Paper Title A B-Learning Program for Developing Mathematical Knowledge for Teaching in In-Service Primary School Teachers

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A b-learning program for developing Mathematical Knowledge for Teaching in in-service primary school teachers

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Abstract

Chile has an unequal access to quality education. Moreover, those who teach in vulnerable districts mostly come from similar backgrounds and receive preparation from teacher training programs that do not provide them with the fundamental knowledge and skills needed to teach. Despite recent progress, the country still struggles to consistently improve mathematics results in public schools, mainly because most teachers lack the proper mathematical knowledge for teaching.
To address this problem we created a b-learning program as part of a partnership between a mathematical research center and the Chilean Ministry of Education. In this paper we describe its main features, the results from two pilot experiences with schools of four urban counties and the improvements made after them.

Background and Framework

Despite the efforts of Chilean authorities to attract high-performing students to teaching careers, there is still an important gap in the scores of the national standardized admissions test between students applying to teacher programs and to other professional careers (Mizala, 2011). Furthermore, institutions present unequal quality levels in their teaching programs (Ávalos, 2014). Pre-service teachers who studied in high performance schools, mostly obtain their teacher certificates in selective private and public institutions and, after graduating, work in middle- and high-class private educational establishments. Meanwhile, teachers who studied in low-income school districts are trained in less selective and less prestigious higher education institutions, and later teach in low-income schools with less favorable working conditions and a majority of vulnerable students (Rufinelli y Guerrero, 2009). This unequal distribution of the teachers in the system contributes to perpetuate educational gaps over time.

Research into the mathematics teaching of in-service teachers in Chile is scarce. However, evidence indicates that teachers grasp procedural knowledge, but are not fluent in the conceptual understanding and specialized content knowledge for teaching mathematics (Rodríguez et al., 2011). This translates into a lack of deductive reasoning, and a prioritization of the use of procedures over comprehension of the concepts (Varas et al., 2008; Araya and Dartnell, 2008; Radovic and Preiss, 2010).

Teacher working conditions

Teaching load in Chile is intense compared to others countries. According to the TALIS 2013 study, Chilean teachers are contracted for an average of 29 hours per week, of which 27 are

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spent in front of a class. This contrasts with the OECD average: 38-hour contracts, with 19 hours spent teaching. The high teaching load leaves teachers with little time for other professional activities, such as lesson planning, collaborative work with peers, and professional development. This is about to change with a new law that establishes the creation of a Professional Development System for Teachers, which includes new requirements to enter teaching, and a new system of salaries and evaluations.

Regarding the access to technological equipment and connectivity, there have been several programs to give Internet access to public schools. Already in 2004, the ENLACES program had secured connectivity in 90% of schools nationwide (UNESCO, 2005). Through Agenda Digital 2020 the government has declared a series of actions that aim to ensure the connectivity of all schools in Chile and substantially improve its quality. Since 2011, it has implemented a connectivity project that seeks to provide quality broadband to 70% of public schools (Subtel, 2013). On the other hand, the most recent ICT census shows that most teachers have a computer, and more than 80% have internet access at home (Mineduc, 2013). According to school principals though, over half of teachers need ICT training, which is consistent with the low frequency of ICT used in teaching.

The conception of the “Suma y Sigue” program

In 2014, the Center for Mathematical Modeling of the Universidad de Chile, in an alliance with the Chilean Ministry of Education, started developing the blended learning program “Suma y Sigue” for primary school teachers who teach mathematics. Blended learning (b-learning) approach was chosen to facilitate the program’s availability for teachers all across the country.

There is a clear benefit in having a deep expertise in the subject matter to teach mathematics (Ball et al., 2005; Ball et al., 2008; Ma, 1999), so the program seeks to improve teachers’ mathematical knowledge and skills. Thus, the main purpose of the program is to deepen their knowledge in fundamental aspects of the teaching of mathematics at primary school level, following the model of Mathematical Knowledge for Teaching (MKT) (Ball et al. 2005; 2008). In accordance with the MKT model, the program has as a goal to develop Common Content Knowledge (CCK) and Specialized Content Knowledge (SCK), promoting:

- the learning of mathematical concepts, structures and ideas through a phenomenological approach;
- a conceptual understanding rather than a procedural knowledge; and
- a reflection about the fundamentals of mathematics for teaching.

Development and main features of the program

In Chile most elementary school teachers are trained as generalists, but it is common for teachers to specialize and teach only in specific grade levels. Thus, our program is organized according to grade levels and curricula domains (see Table 1). Although the program does not seek to be exhaustive, fundamental mathematical topics and those that are more difficult to teach in primary school were prioritized.

