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Instructional coherence as perceived by prospective mathematics teachers: A case study in Chilean universities

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One of the notions that future Chilean teachers hold about their educators is the lack of coherence between the latter's instructional practices and the ways in which they are expected to teach mathematics in school. Upon this basis, we sought to characterize the Instructional Coherence of teacher educators, and particularly the way in which it is perceived by students. By applying a questionnaire to prospective teachers from two Chilean universities, focused on their teaching models, the relevance of replicating certain instructional practices in the school classroom, and the types of modelling observed in their educators, we were able to establish that coherence is perceived when prospective teachers notice, in the practices of their teacher educators, the characteristics of the teaching model that they themselves profess.

Keywords: Mathematics teacher educators, instructional coherence, modelling, pre-service teacher education.

CONTEXT

In Chile, international evaluations of both Chilean educational policy (OECD, 2009) and mathematics teacher quality (TEDS-M; Ávalos & Matus, 2010) have shown that the pedagogical and disciplinary education of the country's newly graduated and practicing teachers is not good enough to result in good performance. Even though major efforts have been made to improve Pre-Service Teacher Education, little light has been shed on the education processes of teachers in university classrooms (the so-called "black box"). In addition to this, and despite the relevance of teacher educators in this process, fewer studies have been conducted in Chile about these participants than about prospective teachers (Cisternas, 2011). Conducting more in-depth research on this issue could help to understand a factor which we consider essential in pre-service teacher

education: the instructional practices of teacher educators and the perception of prospective teachers about the coherence between their educators' discourse and such practices.

THEORETICAL FRAMEWORK

Rojas and Deulofeu (2013) have observed that the teacher educator's instructional practices (mathematical-didactic activities designed and its classrooms management) are strongly related with the construction of the teaching models of prospective teachers. This educational process should include at least two aspects to be constructed: on the one hand, that the body of teacher educators offer future teachers opportunities to learn mathematics in the way their students are expected to learn (didactic model transference) (Chapman, 2008; Deulofeu, Figueiras, & Pujol, 2011), thus generating processes that model teaching practices; on the other hand, that the teacher educator introduce activities which constitute opportunities to learn to teach mathematics, in the sense of planning one's teaching, analyzing classroom management through classroom episodes, and working upon the basis of the mathematical production of secondary school students, which should establish a strong theoretical-practical relationship (Boyd et al., 2009; Gellert, 2005). The general purpose of these activities, in terms of design and implementation, is to allow prospective teachers to construct the knowledge necessary to teach high school mathematics. A major part of these activities depends on how the teacher educator manages them, that is, how he/she uses them to display their underlying didactic-mathematical approaches (Zaslavsky, 2007).

Instructional coherence

However, it is not enough to study the teacher educator's practices. If we consider Chilean students' demands for greater coherence in their educators (MINEDUC, 2005), it is necessary to advance a notion of coherence that is functional within the educator's job. In the literature, coherence is defined as the degree to which the main goals associated to teaching and learning are shared by everyone involved in the education of teachers, and also considers the degree to which learning opportunities are organized, both conceptually and logistically, to achieve these goals (Tatto, 1996). Within this concept, two types of coherence can be identified: conceptual (between the professional perspectives of those who work with teachers) and structural (associated with the design of learning opportunities) (Hammerness, 2006). Beyond capturing the notion of consistency, these definitions stress the idea that coherence requires alignment between ideas and learning opportunities (Grossman, Hammerness, McDonald, & Ronfeldt, 2008). However, none of these conceptions emphasizes the instructional coherence of the teacher educator, understood as the degree of alignment between his/her instructional practice and the *didactic transfer models* that he/she promotes in it, including the theoretical models that support them.

The alignment between the theoretical and didactic models of the teacher educator and his/her instructional practices in the university classroom may provide information about how teacher educators can become models for future teachers. Therefore, a teacher educator will display Instructional Coherence when his/her practices model the didactic-mathematical actions that he/she expects prospective teachers to acquire.

Modelling

The teacher educator is always an example for teachers; thus, when considering the widespread idea that teachers teach in the way they were taught, the modelling role that the educator acquires becomes relevant. In this regard, Lunenberg, Korthagen and Swennen (2007) state that the ways in which the educator models certain views of learning can be more important than the content itself. For the authors, these "ways" are grouped under the notion of modelling, understood as "the practice of intentionally displaying certain teaching behaviour with the aim of promoting student teachers' professional learning" (p. 589). So, considering these ideas, we could study Instructional

Coherence in order to understand the ways in which a teacher educator makes explicit the message that he/she wants to convey to his/her students.

The authors define four types of modelling based on their literature reviews and their own research. These forms of modelling are grouped into implicit and explicit, with the latter having several degrees of complexity.

