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LEARNING TO TEACH PRIMARY SCHOOL MATHEMATICS

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SUMMARY

In Brazil, future pre- and primary school teachers are educated in a 4-year undergraduate program called "Pedagogy". In the Faculty of Education at the University of Brasília (UnB), the present curriculum of the Pedagogy program started in the year 2001 and it included a much stronger focus than the previous curriculum on preparing Student Teachers (STs) to perform educational research. Eight new compulsory Research-Based Project courses (Projects) were included. This study presents some preliminary findings concerning the STs' experiences about the 2001 curriculum and how it has contributed to becoming primary school (mathematics) teachers.

INTRODUCTION

Walsh and Tracy (2004) review what research tends to reveal about the relationship between teacher attributes and student achievement. The two attributes which consistently tend to improve teachers' effectiveness with respect to student achievement are: (a) teachers' level of literacy and (b) the selectivity of the teacher education program. With respect to teachers having a master's degree, Walsh and Tracy conclude that the results "are inconclusive" (p. 2). Recently, Horn and Jang (2017) summarize what research has revealed about the relationship between teacher educational attainment and student achievement. The effects of having a master's degree on student achievement are still unclear. Non-significant or negative effects are found in the context of reading achievement in Kindergarten to grade 8. Positive effects tend to happen "if the teacher obtains a graduate major in a specific field (e.g., math)" (p. 3). Therefore, a research-based preservice primary school teacher education, especially in the case of low achieving countries, may need the inclusion of a strong focus on research on teaching and learning literacy and mathematics because: "After teaching reading, the most important job for elementary and special education teachers is to establish a strong foundation in mathematics" (NCTQ, 2016b, p. 1).

As Student Teachers (STs) may start teaching any primary school grade in a near future, they need to have a strong conceptual understanding (Subject Matter

Knowledge, Shulman, 1986) and some Pedagogical Content Knowledge (Shulman, 1986) of most contents in the primary school curriculum. Teachers' ability to translate Subject Matter Knowledge into mathematical representations is an important part of teachers' Pedagogical Content Knowledge. "The teacher must have at hand a veritable armamentarium of alternative forms of representation" (Shulman, 1986 p. 9).

Hiebert and Carpenter (1992) suggest that after achieving automaticity learners become more reluctant to connect their practiced procedures with other mathematical representations that could provide further links to conceptual knowledge. For this reason, relearning mathematics in preservice teacher education may be a slow process as STs have often achieved automaticity of many procedures when they enter the program. On the other hand, teachers need to acquire enough knowledge to face the social responsibility of providing effective learning experiences for all students. They must develop the ability to work backwards from their symbolic ways of representing mathematics to more informal and diverse ways of representing the subject (Ball and Bass, 2000).

According to Bishop and Goffree (1986), any type of representation needs to be used and to become familiar in order to be accepted and understood by students. If STs are going to use several types of representations and not only symbols in their future teaching, they need to learn the conventions involved in the concrete materials and diagrams that can be used in school mathematics. It is also necessary to help STs draw out clear connections between the symbolic ways of representing mathematics they had in their minds before starting the program and other ways of representing the subject so that different representations for the same concept or operation can be incorporated in the same schema.

This relearning process at teacher education requires specific compulsory courses about mathematics (NCTQ, 2016a). It requires time for experiencing, teaching and researching different representations and activities for the mathematics they are supposed to teach in the future. For this reason, it is suggested that teacher education should consider the variable "Opportunity to (Re)Learn". With also "*instructional time and content* [...] been characterized as core elements of OTL [Opportunity to Learn], along with a number of *instructional quality* indicators" (Elliott and Bartlett, 2016, p. 1). It is interesting to notice that Finnish teachers are academically well prepared in a five- to six-year program for teaching primary school subjects and for performing research on their own teaching. Nevertheless, they are also concerned with time issues and students' achievement in mathematics. Pehkonen (2004), poses an important question:

All teachers who participated in this study were good, competent teachers and innovative in many ways. [...] But mathematics as a school subject seems to have a special character. [...] What is matter with school mathematics? (p. 518)