Due to this focus, development required collaborative work between teachers and mathematicians. To create the scripts and activities, an interdisciplinary team was formed, consisting of teachers with classroom experience and mathematicians with a background in mathematical education. A team of graphic and web designers was constituted to develop the graphics and user interface. Each script went through a series of review instances, where the activities, writing, and graphic design were discussed in-depth to evaluate their appropriateness and relevance. Before implementation, each activity was tested by teachers to assess its functionality and clarity.

We must remark that, although the courses are designed for teachers, the contexts and most of the activities can be adapted for use in the classroom, while others use the classroom as a context.

Program and course structure

Each course is designed to be studied over 9 weeks, with 4.5 dedicated hours per week. There are 3 face-to-face sessions and 4 to 6 virtual workshops, distributed in two modules (see Figure 1). The online part is asynchronous, that is, teachers work at their own pace; at all times, though, they are monitored and supported by virtual tutors.

The face-to-face sessions are meant to introduce teachers to the program, platform and courses; motivate them to complete the course; answer questions about content; and systematize and discuss the learning process they are going through.

The virtual workshops are designed to be developed in about 5 hours and consist of several activities with precise learning goals. Each activity deals with fundamental aspects of mathematics using a constructivist approach; it starts with a contextualized situation in which the mathematical contents appear and are developed step by step. The activities are aimed at promoting: i) mathematical inquiry, through the use of interactive tools; ii) reflection and reasoning, by means of problematic situations, questions and detailed feedback for key questions; iii) the search for different strategies for problem solving; and iv) the need for various representations and models that are illustrated, for example, using diagrams and animations. Many tasks focus on analyzing different strategies and resolution procedures, incomplete solutions, as well as possible errors or difficulties associated with them. In the activities, we privileged the use of short answers, both numeric and textual, over open questions, and multiple-response over multiple-choice questions. The activities and workshops also possess instances for synthesis to connect the contents learnt thus far.

The assessment of each module consists of an online multiple-response test. The test evaluating first module is scheduled one or two weeks after the second face-to-face session occurs. However, the final test, that assesses the contents of second module, is answered before the third session, and therefore teachers can only ask questions and clarify doubts online.

Example of a workshop and tasks

We will now briefly describe the last workshop of a course, suggested for teachers who teach from 5th to 8th grade, whose main topics are multiplication and division of fractions, ratios and proportions. The workshop is about the resolution and analysis of non-routine problems involving these topics, and has a distinctive structure: each activity revolves around a single problem and serves a dual purpose. On one hand, teachers are confronted to apply and extend the contents to new situations, representations, strategies and arguments worked in previous workshops. On the other hand, each activity is aimed at some fundamental aspects of problem solving, such as: to promote the understanding of the problem statement; to identify the assumptions required to solve it; to encourage the use of different representations and resolution strategies; to recognize the error as a learning opportunity; to correctly interpret the results obtained; to acknowledge the importance of answering the problem questions; and to promote the verification of results. Although teachers have the chance to solve the problem and upload their productions, the aim of each activity is not set in solving the problem, but rather in analysing and reflecting about different strategies, procedures, interpretations and new problems that may appear during its resolution.

Fig. 2 describes and summarizes the second activity of this workshop. Its problem solving purpose is to reflect about the assumptions needed to solve a problem and to value mistakes as an opportunity for discussion and learning. To illustrate that a variety of errors enriches the learning process, teachers are encouraged to analyze all incorrect or incomplete student resolutions that present different strategies to address the problem.

Pilot results and improvements

Several pilot experiences have been carried out during the last two years at public schools in 14 counties within two regions in Chile, reaching more than 700 elementary teachers.

During the first pilot in 2015, over one-hundred teachers of three urban counties in the Santiago Metropolitan Region attended three courses. The purpose of applying certain instruments was to characterize the participants and to evaluate the course structure and implementation, which led to several improvements reported below.

After these changes were included, a second pilot was conducted during 2016, reaching 677 teachers of 14 counties within two regions in Chile. Some of the results for the performance analyses of 240 teachers in 4 courses taught in 7 counties in Santiago are shown below.

Methodology

Several instruments were designed and applied: an online questionnaire aimed to characterize teachers and obtain their ICT profile; two surveys to assess the satisfaction with the courses, along with their opinions and perceptions regarding the usability of the platform. Also, during the first pilot two focus groups were conducted to gain insight about teachers' learning experiences and to assess the information obtained through the surveys.

