

How Permeable Are the Beliefs of Future Secondary School Mathematics Teachers to Pre-Service Experiences? Looking Across Their Years of Training

SAGE Open
October-December 2023: 1–27
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DOI: 10.1177/21582440231216836
journals.sagepub.com/home/sgo


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Abstract

Even though it has been recognized that prospective teachers' conceptions of the nature of mathematics, and of mathematics learning and teaching shape their teaching decisions, and, thereby, students' engagement and achievement, to date no research has examined these conceptions from a person-centered perspective taking into account year of teacher education program. Cluster analysis revealed three distinct profiles: anti-socioconstructivist, socioconstructivist, and flexible. Although the same driving dimensions were present at the different stages of the training, the characterization of these three profiles fluctuated, in tandem with the process of construction of a professional identity, the increase of the field experience and the discovery of the complexities of the profession. The analysis of the pedagogical practices support the non-linearity of the beliefs-practices relationship.

Plain Language Summary

This contribution attempts to shed light on pre-service secondary school teachers' beliefs about mathematics, and mathematics teaching and learning and the relationships between their beliefs and their pedagogical practices. To achieve our main objective, the beliefs data were collected by questionnaire from 646 pre-service secondary school teachers in different years of their teacher education program. In order to take into account inter-individual differences in pre-service teachers' beliefs, the data were submitted to cluster analysis. Cluster analysis is a technique that seeks to discern structure in a set of data by grouping respondents according to the similarity of their responses. Cluster analysis revealed three distinct profiles: anti-socioconstructivist/pro-traditional, socioconstructivist/anti-traditional, and flexible. Although the same driving dimensions were present at the different stages of the training, the characterization of these three profiles fluctuated, in tandem with the process of construction of a professional identity, the increase of the field experience and the discovery of the complexities of the profession. Our results provide new insights on three aspects. First, it appeared that the belief profiles of future mathematics teachers are more complex than the commonly accepted binary model. Not only is there the presence of an intermediate profile, but the other profiles are not that clear-cut. Second, the analysis of these profiles and of the pedagogical practices acknowledged by the future teachers in our sample support the non-linearity of the beliefs-practices relationship. Our findings are consistent with, and complementary to, research that has shown the role played by pre-service experiences in this relationship. Finally, our findings support a more balanced approach to the teaching and learning of mathematics, instead of a desire to be on either end of the continuum (traditional vs. socio-constructivist). This contribution provides interesting results for the field. At the end of their training, less than 40% of that year's cohort defended an anti-socio-constructivist conception of the nature of mathematics, its teaching and learning. More than 40% defended a socio-constructivist approach and approximately one-

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fifth of those in their final year adopted a flexible perspective. Further, our results highlight the importance to encourage students to hybridize their conceptions and practices and thus to develop more appropriate teaching practices. Several studies would be interesting to carry out to complete this contribution: longitudinal approach, nuanced with qualitative research, etc.

Keywords

mathematics, pre-service secondary teachers, epistemological beliefs, beliefs about mathematics teaching and learning, pedagogical practices, clustering

Introduction

The mathematical performance of students in compulsory education continues to be the subject of much international attention (Organization for Economic Cooperation and Development, 2019). The current concern is the difficulty in turning the negative curve in students' understanding of mathematics. This is all the more problematic since mathematics performance has been chosen by many countries as an indicator of the efficiency of their education system (Beswick & Fraser, 2019) and is considered to be the main predictor of dropping out of school (Cratty, 2012). At the same time, our societies have a growing need for qualified professionals in science, technology, engineering, and mathematics (STEM). Consequently, many countries are interested in improving STEM education.

Current research points to opportunities to learn, defined in terms of exposure to curriculum content, as one of the key determinants of student performance (Schmidt et al., 2015). The quality of this exposure is related to both the content taught and the pedagogical practices used. This work highlights the direct impact of teachers' pedagogical choices on the quality of student learning.

To understand why teachers act as they do in the classroom, it is necessary to question the thoughts behind these choices. The work carried out on teachers' beliefs is enlightening in this respect. Beliefs operate as a prism through which teachers select, interpret, and evaluate all professional information, whether it is theoretical contributions, recommended pedagogical practices or their own teachings (Hanin et al., 2022; Kelchtermans, 2009; Richter et al., 2021). This professional socialization to the teaching profession begins in childhood (Hanin et al., 2022; Pajares, 1992). In their life history, both personal and academic, future teachers internalize a certain number of beliefs, values, knowledge, etc., which they update and reuse, without question, in their teaching practice. Unfortunately, these beliefs often run counter to contemporary research on what constitutes good practice for mathematical learning, the primary focus of this article (Liljedahl et al., 2019). Wilkins (2008) notes that beliefs

have the strongest influence on teaching practices. As such, it is one of the functions of the teacher education (TE) programs to reshape these beliefs and regulate misconceptions that could impede effective teaching in mathematics (Liljedahl et al., 2019). While researchers agree on this point, they are much less unanimous on the ability of the teacher education programs to achieve it. Some report a certain permeability of beliefs to TE experiences, but only for primary school students (Gravé et al., 2020; Wanlin & Crahay, 2015), while others report changes for secondary school students as well (Gattuso & Bednarz, 2000; Yang et al., 2020). Still others observe a change in certain types of beliefs only (e.g., beliefs about teaching and learning, but not epistemological beliefs; Liljedahl et al., 2019). These inconsistencies raise several issues: does the current TE address only certain beliefs, only certain future teachers' profiles? Are the effects of TE the same whether the student strongly advocates one perspective or opposes one perspective without strongly advocating another? Is the impact of TE on beliefs different depending on the nature of the experiences (practical or theoretical), and associated with this, do future teachers' beliefs change over the course of their training? Our research attempts to shed light on these questions.

More precisely, this contribution attempts to shed light on pre-service secondary school teachers' views about mathematics, and mathematics learning and teaching through the following three objectives: (1) to identify distinct subgroups of teacher candidates with specific combinations of beliefs; (2) to explore how these distinct subgroups are present over the different years of the TE program, and (3) to look at how these profiles differ in terms of teaching practices.

Belief Structuring

Considering the manifold ways used in the literature to define teachers' beliefs, it is difficult to describe them unequivocally (Pajares, 1992; Voss et al., 2013). According to the pioneers of the field most often called upon in current research (e.g., Ajzen & Fishbein, 1980; Pajares, 1992), beliefs refer to psychological

understandings, assumptions, or propositions felt to be true. Educational beliefs pertain specifically to the understandings, assumptions, or propositions about teaching and learning that an individual holds to be true (Beswick et al., 2019). We follow the prevailing trend within the educational science literature in considering beliefs and conceptions as synonymous constructs (Beswick et al., 2019; Liljedahl et al., 2019; Voss et al., 2013).