Similarly, Cockburn (2013) discusses teachers' worries about mathematics teaching and asks the question "Mathematics - a special case?" (p. 140). One of the answers provided by Cockburn is:

Throughout the world mathematics is considered to be of crucial importance and, as a result, governments tend to place tremendous pressure on teaching profession to ensure that standards are as high as possible. (p. 140)

Walsh and Tracy (2004) think that the subject matter preparation of teachers with respect to literacy may be supported by several other subjects in teacher education, that is, “by means of a broad education” (p. 7). The same does not seem to be possible with respect to mathematics. A “12 semester-credit hours” (NCTQ, 2016a, p. 7) of mathematics compulsory courses are said to be necessary in preservice primary school teacher education.

Byman et al. (2009) point out that there is always an ongoing discussion about the content and courses that should be included into the teacher education programs (p. 80). They separate two different levels of teacher education: It can aim just to a basic level, which deals with the mastering the everyday routines and contents of teacher’s work. However, academic teacher education needs to go beyond the basic level to the general level. The aim is to develop teachers’ pedagogical thinking, argumentation and basic research skills, and so to educate pedagogically autonomous teachers. Byman and his colleagues distinguish four different approaches to teacher education. These approaches are defined by two dimensions, namely pedagogical thinking, which bridges the gap between intuitive and rational thinking and the organisation of activities, which can be inductive or deductive. The approaches are 1) *experiential, personal* (intuitive, inductive), 2) *school-based* (intuitive, deductive), 3) *problem-based, case-specific* (rational, inductive) and 4) *research-based* (rational, deductive). According to Byman et al. (2009) a research-based teacher education approach is “based on the development of rational characteristics of pedagogical thinking and argumentation with the help of research” (p. 81).

When new contents, for example research skills, are added to the curriculum, it usually means that something is reduced, too. This is what happened at University of Brasília, when the new research-based curriculum was launched in 2001. This situation raises an important question about STs’ opportunities to [re]learn (Elliot & Bartlett, 2016) mathematics, when more contents and less instructional time are available. Especially in the case of countries which both have low selectivity teacher education programs (Walsh and Tracy, 2004) and low school achievement (OECD, 2016).

THE CONTEXT OF THE RESEARCH

In Brazil, there are no separate entrance examinations to teacher education programs. All students who enter university have had 12 years of compulsory school mathematics. However, many STs come to the primary school teacher education with quite modest knowledge base in school subjects. According to the results of University of Brasília (UnB) entrance exams, it is not hard to get into the Pedagogy program (e.g., UnB, 2017). Each year 240 STs enrol in the Pedagogy program which can be completed in 4 years. The STs in the program vary in age.

Some start the program just after finishing school (17+ years old). Others may be more mature and have part-time or full-time jobs. Most of them are female.

Even though in Brazil a master's degree is not a requirement to teach at any school level, the 2001 curriculum for the Pedagogy program at the University of Brasília included a much stronger focus than the previous curriculum on training STs to perform educational research in several different fields, and not only on the teaching and learning of school subjects. The 2001 curriculum does not include the possibility of any formal specializations in any educational field or school subject. *The main curriculum changes were:*

(a) Eight (8) new compulsory Research-Based Project courses (Projects) were added to the curriculum. The already existing two previous courses related to school teaching (i.e., the practicums) were changed to be more research-based than before and were named Projects 4.1 and 4.2.

(b) In all regular courses, which involved whole classes (with about 40 STs), the teaching time was reduced by 33 per cent. In the 2001 curriculum the only compulsory course in mathematics (*Mathematics Education 1*) was reduced from 75 to 50 hours (of 60 minutes). Both theory related to the teaching of mathematics and strategies for teaching the content in the primary school curriculum must be discussed during this one semester course.