For the second pilot, teacher performance was compared with attendance to face-to-face sessions and ICT profiles. For every course, their performance was measured using the results in both online tests, with a grading scale that goes from 1.0 to 7.0. In this analysis, two groups of teachers were distinguished based on their assistance to the second face-to-face session. It must be highlighted that the other face-to-face sessions were not included in the analysis since they were not expected to profoundly impact teacher performance: the first session simply introduced teachers to the platform and course topics and the last one occurred after they had completed the second and final test. In order to compare results with the ICT profile, teachers were divided into five groups depending on their self-reported competence level.

Results of the first pilot and following improvements

The three courses had a low dropout rate, with an average of 80% retention among those who took the first test. Regarding the teachers' ICT profile, the results show that 90% of them have Internet at home, and 53% had participated in a distance-learning course. However, 25% of teachers declared that their technological skills were poor or very poor.
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Overall satisfaction was very high, and 94% of teachers said that the course experience was satisfactory. Most teachers said the courses were very demanding, appreciated the originality and variety of contexts and said that the contents addressed are relevant to their work and help them develop skills.

The instruments also allowed us to collect information about some of the difficulties faced by teachers to perform optimally in the courses. The length of some explanations came to our attention after several teachers reported having trouble understanding problems, which, according to them, was due to a lack of reading comprehension skills. Although teachers acknowledged the diversity of question formats and the focus on critical thinking, they raised concerns about the difficulty of some of them, particularly multiple-response questions. Finally, some teachers admitted that they did not read carefully the summary sections because they wanted to keep working on the activities, which could ultimately impact their performance.

The main improvements after this first experience are as follows:

- Some texts were shortened and explanations were simplified through the inclusion of graphic demonstrations and animations.
- Questions of intermediate difficulty were added (scaffolding).
- The summary sections were made interactive so teachers are encouraged to actively consolidate their learning.
- Key content sections with teaching ideas and comments were added.
- The design was changed to visually highlight relevant ideas and features of the sections.

Results of the second pilot

Among teachers who participated in this implementation, 85.1% were primary school teachers, 5.3% were special education teachers and 3.2% were secondary school teachers; around 30% had a major in Mathematics Education and 45% had a teaching degree with a major in other fields; and, 24.9% had a diploma and 5.4% had a a master's degree.

All courses had a low dropout rate, with an average of 9% among those who took the first test. The information gathered through the satisfaction survey, which was answered by 116 teachers, shows that 90% of them were satisfied with the course in which they participated, 87% perceived that their expectations were fulfilled and 95% said that the content addressed was relevant for their teaching.

The main purpose of the analysis made was to assess the effectiveness of the program's blended learning approach. The results show that there is a clear trend towards better results for teachers who attended the second face-to-face session compared to those who did not attend. The scores of teachers who attended this instance were between 0.5 to 1.2 points higher on average, in a scale from 1.0 to 7.0 (see tables 2.1 to 2.4). It is worth noting that teachers' attendance to this instance did not only have a positive impact on their performance in the first course evaluation, but also on the second test, which did not include any content directly related to the topics of the second session.

On the other hand, the results show that the ICT profile has no significant influence on teacher performance. As can be seen in tables 3.1 and 3.2, the average grade, considering all the courses, has no significant differences according to the self-reported ICT profile, where 1 is the lowest and 5 is the highest level. This result provides some evidence that the proposed model allows teachers who do not feel competent in the use of technology to perform adequately and not be limited by their previous abilities with this type of resources.

Final comments

During the development of the program the collaboration between math teachers and mathematicians was crucial. Each course development team became involved in many discussions about how to introduce the contents in an intuitive way, using meaningful contexts for both teachers and students, while preserving the rigour required by the learning and teaching of mathematics. Review meetings were critical to define the learning goals, and also proved to be very useful for increasing each team understanding of elementary mathematics. All this led to better protocols and processes for designing the activities, which resulted in better and richer mathematical tasks.

Although the program is still in development, the pilot results are promising and have allowed us to significantly improve the learning activities and user experience. As a result of these improvements, it seems that the ICT teacher profile is not decisive for their performance during online tests. Also, even though further analyses are needed to evaluate how the model facilitates teacher experience, the online guidance and follow-up during course development seem to be key for the overall satisfaction and low dropout rate enjoyed by the program.