Individuals' beliefs are structured in systems (Green, 1971; Pajares, 1992). This system is governed by three key principles. First, it has a quasi-logical structure: beliefs are linked to each other according to a principle of primacy. The first beliefs influence the construction of subsequent beliefs. Second, beliefs are spatially organized: the most influential beliefs are at the center of the system while those with less weight are at the periphery. In this respect, beliefs formed early in life are more likely to be the most central because of their role in the formation of later beliefs. Third, beliefs are organized in independent clusters, allowing contradictory beliefs to coexist in the same individual. This is the case for future teachers for whom the beliefs developed in TE are not always in line with those constructed during their own schooling.

When considering mathematics education, two types of beliefs are commonly identified: epistemological beliefs and beliefs about teaching and learning mathematics.

Mathematical Epistemological Beliefs

Epistemological beliefs (also called beliefs about the nature of mathematics) refer to beliefs about the nature of knowledge and how it is acquired (Hofer, 2000; Hofer & Pintrich, 1997). The nature of knowledge is usually described by two dimensions: the certainty of knowledge (stability) and the simplicity of knowledge (i.e., structure). Regarding the nature of knowing, it is also characterized by two dimensions. The first dimension is the source of knowledge. Stances range from strict beliefs in knowledge residing in authorities (external source) to an understanding of the importance of critical judgment, scrutinizing authorities, and of the ability to generate knowledge through one's own thinking (individual or/and social construction). The second dimension is the justification of knowledge and refers to how individuals evaluate claims. It ranges from denying the need for data and experiments to support arguments (self-evidence knowledge) to the acceptance that knowledge must be justified via a variety of tools to attain the status of knowledge.

Several studies have pointed out the specificity of these epistemological beliefs in reference not only to the educational and socio-cultural context in which they are constructed, but also to the discipline investigated (Therriault et al., 2010). At the level of mathematics,

there are many categorizations (Table 1). Two are particularly used within the international literature (Beswick, 2012; Dunekacke et al., 2015; Felbrich et al., 2012). The first is Ernest's (1989) typology that proposes three ways of conceiving of mathematics. In the instrumental view, mathematics is seen as a set of unrelated facts, rules, and procedures to be used in the pursuit of an external purpose. The Platonic view sees mathematics as a unified but static field of knowledge: mathematics is discovered, but not created. Finally, the problem-solving perspective views mathematics dynamically, as a continuously expanding human creation and as a cultural product. The second perspective is that of Grigutsch et al. (1998) who suggest a fourth perspective that sees mathematics as a tool for everyday life. The current integrative perspective views mathematics either as an objective collection of facts and procedures (behaviorist view) or as the result of subjective processes of knowledge construction (constructivist view; Fortier & Therriault, 2019; Voss et al., 2013).

Beliefs About Mathematics Learning and Teaching

Beliefs about teaching and learning mathematics refer to the teacher's preferred ways of teaching and learning (Chan & Elliot, 2004). These beliefs have been examined from a variety of theoretical perspectives, resulting in numerous typologies, some of which may be combined or even overlapped (Table 2). In an integrative approach, several researchers have examined the common denominator of existing typologies. What emerges is a binary typology of beliefs about teaching and learning mathematics that echoes the one defined for epistemological beliefs. On the one hand, we find the traditional conception, also called behaviorist or teacher-centered. Learning is understood as a process of transmission of information by the teacher to more or less passive receivers, the students. On the other hand, stands the (socio)constructivist conception also named the student-centered perspective. The student is at the heart of the learning process, with the teacher assuming the role of facilitator.

State of the Art of Secondary School Mathematics Teachers' Beliefs

Of the work that has investigated teachers' beliefs about mathematics, many have focused on practicing teachers (Beswick, 2012; Voss et al., 2013) and elementary school teachers (Dunekacke et al., 2015; Felbrich et al., 2012; Holm and Kajander, 2012). Little work has focused on prospective secondary teachers. In the following, we present three pieces of research that have focused on this specific audience.

Table 1. Different Conceptualizations of Epistemological Beliefs About Mathematics.

Fortier and Therriault (2019), Voss et al. (2013)	Behaviorist/transmission view		Constructivist view	
	Mathematics as a toolbox (described as a set of rules, formulas, and procedures) Instrumentalist view	Mathematics as a system (characterized by logic, rigorous proofs, and exact definitions) Platonic view	Mathematics as a process (emphasis on the relations between notions and sentences) Problem-solving view	Mathematics as an application (emphasis on its relevance f or society and life)
Grigutsch et al. (1998)				
Ernest (1989)				

Table 2. Different Conceptualizations of Beliefs About Teaching and Learning Mathematics.

Beliefs about teaching and learning	Blömeke and Kaiser (2014), Fortier and Therriault, 2019, Voss et al. (2013)	Behaviorist/ transmission theories		(Socio-)constructivist theories
		Content-focused approach with an emphasis on performance	Content-focused approach with an emphasis on conceptual understanding Learning as an active construction of understanding	
Beliefs about teaching	Kuhs and Ball (1986), Van Zoest et al. (1994)			Learner-focused approach
Beliefs about learning	Ernest (1989)	Learning as the mastery of skills through passive reception of knowledge		Learning as an autonomous exploration of one's own interests

A first study is the survey conducted in Switzerland, by Wanlin and Crahay (2015), with 90 pre-service secondary school teachers. Their findings highlight that candidates' conceptions of teaching and learning and this, regardless of the discipline taught, are less cleaved than expected. The latent class analysis does indicate that the majority of future teachers have a mixed profile (endorsing both behavioral and constructivist perspectives). Their results also show that, contrary to the conceptions of primary school teachers, for which an evolution is visible during the training, those of secondary school candidates remain rather favorable to the transmissive approach, whether they are at the beginning or at the end of their TE. A similar study conducted in French-speaking Belgium by Gravé et al. (2020) among 265 secondary school teachers supports this finding.

The third study questioned both the epistemological beliefs and the beliefs about teaching and learning mathematics of future secondary school mathematics teachers (Gattuso & Bednarz, 2000). The analysis conducted with 71 students entering training and 51 students in their final year of training revealed significant changes in their conceptions. While definitions, symbolism, language and vocabulary are given a central place at the beginning of training, this is much less the case at the end of it. This change goes hand in hand with a conception of teaching and learning mathematics that is no longer centered on memorization and application of formulas and procedures, but on the learner.