In these reduced facilities, the teaching program in the course *Mathematics Education 1* had to be changed to fit into less hours. The program was designed with the aims of improving STs' conceptual understanding and Pedagogical Content Knowledge of the contents they would be expected to teach in the future. This was connected to the action research, which was started in 1995, and is still continuing through the course Mathematics Education 1 in pre-service teacher education (Amato, 2010). In the action steps of the research, the re-teaching of mathematics Subject Matter Knowledge was integrated with the teaching of Pedagogical Content Knowledge by asking the student teachers to perform children's activities which have the potential to develop conceptual understanding for most of the contents in the primary school curriculum.

The selection of representations used in the program of the course Mathematics Education 1 program was based on two pedagogical criteria: (a) clear embodiment of concepts and (b) versatility. However, many student teachers need time to accommodate all the mathematical concepts, connections and representations involved in the activities.

More practical and iconic written activities were planned for the contents that proved to be more difficult. They are started at the beginning of the semester and continue until the last day of each semester. The number of activities for natural numbers was greatly reduced in order to have more time for concepts and operations with rational numbers. In the 2001 curriculum the classes became even more focused on the primary school mathematics of grades 4 and 5 which were considered to be more difficult to STs (i.e., rational number operations and measurement of length, area and volume). However, through operations with

mixed numbers and decimals (e.g., $35\frac{3}{4}+26\frac{1}{4}$), Student teachers (STs) still have opportunities to relate operations with natural numbers to operations with fractions and decimals. Another way to provide STs with more opportunities to relearn difficult contents was to increase the home assignments.

RESEARCH QUESTION

At the University of Brasília (UnB), STs and teachers seem to be disappointed at the 2001 curriculum for various reasons (Unb, 2014). A new proposal is being discussed, but it has not been implemented until the present date. The on-going study evaluates the 2001 research-based curriculum of University of Brasília primary school teacher education. In this paper, we will focus on STs' views on the teacher education program and report preliminary findings to the question: How the research-based teacher education curriculum has helped or not helped the STs' to become (mathematics) teachers?

DATA, PARTICIPANTS AND METHODS

The data for this piece of study was collected in the years 2015 - 2017. The first phase of the data collection consists of 246 Student Teachers' written answers to a single open-ended question administered to obtain their views about the teacher education program. The participants were asked to write their answer the question "Which do you consider to be the most urgent changes in the curriculum of the Pedagogy program?" Purposefully, the question was formulated so that it did not led to write any particular aspects of the curriculum. In addition to the written responses, twelve STs and nine faculty teachers were interviewed to get a somewhat more detailed understanding about the situation. The data of this study only consist of the written answers to the open-ended question above.

The participating STs were from different semesters of the program. Many were from the fifth and sixth semesters, but there were also some from the second and the last two semesters. The STs were regarded old enough to reliably express their views about the curriculum. They were also the ones who really experienced the curriculum implementation.

The data were analysed following the phenomenographic qualitative method outlined by Marton (1988) who argues that it is a research method to investigate the distinctly different ways in which people conceptualise phenomena: "An effort is made to uncover all the understandings people have of specific phenomena and to sort them into conceptual categories" (p. 145). Altogether, each response was read about six times. After a third reading of the STs' answers, the borderlines of most of the categories were defined. Each subsequent reading was considered as checks of the categories, as they were done on different days.

Queries performed in a Microsoft Access data base provided a final check of the categorisation. The result of each query was a table combining all responses

which belonged to a specific category. In that way, the responses related to a single category could be read together to check if any of them did not follow the main pattern behind the category. Several categories have been identified, and they are still being structured into themes. However, some more frequent categories and themes have already emerged from the data. In the following, some preliminary findings will be presented.

FINDINGS

Regarding the research question, how the teacher education program has helped the STs to become (mathematics) teacher, preliminary findings are presented. We start with issues concerning mathematics education and proceed then to some more general themes which emerged from the data and which indirectly may have an effect on the mathematics learning needed for teaching in primary schools.

Altogether 20% of the participants (49 STs out of 246) spontaneously wrote about their experiences with mathematics education. These STs' main concern was to deepen both their content and pedagogical knowledge in mathematics (and in some other school subjects, too) to be more prepared for the demands of school practice. They asked for more compulsory courses and more teaching time.