The analysis of teacher performance during the second pilot has raised some concerns that could be addressed in future improvements. One is related to the role of the third face-to-face session, currently intended as a closing session that presents some examples of classroom activities and discusses curricular implementation. Regarding the influence that the second instance has on test results, moving the third session before the final test has been considered. Finally, we are still faced with the challenge of developing instruments to measure the variation in teachers' mathematical knowledge for teaching, that will in turn permit a more accurate evaluation of the program's effectiveness.

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Name	Contents	Domain	Level	State
Initiating geometric thinking	Visualization and spatial relations; measurement	Geometry	K-2º	⚙
Working with the decimal system and addition and subtraction problems	Counting; decimal system; addition and subtraction of natural numbers	Numbers	1º- 2º	✓
Initiating statistical reasoning	Investigation cycle; collecting, organizing and visualizing data	Data and probability	1º- 4º	⚙
Working with multiplication and division of natural numbers	Multiplication and division of natural numbers	Numbers	3º- 4º	✓
Working with fractions and their representations	Interpretations and representation models of fractions; multiplication and division of fractions	Numbers	3º- 6º	✓
Developing geometric reasoning	Visualization and spatial geometry; geometric bodies; geometric language; basic geometric constructions	Geometry	3º- 6º	✓
Working with measures and measurement	Measurement of length, area, volume, time and weight; properties of measures	Measurement	3º- 6º	⚙
Working with fractions, ratios and percentages	Multiplication and division of fractions; ratios and percentages	Numbers	5º- 8º	✓
Developing algebraic reasoning	Patterns; algebraic language; problem solving with diagrams and equations	Algebra	5º- 8º	✓
Developing statistical reasoning	Investigation cycle; collecting, organizing and visualizing data; summary statistical measures	Data and probability	5º- 8º	⚙
Analyzing proportional relationships and graphics.	Ratios; percentages; proportionality; interpretation of graphics	Algebra	7º- 8º	✓
Developing probabilistic reasoning	Randomness and probability; empirical and classical definitions of probability; counting methods	Data and probability	7º- 8º	⚙

✓ Developed
⚙ On planning stage

Table 1: The list of courses in the program.

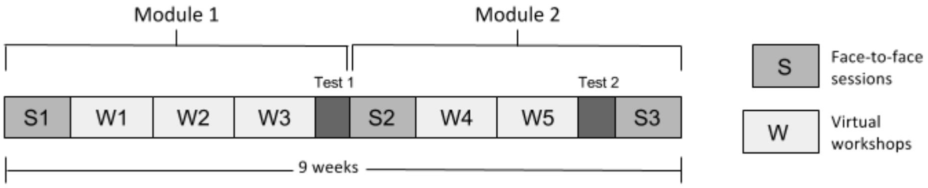

Figure 1: Structure of a course.