Taken together, these studies underscore the complex relationship between future teachers' beliefs and their training experiences. In order to better understand this complex dynamic, several limitations must be addressed. First, current work has relied mainly on the dichotomous approach (behaviorist vs. constructivist perspective) of mathematics beliefs. Yet, this dichotomy has proved to be incomplete to account for the complexity of the educational beliefs system of (future) teachers (Hanin et al., 2021). Second, to our knowledge, no study has looked at the different years of training. Uncovering mathematics teacher candidates' beliefs at the different stages of their educational program will make it possible to better understand the influence of the current program—both the theoretical and the practical parts—on their educational beliefs and, thereby, to make the program more effective in changing counterproductive beliefs (Yang et al., 2020). The adoption of a cross-sectional design is all the more relevant as, on the one hand, several studies have shown that teaching experiences have a significant impact on teacher candidates' beliefs (Gravé et al., 2020) and, on the other hand, it has been uncovered that TE programs are characterized by distinct stages of professional development (Bernal Gonzalez et al., 2018). Third,

most of this research has tended to favor a variable-centered approach, that is, one that describes the associations between variables found to a similar degree in all individuals. Yet, teachers' beliefs are inherently highly individual (Voss & Kunter, 2019). So, taking into account inter-individual differences in pre-service teachers' conceptions of the nature of mathematics and of teaching and learning mathematics, that is, adopting a person-centered approach, is a critical issue not only for educational theorists but also for teacher educators. At the conceptual level, a person-centered approach reflects teacher candidates' diversity in a more fine-grained way, while at the practical level, it allows for designing tailor-made and, hence, more effective, training programs aimed at developing desirable beliefs in terms of instructional practices and students' learning outcomes. Finally, research that has examined the link between beliefs and practices reports mixed results (Hanin et al., 2021, 2022; Cross Francis, 2015). A better understanding of this articulation is essential. As Crahay et al. (2010, p. 94, free translation) point out: "The teacher must be a professional who knows why he or she acts in one way rather than another. In other words, the quality, soundness, and consistency of the arguments and/or justifications behind the choice of a practice are just as important as the supposed effects of that practice."

Research Questions

The research reported here adopted a person-centered perspective to examine future mathematics secondary school teachers' conceptions about mathematics, and mathematics teaching and learning and how these conceptions differed at different points in their teaching program.

The research was guided by the following research questions:

RQ1: What meaningful distinct subgroups of prospective mathematics secondary school teachers with specific combinations of conceptions of mathematics, and mathematics learning and teaching can be identified? More precisely, how do pre-service teachers, at each stage of their TE program, combine the various conceptions observed in the literature into a personal position?

RQ2: How are these distinct subgroups present over the course of the TE program?

RQ3: Do these distinct subgroups differ regarding their pedagogical practices?

Method

Educational Context

In French-speaking Belgium, two distinct institutions share the training of future teachers. On the one hand,

Table 3. Distribution of Student Teachers by Year of Study and Pedagogical School Attended.

	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	Total
First year	24	38	112	92	6	0	272
Second year	16	26	71	52	12	13	190
Third year	19	17	67	51	21	9	184
Total	59	81	250	195	39	22	646

Note. PS = pedagogical school.

pedagogical schools prepare teachers from preschool to lower secondary school (students from 2.5 to 15 years old) and, on the other hand, universities are responsible for the training of upper secondary school teachers (students from 15 to 18 years old). These two types of training are based on the same set of seven competences (Appendix A; Fédération Wallonie-Bruxelles [FWB], 2022). In this research study, we are interested in the educational program of lower secondary school trainees. The latter is a professional bachelors degree spread over 3 years, at the end of which the student can move directly into teaching. It proposes an alternate training program: theoretical courses (i.e., communication, psychology, pedagogy, didactic, and mathematics contents) and teaching experiences are articulated throughout the formation. Concretely, future teachers have a minimum of 700 hours of practical training (FWB, 2022): 1 week of participant observation in the first year, 4 weeks of taking charge of the classroom in the second year and 10 weeks of taking charge in the third year, when the trainee usually takes charge of the class independently.

Sample and Procedure

A total of 646 prospective teachers consented to participate in this study (Tables 3-5). They came from six pedagogical schools located in the six French-speaking geographical areas and were in different years of study within the teacher education program.

The questionnaire used to assess conceptions of mathematics and its learning and teaching was completed online by the students during a class session (15 minutes). It was accompanied by a brief description of the research context, instructions for completion and a guarantee of the confidentiality of the data collected.

Measures

Data were collected using the French mathematics conceptions scale developed by Gattuso and Bednarz (2000) especially for prospective secondary school teachers. The scale captures four dimensions: (1) epistemological beliefs/conceptions of the nature of mathematics (11 items, vision of math as a human construction vs. vision of math given a priori); (2) mathematics learning beliefs

(7 items, math seen as a students' construction that may or not fit into a social context vs. math seen as an imitation of a given model); (3) mathematics teaching beliefs (16 items, interactive process of reflection in which the student is taken into account vs. a priori determined transmission of knowledge); and (4) their pedagogical practices (19 items, socio-constructivist vs. traditional/behaviorist). Respondents gave their opinion on the 53 statements using a four-point Likert type scale ranging from totally disagree (1) to totally agree (4). It should be noted that prior to large-scale use, the questionnaire was submitted to 15 novice teachers in order to check for understandability and clarity. Only the negatively phrased items (one per dimension) raised a few comments about the fact that they require more concentration to be processed. Given their importance in countering possible biases such as the halo effect (Langevin et al., 2011), the original questionnaire was retained as it was.

Data Analysis

The few studies that have examined the links between teachers' conceptions of mathematics, its learning and teaching have done so using a variable-centered approach. While the latter approach takes the variables under study as the focal point, the profile analysis focuses on particular combinations of variables as they exist within groups of individuals (Hayenga & Corpus, 2010), allowing the growing heterogeneity of teacher candidates to be taken into account. This perspective is of particular importance for both educational theorists and practitioners. At the conceptual level, a profile analysis reflects students' diversity in a more comprehensive way, while at the practical level, it allows for a more accurate and personalized assessment of students' needs and, thereby, tailoring of educational interventions accordingly.

To achieve the three objectives of the study, we follow a three-step analysis. First, confirmatory factor analysis using STATA software were performed to ensure that the model proposed by Gattuso and Bednarz (200) fit the data well. Then, the beliefs data from the 646 pre-service secondary school teachers in different years of the teacher education program were submitted to cluster analysis, as described by Hair et al. (1998). Cluster analysis is a technique that seeks to discern structure in a set

Table 4. Distribution of the Sample in Terms of Age, Gender, and School Location, by School.