[ST001] Geography, Mathematics, and Science Teaching have little classroom time. Because of this, the teachers present a series of contents in a short period of time.

[ST181] After doing two courses (Mathematics 1 and Teaching Portuguese Language [the mother tongue language of Brazil]) I realized that there is a need for more time for them, since there is a lot to learn and only one course is required [as compulsory].

Sixteen percent of the participants (40 out of 246) wrote remarks more related to the optional course Mathematics Education 2. They either mentioned that: a) this should become compulsory (n = 28), b) more time, more credits or more emphasis were needed for Mathematics courses (n = 9), or c) the number of compulsory courses in mathematics should be increased (n = 3). For example, one student [ST030] wrote: "Mathematics Education 2 should be compulsory because literacy and mathematics are basic languages." These remarks were perceived as related to the short time available in the only compulsory course Mathematics Education 1 to relearn the most difficult contents in the primary school curriculum:

[ST120] To have more than one of compulsory courses which are the basis for pedagogical practice, such as Literacy Education 2 and 3, Mathematics Education 2 and 3, Science Education, History and Geography 2 and 3, which give continuity to the process learned in the former [courses number 1].

Usually only one class of the optional course Mathematics Education 2 is offered each semester. If it were a compulsory course, it would have to be offered to all

120 STs (three classes with about 40 STs) who enter in the program each semester. For this reason, several STs do not manage to enrol in some optional courses.

Concerning the urgent changes in the curriculum of the Pedagogy program, the most striking matter that could be identified in the data was the theory-practice relationship. Altogether 52% (i.e. 128 out of the total 246 respondents) expressed their concerns about this matter in three interrelated themes: (a) “more practice” (n = 115); (b) “less theory” (n = 52); and (c) “theory should be related to practice” (n = 30). These themes involve serious worries of the STs about how to become a *teacher*, a practitioner in the classroom. The following examples of the data illustrate these themes:

More practice: [ST023] The integration of practice in the curriculum. [...] It is fundamental to reflect about our work, and we need to be prepared to do this. However, when the issue is to deal with students and school, either we search for ourselves or we will not be able to act [as a teacher].

Less theory: [ST089] The program is very theoretical, and it is not helping STs in the practical part. We leave the program full of theories and concepts and with not much of practice. We become pedagogues who do not know how to act inside a classroom.

Theory related to practice: [ST043] What disturbs me most is the fact that during the classes the theories are much more developed than teaching practices. For example, what is the point of learning everything about Piaget or Vygotsky and not knowing how to teach a child [mentioned the name of a school subject]?

As can be noticed from the two latter citations, often the themes were intertwined with each other in STs’ responses. These findings suggest that STs experience various gaps between theory and practice in teacher education at University of Brasilia. During the Pedagogy program STs gain school practice by getting employed as teacher’s assistants and by the practicum Projects (Projects 4.1 and 4.2). However, some of the mentoring teachers they work with may still be novices trying to acquire Pedagogical Content Knowledge. So, the practice may not be of much help in learning to teach:

[ST002] The program does not prepare us to work. [...] When I did Project 4.1 in a classroom with a novice teacher who got the degree at UnB [University of Brasília], I noticed that she had the same difficulties I had: to get into a classroom without knowing how to teach [...] [mentioned the name of a school subject]. We have all possible theories, but no directions about how to apply [them] in practice even having done a related optional course [about the subject].

Indeed, 37% of the participating STs found that the program should have a stronger focus on school teaching, and altogether 11% of the them mentioned that they lack confidence in their readiness to teach at schools. They do not seem to regard theory as unimportant, but they do not appear to have the maturity to perform by themselves the didactic transposition from theory to practice as

proposed by Chevallard (1989). Yet some of the regular curriculum courses (see the answers of [ST120] and [ST002] above and [ST150] below) were perceived as providing a clearer didactic transposition than others:

[ST041] I believe the curriculum needs a greater emphasis on pedagogical practice. Mainly in the courses with the contents that we as teachers will be working in the classroom. We need to be taught how to teach.