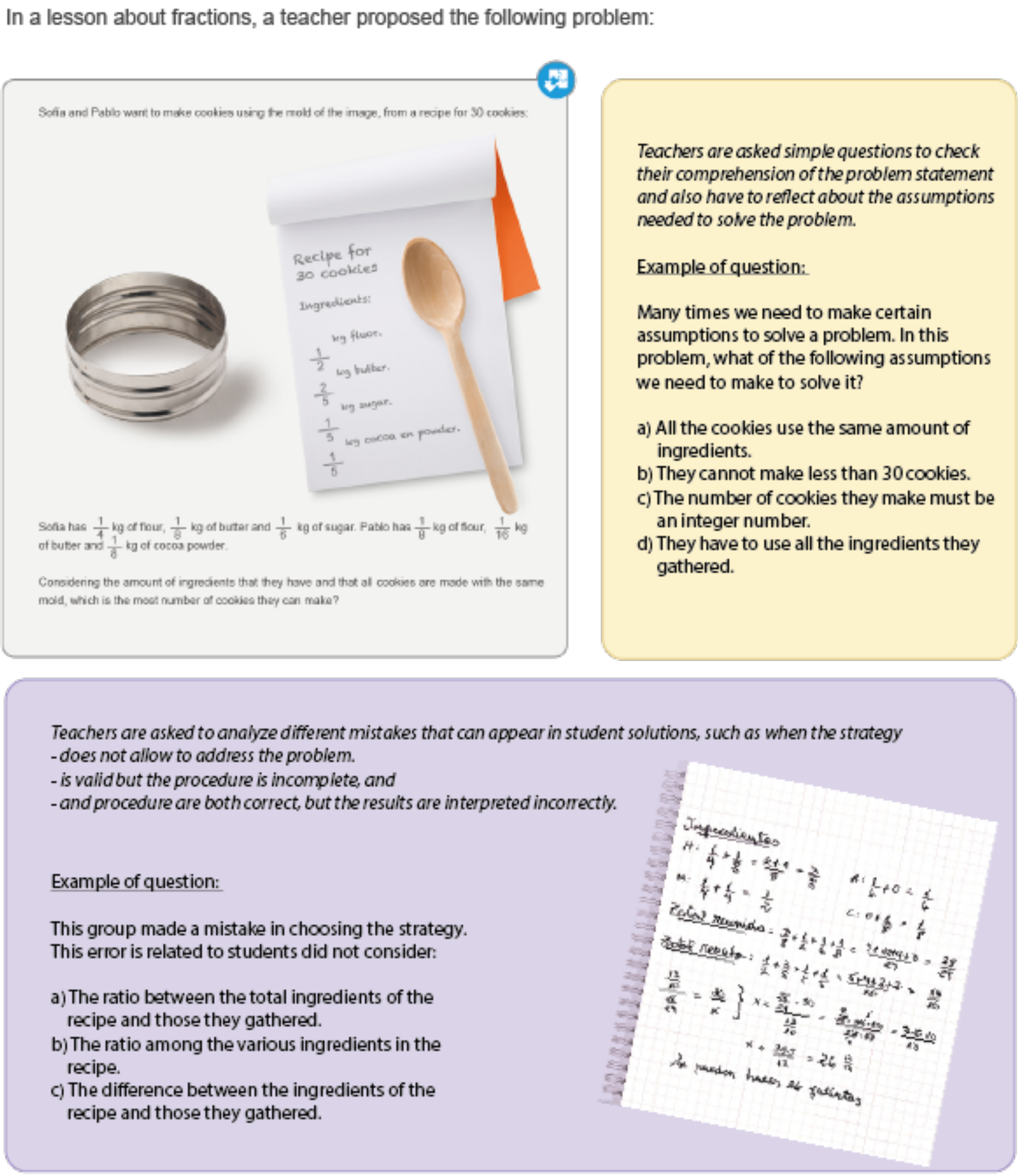

Figure 2: Example of some tasks teachers are asked to solve in the workshop on problem solving with fractions, ratios and proportions.

	Attendance	Q1	Median	Q3	Mean	sd	n
Test 1	Yes	4,7	5,4	5,9	5,3	1,01	38
	No	4,3	4,6	5,2	4,8	0,78	27
Test 2	Yes	5,2	5,7	6,2	5,6	0,96	37
	No	4,9	5,4	5,7	5,1	1	28

Table 2.1. Teacher performance in course "Working with the decimal number systems, addition and subtraction".

	Attendance	Q1	Median	Q3	Mean	sd	n
Test 1	Yes	4,9	5,7	5,8	5,4	0,5	12
	No	4,0	4,6	5,4	4,4	1,25	17
Test 2	Yes	4,1	5,6	6,2	5,3	0,94	11
	No	4,8	5,2	5,6	4,8	1,36	11

Table 2.2. Teacher performance in course "Working with multiplication and division of natural numbers".

	Attendance	Q1	Median	Q3	Mean	sd	n
Test 1	Yes	5,4	5,9	6,1	5,64	0,75	25
	No	4,1	5,4	5,8	4,9	1,37	33
Test 2	Yes	5,5	5,9	6,2	5,8	0,46	24
	No	4,9	5,7	5,9	5,2	1,34	28

Table 2.3. Teacher performance in course "Developing algebraic reasoning".

	Attendance	Q1	Median	Q3	Mean	sd	n
Test 1	Yes	5,4	5,6	5,8	5,2	1,35	12
	No	4,5	4,8	5,3	4,7	0,97	20
Test 2	Yes	4,9	5,4	5,6	5,2	0,66	13
	No	3,9	4,1	4,7	4,0	1,01	21

Table 2.4. Teacher performance in course "Developing geometric reasoning".

	1	2	3	4	5	DK/NA
Mean (sd)	6,0	5,3 (0,70)	5,3 (0,65)	5,2 (0,83)	5,0 (0,88)	5,1 (1,17)
Obs.	1	8	33	71	43	36

Table 3.1. Average teacher performance in test 1 according to ICT self-reported competence.

	1	2	3	4	5	DK/NA
Mean (sd)	6,4	5,7 (0,32)	5,4 (0,89)	5,2 (0,75)	5,4 (0,73)	5,2 (0,76)
Obs.	1	8	32	69	40	27

Table 3.2. Average teacher performance in test 2 according to ICT self-reported competence.