	PS 1 (n = 59)	PS 2 (n = 81)	PS 3 (n = 250)	PS 4 (n = 195)	PS 5 (n = 39)	PS 6 (n = 22)
Age in years (mean $\pm$ SD)	20.69 $\pm$ 4.62	21.04 $\pm$ 1.34	22.08 $\pm$ 4.01	21.09 $\pm$ 5.52	20.06 $\pm$ 1.50	20.3 $\pm$ 2.34
Gender (% women)	55.0	61.0	48.4	61.0	58.4	62.5
School location	Urban	Urban	Rural	Urban	Rural	Rural

Table 5. Distribution of the Sample in Terms of Age and Gender, by Year.

	First year (n = 272)	Second year (n = 190)	Third year (n = 184)
Age in years (mean $\pm$ SD)	20.69 $\pm$ 4.60	21.9 $\pm$ 2.95	20.8 $\pm$ 2.96
Gender (% women)	47.8	62.1	70.7

of data by grouping respondents according to the similarity of their responses. In this study, the technique was employed to identify distinct subgroups of future secondary school teachers in each year of TE program who were similar in terms of their conceptions of the nature of mathematics, mathematics teaching and learning. Finally, we validate the cluster solution with a one-way MANOVA.

Results

There was very little missing questionnaire data, due to the fact that after students completed the questionnaire, one of the team's researchers checked that students had not left particular items blank. When this occurred (<2% of cases), she returned the scale to the student to complete those item(s).

Summary statistics for each variable under research are available in Appendix B.

Validation of the Instrument's Structure

First, we applied confirmatory factor analysis (CFA) to the model proposed by Gattuso and Bednarz (2000). The full model (including the four latent variables, i.e., epistemological conceptions, conceptions of learning, conceptions of teaching, and pedagogical practices) did not converge, even after the two problematic items were removed. Therefore, we considered each latent variable as a different model and ran them independently. Both the standardized loadings and the fit indices (Hu & Bentler, 1999) are evidence of models that are poorly fitted to the data (see Appendix C). Several parameters can explain the non adjustment of the model to our data. First of all, the number of years separating the two studies (22 years) and therefore the evolution of initial teacher training and of the educational system, more globally. Second, the difference in cultural and educational contexts between the two studies. In Belgium, future lower secondary school

teachers are trained in 3 years, while in Quebec they are trained in 5 years (bachelor + master).

Since the model from the literature could not be validated, we turn to an exploratory approach in order to amend the scale so that it reflects the current educational reality. Therefore, factorial analyses (EFA) were performed in order to identify the structure that best fits our data. Principal axis factoring was selected as the method of extraction. As we expected the factors to be correlated, we chose Oblimin with Kaiser normalization for factor rotation (Field, 2009). To ensure a solid psychometric foundation, items meeting one of the following conditions were removed: loading above .30 on more than one factor, loading below .50 (Brown, 2006). The analysis highlighted three factors for the conceptions of mathematics (i.e., procedural view, formal view, and open view) accounting for 55% of the total variance. Then, in order not to end up with factors taping only two items, we grouped the conceptions of learning and the conceptions of teaching together. Note that this structure is the most commonly used in recent research on the subject (Blömeke & Kaiser, 2014; Fortier & Therriault, 2019; Voss et al., 2013). Three factors emerged from the analysis for the conceptions of mathematics teaching and learning (i.e., promotion of critical thinking, promotion of procedures' application, transmissive approach) accounting for 50.7% of the total variance. Regarding pedagogical practices, factors with only two loadings were also observed. To avoid this, we removed the items related to the practice of symbolism that systematically load in pairs. Three factors have been identified (i.e., student-centered practices, regulation by the teacher, differentiation practices) accounting for 51.5% of the total variance (Table 6). In this regard, let us specify that it is the declared pedagogical practices that are collected here, that is, what the student says about what (s)he does (Duval et al., 2016). The factor pattern matrix is presented in Appendix D.

Table 6. Description of the Scales.

Scale name	Number of items	Omega coefficient			Sample item
		First year (n = 272)	Second year (n = 190)	Third year (n = 184)	
Conceptions of mathematics					
Procedural	3	.77	.67	.64	Solving problems in math means applying calculation rules. Without the language and vocabulary specific to it, there is no mathematics. Solving problems in math is mainly about using intuition and creativity.
Formal	3	.81	.75	.63	
Open	3	.74	.70	.65	
Conceptions of mathematics learning and teaching					
Promotion of critical thinking	4	.74	.75	.81	Teaching mathematics means inviting students to describe their own approaches to solving problems, to understand the approaches developed by others and to discuss them. Teaching mathematics means proposing problems that students should be able to tackle easily by mobilizing the mathematical notions and procedures that they have just seen in class. When the student arrives at school, the teacher has to show him/her everything.
Promotion of applying procedures	6	.71	.71	.69	
Transmission approach	5	.67	.69	.67	
Pedagogical practices					
Student centered	8	.83	.81	.82	As a math teacher, it is important for me to encourage students to participate in class discussions and express their ideas. As a math teacher, it is important for me to make sure that students do not make mistakes or errors in their work. As a math teacher, it is important for me to use different representations in the presentation of a subject, a concept.
Regulation by the teacher	3	.78	.69	.73	
Differentiation	4	.72	.68	.67	

Cluster Analysis

Variables were standardized through Z-transformations before starting the cluster analysis. Hierarchical cluster analysis using Ward's linkage method and squared Euclidean distances as the measure of similarity was used to identify the number of clusters and to fix cluster centers (Aldenderfer & Blashfield, 1984). Further, Hair et al. (1998) underlined the importance of examining a range of possible cluster solutions in order to determine a final solution that best fits with theoretical categories or other reliable evidence. Several variations of the clustering procedure were thus considered. On examination of the dendrogram, it was determined that, for each year of the program, three clusters fit the data best. The three-cluster solutions were interpretable and had a good distribution of cases across clusters. Next, a *K*-means cluster procedure with a three-cluster solution was run to construct the final solution (Bergman, 1998). Specifically, the three clusters revealed by Ward's analysis were used as the initial cluster centers. The final cluster centroids for the

three clusters characterizing each year of TE program are displayed in Tables 7 to 9 and in Figures 1 to 3. Centroids reflect students' means for each belief dimensions in each cluster. It is worth mentioning that, as scales were standardized, a positive centroid indicates a higher score than the overall sample mean and a negative centroid reflects a lower score than the average score of the sample. The reliability of this solution was also examined through a MANOVA, as described below.

