reality experienced by the students. This finding leads to rethinking the work carried out at school and university, in such a way as to contribute to overcoming this fragmentation. It's true that I cannot understand all my questions, I end the work with the conviction that there is a lot to be studied in the teaching of biology (ORSO, 2000, p. 3, our translation).

Finally, all students described here also emphasize the practical experiences lived through research in the teaching of biology as a requirement for building knowledge and

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learning in the sciences. These observations contribute to fostering the practice of research in the classroom, as well as in other question-based practices. More specifically, they suggest the importance of offering students who are in the process of formation to teaching opportunities to experience this didactic strategy in a practical way, in order to build a professional identity. This trend among undergraduates was also found in the literature (WINDSCHITL, 2003, MENEZES, 2017).

Final considerations

Trying to understand the contribution of research experiences in changing the conceptions of teaching degree students, it was observed that practical disciplines provide students with experiences that modify their conceptions of research in the classroom. These changes are presented in the way that students reflect on the research process in Science Teaching in the classroom, bringing them closer to the production of knowledge. Thus, it is possible to infer that the teaching degree students were able to understand the different aspects of inquiry-based learning. Our third question relates the importance of Teaching Practice disciplines and how they contribute to teaching degree students to acquire skills in inquiry-based Science Teaching. Despite noting the importance that practical disciplines have in the development of students, it is noteworthy that the research has some limitations. Regarding these limitations, it is mentioned that the study participants were observed in a situation of initial formation and not in their own classrooms, the type of interpretation of the results and the small sample size. Due to these limitations, we are unable to determine the degree to which the use of research in the classroom has developed a better understanding by teaching degree students of the main features of research. However, our results demonstrate that the involvement of undergraduate students in this process supported reflections on the dynamic characteristics of the investigation.

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