Implicit modelling: Even though the educators recognize that they must be good examples of the conceptions of teaching that they attempt to transmit, students often do not see these conceptions in practice. In fact, many educators do not manage to make their teaching models explicit, and their students' preconceptions about teaching and learning do not change significantly.

Explicit modelling: teacher educators should make explicit which choices they make while teaching, and why. Some techniques to achieve this goal could be journal writing, "thinking aloud", or co-teaching. Although these ways of making educators' didactic decisions explicit may be useful, they are not naturally observed in their actions.

Explicit modelling and facilitating translation into student teachers' own practices: even if educators explicit their decisions, students should be able to transfer them to their own classroom practices. This requires reflection and an analysis of the educator's instructional practices, combined with an attempt to define what they mean in teaching terms. From this starting point, students will be able to make their own decisions.

Connecting exemplary behavior with theory: it is clear that the theory-practice connection is essential in teacher education. For this reason, it is necessary to go beyond making pedagogical decisions explicit and giving students the chance to analyze them; students should connect practice with theoretical structures that allow them to explain these decisions and characterize them to inform their decision-making.

In order to identify which of these characteristics of their educators' instructional practices were present in the lessons observed, the questionnaire included referred to the modelling that students observed in

their educators when conducting certain actions aimed at developing their knowledge for teaching.

Questionnaire dimensions

Both for educators and students, mathematics teaching involves the consideration of several theories that make it possible to construct a didactic model (Steiner, 1990) which has stable foundations and which can be implemented flexibly (Godino, 1991). Therefore, to study said models at any educational level, it is necessary to break down the practice of the participants involved according to the fundamental characteristics of the model that they profess.

In order to do this, and on instrumental terms, our questionnaire was created considering a set of theoretical approaches which are currently observed in Mathematics Education research. In this regard, Furinghetti, Matos and Menghini (2013) distinguish certain dimensions that make it possible to study theoretical teaching models. The first dimension, which emerged from early 19th century mathematics, concerns the promotion of mathematical thinking. This dimension also involves the promotion of statistical thinking, which is distinguished from mathematical thinking in that the argumentation of the former is based on data (Ben Zvi & Garfield, 2004). The second dimension is associated with the psychological-cognitive theories of the teaching and learning of mathematics advanced by Piaget, Vygostky, Dehaene-Gingerenzer, Bruner, Ausubel, and Van Hiele, among others. The third dimension defined here groups cultural and social approaches together. The theories it concerns are those of Freudental, Kilpatrick, Polya, and Shoenfeld; social epistemology, socio-criticism, the Theory of Didactic Situations, and the Theory

of Didactic Transposition, given their sociocultural nature. In addition, considering the latest results of Lesson Study, we added a fourth dimension which is associated with the hermeneutic processes that characterize the Japanese teaching model.

The following are the characterizations that we have constructed for each dimension in order to illustrate how indicators present them.

RESEARCH QUESTION

By singling out instructional coherence as a key element in teacher education, due to its role in the construction of the teaching-learning models of future teachers, our study is guided by a fundamental question: Which characteristics of teacher educators’ practices make students regard them as coherent? More specifically, this article focuses on *student perceptions about the coherence displayed by their educators* which can be useful as issues for reflection.

METHODOLOGY

Given that the purpose of this research is to assess students’ perceptions about the instructional coherence of their educators, we used techniques and instruments capable of measuring this qualitative variable. Thus, we employed Likert qualitative measurement scales, because they are capable of generating a discrete ordered continuum of the students’ perception level.

Sample

In order to look into students’ perceptions about the instructional coherence of their professors, students

Dimension	Theoretical Characterization
Mathematical Thinking	This dimension is expected to capture characteristics of the mathematics teaching model which revolve around mathematical work, considering key aspects of mathematical or statistical thinking.
Psychological-Cognitive	This dimension is expected to capture characteristics of the mathematics teaching model that focus on cognitive-structural aspects of mathematics learners. It should also identify aspects that shed light on the reasons behind learners’ behaviors and actions concerning mathematics.
Socio-Cultural	This dimension is expected to capture characteristics of the mathematics teaching model associated with the relationships established by social and cultural groups when learn or create mathematical meaning.
Hermeneutic	This dimension is expected to capture characteristics of the mathematics teaching model which are aimed at creating expertise and command of mathematical knowledge via the thorough use of processes and strategies.