Validation of the Cluster Solution

A one-way MANOVA was computed, with cluster membership as the between-subjects factor and the six cluster variables as dependent variables. The overall MANOVA was significant for the three years (first year: Pillai's trace = 1.31; $F(12,530) = 84.0$, $p < .001$, $\eta^2 = .66$; second year: Pillai's trace = 1.16; $F(12,366) = 41.8$, $p < .001$, $\eta^2 = .58$; and third year: Pillai's trace = 1.21; $F(12,354) = 45.61$, $p < .001$, $\eta^2 = .61$). Given the

Table 7. Cluster Centroids (Mean Values) and MANOVA Results for the First Year of Training ($n = 272$).

Cluster Patterns	Cluster 1: Anti-traditional	Cluster 2: Flexible	Cluster 3: Anti- socio-constructivist	$F(2)$	η^2
n (%)	102 (37.5)	64 (23.5)	106 (39.0)		
Conceptions of mathematics					
Procedural	−0.51a	0.47b	0.59b	58.93***	0.31
Formal	0.37b	−10.04a	0.44b	80.46***	0.37
Open	0.62c	−0.16b	−10.06a	140.49***	0.51
Conceptions of mathematics teaching and learning					
Promotion of critical thinking	0.11b	0.61c	−0.65a	57.64***	0.30
Promotion of applying procedures	−0.30a	0.40b	0.32b	18.44***	0.12
Transmission approach	−0.55a	0.23b	0.62c	46.87***	0.26

Note. The letters indicate post hoc comparison groupings for each variable based on the Bonferroni test; cluster centroids with different letters (reading across the row) differ significantly.

*** $p < .001$.

Table 8. Cluster Centroids (Mean Values) and MANOVA Results for the Second Year of Training ($n = 190$).

Cluster Patterns	Cluster 1: Anti-traditional	Cluster 2: Flexible	Cluster 3: Pro-traditional	$F(2)$	η^2
n (%)	73 (38.4)	47 (24.7)	70 (36.8)		
Conceptions of mathematics					
Procedural	−1.03a	0.61c	0.13b	54.04***	0.37
Formal	−0.81a	0.28b	0.49b	40.83***	0.31
Open	0.11a	0.95b	−0.12a	20.02***	0.18
Conceptions of mathematics teaching and learning					
Promotion of critical thinking	0.19b	1.13c	−0.58a	75.52***	0.45
Promotion of applying procedures	−1.07a	0.43b	0.59b	90.22***	0.49
Transmission approach	−0.46a	0.30b	0.31b	15.15***	0.14

Note. The letters indicate post hoc comparison groupings for each variable based on the Bonferroni test; cluster centroids with different letters (reading across the row) differ significantly.

*** $p < .001$.

significance of the overall tests, the univariate main effects were considered each time. As shown in Tables 6 to 8, the univariate tests for each cluster variable were all significant, and cluster membership explained between 10% and 51% of the variance in the six variables used to create the clusters. Results suggested that the composition of each cluster was significantly different from the others.

Further, a cross-validation procedure was set up to assess the replication of the three-cluster solution (Breckenridge, 2000; Tibshirani & Walther, 2005). To do so, the data set related to each year of training was randomly divided into two samples (first year: $n_1 = 138$, $n_2 = 134$; second year: $n_1 = 100$, $n_2 = 90$; third year: $n_1 = 98$, $n_2 = 86$). K -means clusters—specifying a three-cluster solution—were performed separately on samples 1 and 2 using the cluster centroid derived from the global sample. According to Cohen's (1960) recommendation, the agreement between the cluster solutions for the whole sample and for the two subsamples was substantial (average κ for the first year = .72; average κ for the second year = .71; and average κ for the third year = .78).

Description of the Clusters

The three-cluster solution, with the clusters' validity confirmed by both theoretical and statistical criteria, revealed meaningful profiles of conceptions of mathematics, mathematics teaching and learning, and highlighting specific patterns of variables for each year of the program.

First Year Students

1. Anti-traditional ($n = 102$; 37.5%): the first cluster was entitled the *anti-traditional profile* due to a rejection of a traditional approach of mathematics. The latter is evidenced by low centroids for a procedural view of the discipline as well as for teaching and learning practices promoting procedures' application and transmission. Instead, students in this profile defend an open vision of mathematics which cohabit, albeit in a less pronounced way, with a formal vision of mathematics.