[ST099] The present curriculum does not educate teachers, but researchers. This is a very serious problem because after finishing the [Pedagogy] program the majority of STs will be teaching classes. This is as harmful to the teaching of [school] children/students as it is to the STs.

[ST150] The curriculum of Pedagogy [program] should have more focus on how to act in the classroom, not despising the theory, but it would be much better to listen to the theory and try to put [the ideas] into practice, equal to [what happens in the courses General] Didactics, Mathematics [Education] 1, Teaching and Learning of Portuguese language, among others.

DISCUSSION AND RECOMMENDATIONS

Above, we have tried to shed some light on the STs' views about their present teacher education program at University of Brasília. The preliminary findings suggest that there are time problems in implementing a broad research-based curriculum in a low selectivity teacher education program. In addition, some STs feel that they are lacking confidence in their abilities to teach. There are signs that the research-based curriculum has not helped the STs' to become (mathematics) teachers and practitioner researchers in the best possible way in a teacher education program which only involves four years.

Comparing to the high-level applicants and strict selectivity (Walsh and Tracy, 2004) of Finnish teacher education five to six-year programs (Pehkonen, 2004), the situation at University of Brasília is very different. The admission to the University of Brasília primary school teacher education program is easy and many STs enter the program with insufficient knowledge base in the school subjects they will be teaching in the future (e.g., UnB, 2017). When the instructional time is more devoted to the learning of research activities, it is reduced from the pedagogical and content knowledge issues. The findings reveal that many STs think that they have had not enough opportunities to learn (Elliot & Bartlett, 2016) what they need to be able to teach school subjects. Compulsory Mathematics Education courses are the main place to provide all 120 STs who enter the program each semester (240 STs per academic year) with opportunities to relearn mathematics.

In terms of Byman et al. (2009), the participating STs expect rather a more school-based than a research-based teacher-education. Perhaps in such cases teacher educators could face the "wish to be taught how to teach" as a responsible attitude on the part of unexperienced STs. Hart (1993) argues that school students

benefit from a sense of confidence on the part of the novice teacher: "Remember, if you are being fed by a 'plain cook' it might be best to have the food he can cook, everyday, rather than starve until he is able to produce a single gourmet dinner" (p. 30). According to Darling-Hammond (1996), students' right to learn is directly connected to their teachers' opportunities to learn what is needed to teach well.

Slowly novice teachers can start to adopt a broader research-based approach to their teaching by combining the ideas gathered from research publications with their own pedagogical ideas. However, in low selectivity and low performance contexts, the development of rational pedagogical thinking and argumentation (Byman et al., 2009) may be more effective with respect to school mathematics if teacher education has a greater focus on developing STs' specific research skills on mathematics teaching and learning.

Using children' practical and iconic activities which have the potential to develop conceptual understanding of mathematics proved to be an effective way to improve STs' Subject Matter and Pedagogical Content Knowledge. However, it is an approach which requires a reasonable amount of class time for working with several interrelated practical and iconic activities. It is difficult to accept that many Brazilian school students cannot cope with the word problems presented in PISA tests (OECD, 2016). The vicious cycle "of teachers with weak conceptual backgrounds providing conceptually impoverished instruction" (Simon, 1993, p. 252) will not be broken if only shorter interventions continue to take place in teacher education.

The research-based Projects could be an important contribution in improving school achievement if they are more focused on research on the teaching and learning of school subjects, because primary school teachers are responsible for teaching the foundations of several subjects. A research-based program should have at least one more academic year as it happens in the Finnish research-based teacher education program (Pehkonen, 2004). Finally, more hours are needed for mathematics courses. According to (NCTQ, 2016a), the ideal situation requires STs to take three compulsory mathematics courses. It is not easy to conceive the idea of performing research on any other educational field, without first having acquired a deep and broad theoretical understanding about the teaching and learning of the school subjects they will have to teach in the future.

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