Table 1

and educators belonging to education programs for secondary school mathematics teachers at Chilean universities were invited to participate. In order for a university to be selected, the following requirements had to be met: (a) having a teacher education program accredited for 4 or more years¹, (b) having had a minimum admission score of 550 points in the mathematics part of the test for the last 4 years², (c) having 14 or more Mathematics classes, and (d) 3 or more didactics/method classes in the program curriculum³. These values were established after analyzing the data for the 36 secondary education programs in Chile, since it was necessary to set a minimum quality level according to the parameters used in the national context. Of all the teacher education programs studied, only two met these criteria.

Specifically, the classes chosen were those belonging to the didactic or methodological area, since they are where students' mathematics teaching knowledge is strengthened, regardless of their formal name in each teacher education program. Finally, a total of 42 students, 11 from one university and 31 from the other, answered the questionnaires.

Questionnaire structure

The coherence variable is complex to study; therefore, in order to collect information about it from the students' perspective, an instrument comprising three parts (A, B, and C) was used. In part A, the students were asked about their academic trajectory in the teacher education program they are part of (number and type of courses taken) and their perception about their preparation for teaching the syllabus contents at different educational levels. In part B, they were asked about their beliefs concerning the main characteristics of mathematical activity in schools through a Likert scale (Likert I) that presented several strat-

egies or methodologies which they would regard as necessary for their pupils to generate mathematical knowledge. In part C, they were asked about the educational process that they had experienced in their programs via two Likert scales. The first of them (Likert II) presented instructional practices, which can be observed in courses of a didactic or methodological nature. Students were asked which of these practices they believed were useful to replicate in schools, in order to identify which instructional practices were making an impact on the construction of their teaching-learning models. The second scale (Likert III) aimed to identify the type of instructional modelling used by their professors. In order to achieve this, the same indicators present in the previous scale were presented, but identified as actions performed by the educator. For each of them, students were asked to classify the indicator according to the modelling types described above.

Analytic process

In order to evaluate perceived coherence, this study analyzes parts B and C of the instrument. Likert I (Part B), was coded binarily, assigning 1 to "Yes" and 0 to "No", and Likert II (Part C), was again coded binarily, assigning 1 to the option "Useful to replicate" and 0 to the option "Not useful to replicate". The second scale of part C (Likert III) was coded binarily for each instructional model. That is, the implicit model was first identified with number 1, while 0 represented the rest; then, number 1 was used for the explicit model and 0 for the rest, and so on. In this way, 4 dichotomous scales were obtained, which made it possible to compare and group the indicators for each of the models. Binary scales were used because, to perform hierarchical and event tree analyses on the indicators for determining concentration in categorical variables when N is small, it is necessary that data be binary or be arranged into a Likert scale, that no normality be observed, and that no relations be present among them.

To analyze the binarily-coded scales, a hierarchical cluster analysis was performed using the Jaccard index, which makes it possible to determine the homogeneity between two indicators. These indicators reflect each of the characteristics of the mathematics teaching models within the frameworks established and described above. Index I is defined as $I = x / (x + y - z)$, with "x" reflecting the number of prospective teachers who chose indicator X, "y" reflecting the number of

1 The accreditation of programs certifies their quality according to their declared purposes and the criteria established by each academic and professional community (see www.cnachile.cl).

2 The University Selection Test (Prueba de Selección Universitaria, PSU) is a standardized measurement with a mean of 500 points and a standard deviation of 110. The selection process for students who wish to become teachers requires that they obtain at least 500 points in the PSU.

3 Teacher education processes are heterogeneous in terms of the number and types of classes that they offer their students. The programs available are concurrent and consecutive, with 8 to 24 mathematics courses and 1 to 7 methods (didactics) courses.

prospective teachers who chose indicator Y, and “z” reflecting the number of prospective teachers who chose both X and Y.

RESULTS

In order to characterize the students' perception of their professors' instructional coherence, three key elements reported by the above Likert scales were considered: the students' teaching models (Likert I), the usefulness of replicating the instructional practices of their educators in their own teaching (Likert II), and the type of modelling under which they observe said practices (Likert III).

Students' teaching models (Likert I)

With respect to the predominant mathematics teaching and learning models among prospective teachers, when asked “For a student to generate mathematical knowledge, it is necessary to”, the hierarchical cluster analysis revealed two clusters with Jaccard homogeneity indexes over 70%.

The first cluster grouped the next indicators: 3. *Consider the mental structures of students in terms of the concepts' abstraction level*, 4. *Consider the discussion between students to generate the concept*, 5. *Show examples and counterexamples*, 6. *Create a representation of the concept in the student*, 8. *Consider that students have a certain knowledge and that they will use it to understand concepts*, 9. *Consider the socio-cultural aspects of students in connection with the activity*, 14. *Transform pure mathematical knowledge into knowledge that can be taught*, 16. *Present situations which are significant to the student*.