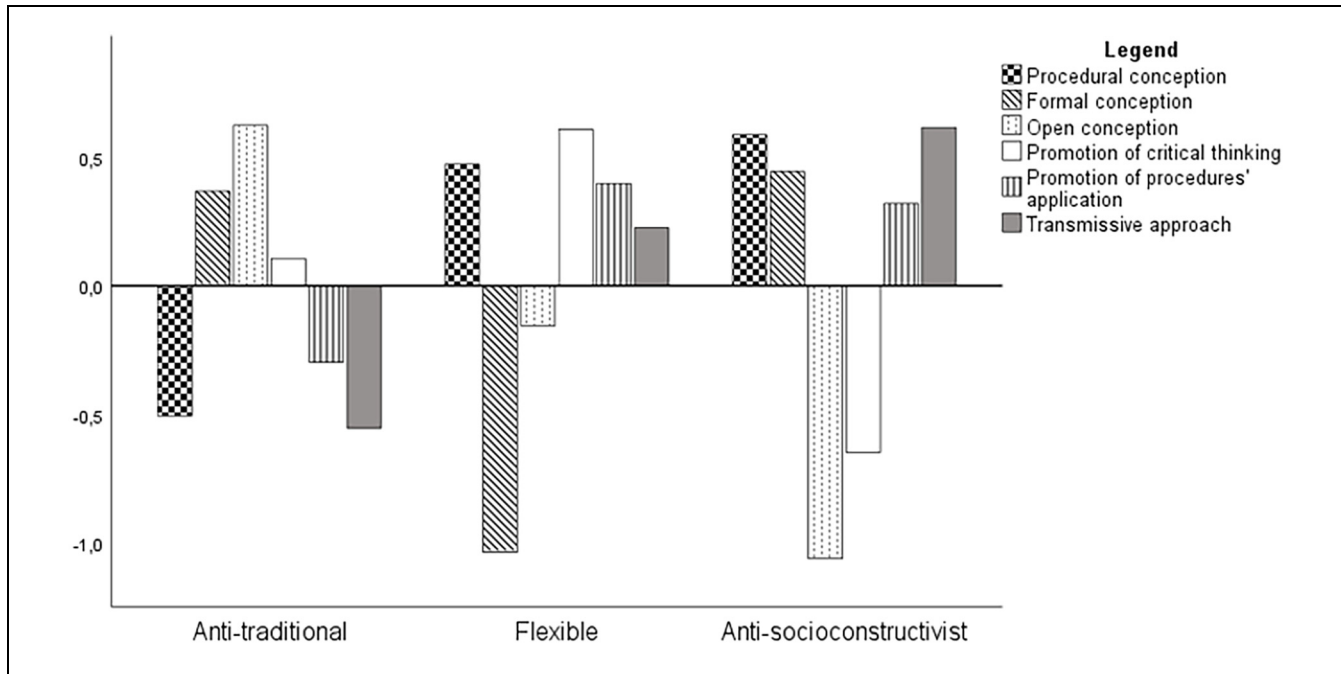


Figure 1. Standardized means of cluster variables for each profile for the *first* year of training ($n = 272$).

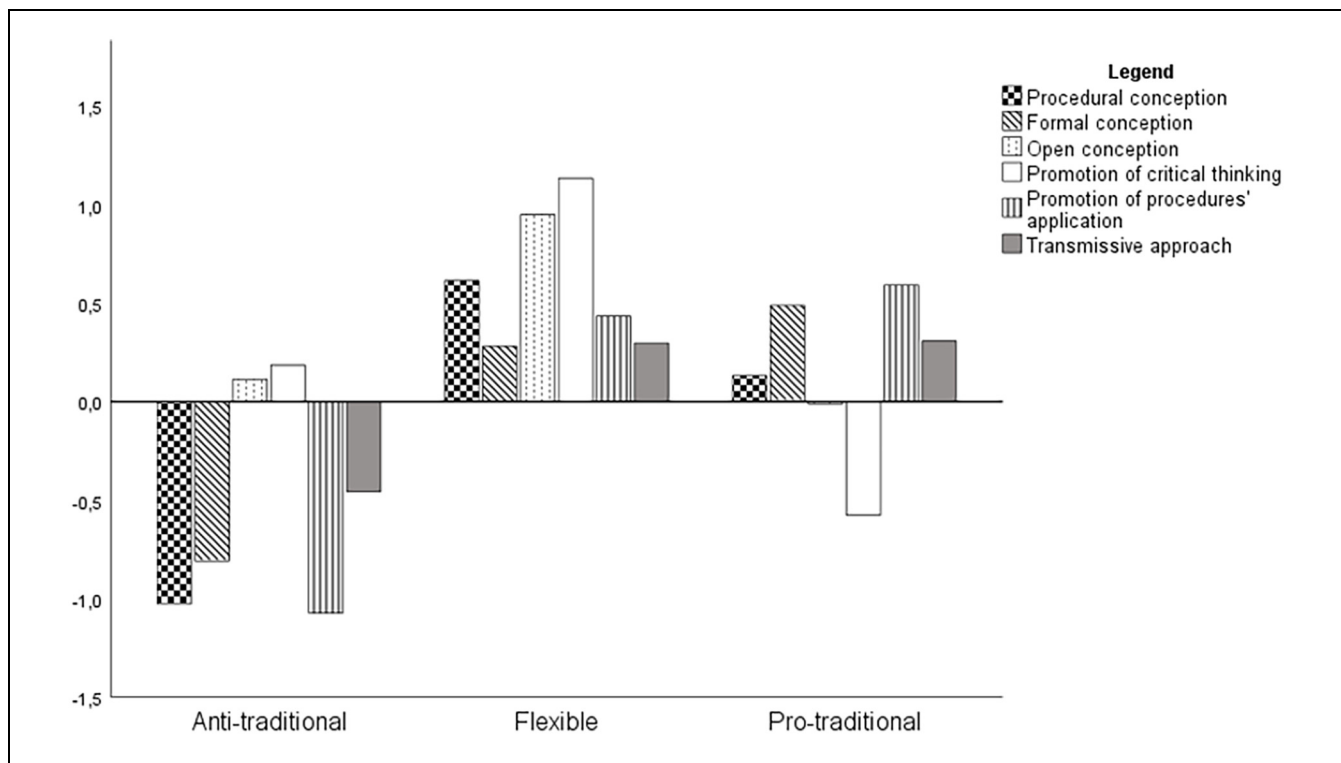


Figure 2. Standardized means of cluster variables for each profile for the *second* year of training ($n = 190$).

2. Flexible ($n = 64$; 23.5%): the second cluster was labelled the *flexible profile* due to moderately high centroids on both constructivist and traditional dimensions. A typical student from this

cluster would defend a procedural view of mathematics and strongly reject a formal vision of it. (S)he is very slightly opposed to an open vision of the discipline. In terms of teaching and learning,

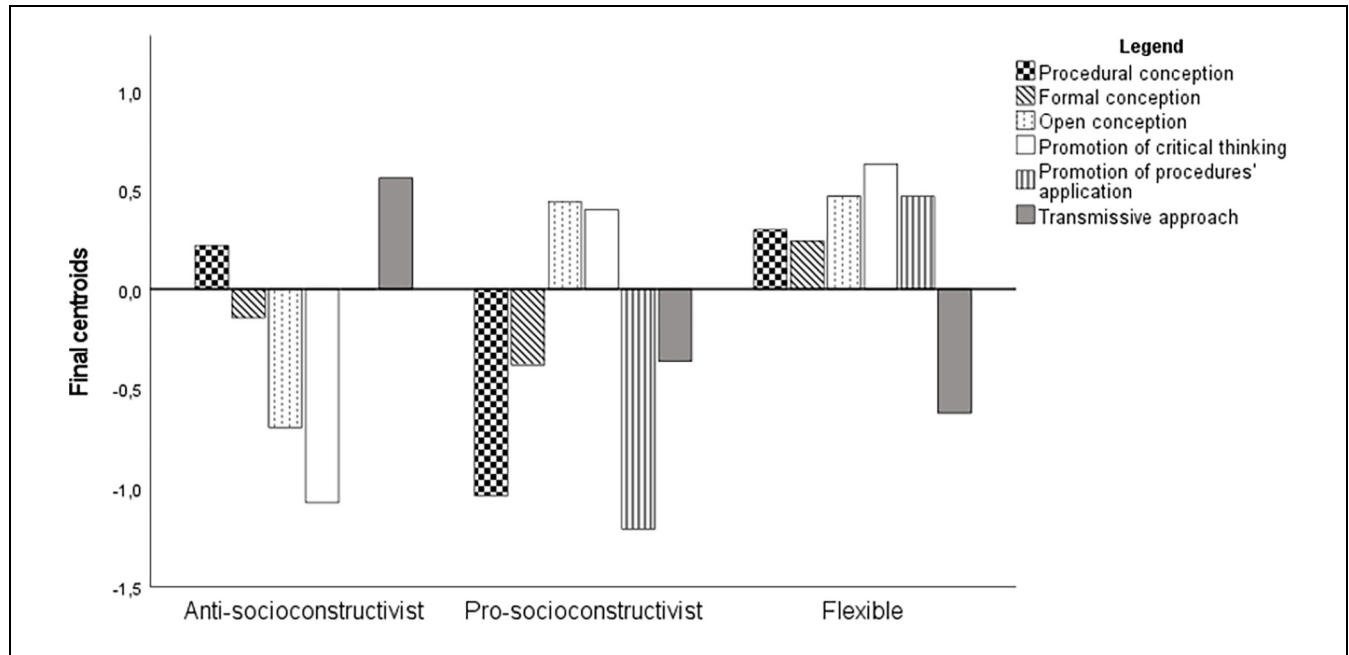


Figure 3. Standardized means of cluster variables for each profile for the *third* year of training ($n = 184$).

(s)he would encourage the development of critical thinking and, in a lesser extent, the application of procedures and transmission.

3. Anti-socioconstructivist ($n = 106$; 39.0%): in contrast to the first profile, students with an *anti-socioconstructivist* profile are strongly opposed to anything related to a socioconstructivist conception of the nature of mathematics, its teaching and learning. They exhibited markedly low centroids for both the open view of mathematics and the promotion of critical thinking. Instead, these students defend a procedural and formal vision of the discipline. In terms of teaching and learning, they moderately promoted transmissive practices and, in a lesser extent, the application of procedures.

Second Year Students

1. Anti-traditional ($n = 73$; 38.4%): the first cluster is characterized by a firm position against a traditional approach to mathematics, its teaching and learning and therefore was named *anti-traditional* profile. These students are strongly opposed to a procedural and formal conceptions of mathematics and firmly reject practices that rely on the application of procedures and the transmission. We also note that their position in favor of an open approach to mathematics and the development of critical thinking is very soft.
2. Flexible ($n = 47$; 24.7%): the second cluster was termed the *flexible* profile due to the cohabitation

of a traditional and socioconstructivist conception of the nature of mathematics, its teaching and learning. Students in this profile stand up for an open and procedural conception of mathematics with a touch of formalism. In terms of teaching and learning, they strongly promote critical thinking practices and, more modestly, the application of procedures as well as the transmissive approach.

3. Pro-traditional ($n = 70$; 36.8%): the final cluster included high centroids on the different dimensions associated to a traditional vision of the nature of mathematics and of mathematics teaching and learning, and therefore was labeled the *pro-traditional* profile. Students in this profile defend a formal view of mathematics as well as practices relying on the application of procedures and on transmission. They are opposed to critical thinking practices.

Final-Year Students

1. Anti-socioconstructivist ($n = 67$; 36.4%): the first cluster was named the *anti-socioconstructivist* profile due to substantial low centroids for an open view of mathematics and for the promotion of critical thinking teaching practices. Students in this profile seem to hold a traditional conception about the nature of mathematics, its teaching and learning, as evidenced by an above-average centroid for a procedural view of the discipline and a high centroid for transmissive practices.

Table 9. Cluster Centroids (Mean Values) and MANOVA Results for the *Third Year of Training* ($n = 184$).

Cluster patterns	Cluster 1: Anti-socio-constructivist	Cluster 2: Pro-socio-constructivist	Cluster 3: Flexible	$F(2)$	η^2
n (%)	67 (36.4)	77 (41.9)	40 (21.7)		
Conceptions of mathematics					
Procedural	0.22b	-1.04a	0.30b	47.06***	0.34
Formal	-0.15a	-0.38a	0.24b	7.70**	0.10
Open	-0.70a	0.44b	0.47b	48.63***	0.35
Conceptions of mathematics teaching and learning					
Promotion of critical thinking	-1.08a	0.40b	0.63b	91.50***	0.51
Promotion of applying procedures	0.00b	-1.21a	0.47c	63.69***	0.41
Transmission approach	0.56b	-0.36a	-0.63a	40.61***	0.31

Note. The letters indicate post hoc comparison groupings for each variable based on the Bonferroni test; cluster centroids with different letters (reading across the row) differ significantly.

** $p < .01$. *** $p < .001$.

2. Pro-socioconstructivist ($n = 77$; 41.9%): in contrast to the previous profile, students with a *pro-socioconstructivist* profile are strongly opposed to anything related to a traditional conception of the nature of mathematics, its teaching and learning. They manifest notably low centroids for both the procedural view of mathematics and the promotion of procedures' application. To a lesser extent, these students take also a stand against a formal view of mathematics and transmissive practices. They promote an open conception of the discipline and the development of critical thinking.
3. Flexible ($n = 40$; 21.7%): the third cluster was labeled the *flexible profile*, due to the coexistence of a constructivist and traditional conception of the nature of mathematics and of mathematics teaching and learning. A typical student from this cluster fosters an open view of mathematics and, in a less marked way, a formal and procedural conception of it. As regards teaching and learning, we note a strong positioning of the student of this profile in favor of the development of critical thinking and the application of procedures and against transmissive practices.

Clusters and Outcomes

The first part of our third objective focuses on how these distinct subgroups differ regarding gender composition (Table 10). The analyses concluded that these combinations are not gender-related (Y_1 : $\chi^2(2) = 0.45$; $p = .80$; Y_2 : $\chi^2(2) = 3.06$; $p = .21$; and Y_3 : $\chi^2(2) = 1.31$; $p = .52$).

The second part of it looks at the differences between the clusters in terms of pedagogical practices (i.e., student-centered practices, regulation by the teacher, and differentiation), multilevel analyses of variance were performed with age and school as covariates.

As regards *student-centered practices*, significant differences were found between the profiles, in each year of TE program (Y_1 : $F(2,269) = 13.26$, $p = .001$, $\eta^2 = .09$; Y_2 : $F(2, 187) = 12.27$, $p < .001$, $\eta^2 = .12$; Y_3 : $F(2, 181) = 27.54$, $p < .001$, $\eta^2 = .23$; see Table 11). More precisely, post hoc comparisons based on the Bonferroni test showed that, among first-year students, both the anti-traditional and the flexible profiles resort to student-centered practices significantly more than the anti-socioconstructivist profile. Among second-year students, the same differences were observed in addition to a greater use of student-centered practices by the flexible profile as compared to the anti-traditional profile. In the final year, students with a pro-socioconstructivist and a flexible profiles rely significantly more to these type of practices compared to students with an anti-socioconstructivist profile.