This set of indicators shows that students attach great importance to their pupils' previous knowledge, both cognitive and sociocultural. This reveals that the socio-cultural dimension, as well as the psychological-cognitive dimension, are among the elements that characterize the model that prospective teachers use to teach mathematics.

The second cluster concentrated the following indicators: 9. *To formulate a problem for knowledge to emerge in response to it* and 13. *To face the student with a problematic situation*. Both of them are associated with problem-solving as a strategy to generate knowledge. Said indicators are included in the socio-cultural dimension of the theories about how mathematics

should be taught; specifically, they are linked with the Theory of Didactic Situations and Polya's notion that mathematics should be learned by simulating the activity of a mathematician.

Usefulness of replicating their educators' instructional practices (Likert II)

Concerning the instruction provided by university professors, the actions which are part of or characterize their teaching model are those which students believe would be useful to replicate in schools. Specifically, the following clusters displayed a Jaccard homogeneity coefficient over 75%.

Cluster 1: 1. *The way in which mathematical problems were solved*, 3. *The way in which students were made to participate*, 4. *The way in which discussions were generated about the mathematical learning activities conducted*, 10. *The way in which students were made to reason*, 11. *The way in which complex didactic and/or mathematical activities were approached (breaking something down into smaller elements, giving examples and counterexamples, using analogies, etc.)*.

Cluster 2: 17. *The way in which students' comprehension was verified*, 18. *The way in which mathematics education theory was used*.

Both clusters are part of the social and cultural dimension of how mathematics is taught, which intersects with the elements that characterize the students' teaching model. It is noteworthy that, even though the indicators ask students to reflect on the aspects in which the educator's work—his/her way of conducting activities in the classroom, on the one hand, and his/her “mathematical-pedagogical” work, on the other—it is precisely the “form” of mathematical-pedagogical action that is relevant when generating an impact on the knowledge of prospective teachers.

Modelling type observed in the educators (Likert III)

Finally, regarding the forms of modelling observed by the students, only transfer modelling displayed an association with the indicators in the clusters that characterize the students' mathematics teaching-learning models. Although the Jaccard coefficient was lower than those of previous classifications, it never dropped below 45% in any of the clusters of the transfer model.

Cluster 1: 14. *To identify students' mathematical errors*, 15. *To tackle students' mathematical errors*.

Cluster 2: 10. *To make students reason*, 3. *To make students participate*

Cluster 3: 4. *To generate discussions about mathematical learning activities*, 17. *To verify students' comprehension*, 19. *To motivate or involve students in classroom tasks or activities*.

As can be observed, the three clusters again belong both to the social-cultural and the psychological-cognitive dimensions. In addition, it is interesting to note that the aspects or actions associated with evaluation, such as providing feedback to students about their work, were observed to have 50% of homogeneity, but in the implicit model of the educator.

CONCLUSIONS

When comparing the dimensions *students' teaching model*, *usefulness of replicating educators' instructional practices*, and *type of modelling observed*, three strong associations can be observed. First, comparing the students' teaching models with the usefulness of replicating certain instructional practices (Likert I & II) reveals that those deemed useful correspond to the same dimensions that characterize their own teaching models, and are associated with aspects of the socio-cultural and psychological-cognitive theories of mathematical education. Second, when comparing teaching models with the modelling types observed in instructional practices (Likert I & III), the students manifest the same traits (indicators) that characterize their teaching model only for a specific modelling type: the transfer model. This implies that students observe characteristics of their own teaching model when the educator connects instructional practices with the reality of schools. Third, comparing the usefulness of replicating certain instructional practices with the modelling type displayed by the teacher educator (Likert II & III) reveals that those deemed useful are precisely those that belong to the transfer model. These associations indicate that, when the educator manages his/her class in such a way that allows him/her to relate didactic-mathematical actions with the school classroom, the student regards such actions as relevant because they are the ones which belong to his/her teaching model. In terms of perceived instructional coherence, students regard their professors as

coherent when their practice reflects their teaching model.

We believe that the results provide empirical evidence of a phenomenon that we knew, but which we had not characterized. In this regard, it is worrying for our national teacher education system, as well as for other systems, to know that students only consider their teaching to be effective in terms of coherence when instructional practices match their didactic models. This prompts a question: to which degree has the education received affected students' conceptions of teaching and learning? In the case of the education of secondary school teachers, one of the main characteristics of education programs is their strong disciplinary focus, which contrasts with a brief period of pedagogical instruction. So, how has disciplinary instruction helped to change the traditional teaching patterns of school mathematics? This and other questions lead us to consider the need to know the initial didactic models of students, that is, how they see the teaching and learning of mathematics when they enter university, and how their views change as they progress in their teacher education program.

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