About the practices fostering the *regulation of learning by the teacher*, significant differences were also observed throughout the training (Y_1 : $F(2,269) = 4.5$, $p = .01$, $\eta^2 = .04$; Y_2 : $F(2, 187) = 3.89$, $p = .02$, $p < .001$, $\eta^2 = .04$; Y_3 : $F(2, 181) = 13.6$, $p < .001$, $\eta^2 = .13$). Among first-year students, anti-traditional regulate their students' learning significantly less than the flexibles and the anti-socioconstructivists. During the second year, only the difference between the anti-traditional and the pro-traditional profiles persisted. In the final year, the pro-socioconstructivists stand out significantly from their peers with an anti-socioconstructivist and a flexible profiles.

Finally, concerning *differentiation* practices, significant differences were also noticed between the profiles in each year of the teacher education program (Y_1 : $F(2, 269) = 26.6$, $p = .001$, $\eta^2 = .17$; Y_2 : $F(2, 187) = 13.19$, $p < .001$, $\eta^2 = .13$; Y_3 : $F(2, 181) = 19.80$, $p < .001$, $\eta^2 = .18$). More precisely, the same results are observed throughout the training program: students with a flexible

Table 10. Percentage of Women in Each Cluster for Each Year of Training.

First year (48.8 %)			Second year (62.1%)			Final year (70.7%)		
Profile 1: Anti-traditional (n = 102)	Profile 2: Flexible (n = 64)	Profile 3: Anti-socio-constructivist (n = 106)	Profile 1: Anti-traditional (n = 73)	Profile 2: Flexible (n = 47)	Profile 3: Pro-traditional (n = 70)	Profile 1: Anti-socio-constructivist (n = 67)	Profile 2: Pro-socio-constructivist (n = 77)	Profile 3: Flexible (n = 40)
49.0%	50.0%	45.3%	71.2%	48.9%	61.4%	67.2%	77.5%	70.1%

and an anti-traditional/pro-socioconstructivist profile differentiate significantly more their practices than their peers with an anti-socioconstructivist/pro-traditional profile (Table 11).

Discussion

This study investigated future secondary school teachers' beliefs about the nature of mathematics and about mathematics teaching and learning. This contribution was guided by three objectives. In this section, the first two objectives are addressed concurrently. As a reminder, the first one seeks to document how future teachers at each stage of their TE program combine the different beliefs investigated into a personal position while the second questions whether these personal positions tend to differ over the course of the training program. The third objective, which aims at shedding light on whether these combinations explain differences in the pedagogical practices favored by future teachers, is discussed in a second step.

Evolution of the Anti-socioconstructivist / pro-traditional Profile During Training

In the first year, students with an anti-socioconstructivist profile (39% of the cohort) defend a procedural and formal approach of the nature of mathematics and are virulently opposed to an open vision. Their second-year counterparts (36.8% of the cohort) are almost neutral on both the procedural and the open vision of mathematics and defend with as much conviction as their predecessors a formal vision of the discipline. Final year students (36.4% of the cohort) reaffirm, but very modestly, a procedural view of mathematics, only slightly a formal conception and vigorously reaffirm their opposition to an open vision of the discipline. Regarding the conception of learning and teaching, first-year students are strongly opposed to a critical thinking approach, defend the application of procedures, but in a rather modest way, and are relatively strongly in favor of transmission. Conversely, in the second year, students are more modestly opposed to the open view of mathematics, more strongly favorable to the application of procedures and are much less in support of a transmissive approach. In the final year, they strongly reaffirm their opposition to the promotion of critical thinking and their pro-transmission stance. On the other hand, they defend a neutral vision of the application of procedures and modestly position themselves against a procedural vision of mathematics.

Several hypotheses can be put forward to explain the observed changes. Our results support previous work by indicating that teacher candidates enter TE with preconceptions built when they were in school (Hanin et al.,

Table 11. Post Hoc Comparison Among the Three Profiles, for Each Year of the Training Program, on the Three Pedagogical Practices Assessed.

	First year			Second year			Third year		
	Profile 1: Anti-traditional	Profile 2: Flexible	Profile 3: anti- Socio-constructivist	Profile 1: Anti- traditional	Profile 2: Flexible	Profile 3: Pro-traditional	Profile 1: Anti- socio-constructivist	Profile 2: Pro- socio-constructivist	Profile 3: Flexible
Student-centered practices	0.37b	0.29b	−0.27a	0.06b	0.49c	−0.39a	−0.78a	0.06b	.29b
Regulation by the teacher	−0.22a	0.19b	0.13b	−0.26a	0.00ab	0.27b	0.04b	−0.62a	.32b
Differentiation	0.34b	0.11b	−0.62a	0.25b	0.59b	−0.27a	−0.51a	0.40b	.01b

Note. The letters indicate post hoc comparison grouping based on the Bonferroni test; means with different letters differ significantly.

2021; Hanin et al., 2022; Liljedahl et al., 2019; Voss & Kunter, 2021). At the same time, they are in line with the work that has shown that beliefs are permeable to teacher education experiences. More specifically, this "vulnerability" to the dominant paradigm conveyed in initial training quite logically concerns second-year students. We observe a much more modest position on the transmissive approach, almost neutral on the procedural vision and a very slight opposition to an open vision of the discipline and the promotion of critical thinking. It is, in fact, in the second year that they discover the complexity of the profession (e.g., the large number of tasks that fall to the teacher) through the first internships. They are therefore highly dependent on the advice, guidance, and practices provided by the trainers (Hanin & Cambier, 2023). However, in initial training both the theoretical content taught and the pedagogical practices adopted by the trainers are based almost exclusively on the socioconstructivism paradigm (Dejemeppe, 2018). Furthermore, research shows that they have difficulty to manage their dual identity (teacher and student): the second year is characterized by phases of insecurity and tension (Bernal Gonzalez et al., 2018). The construction of their identity is all the more difficult because they defend colors that are contrary to those advocated in initial training. All the messages, feedback and content they receive invite them to adopt a socioconstructivist vision. In addition to these identity-related reasons, strategic reasons (e.g., success in training) can also be put forward to explain why this affirmation is all the more difficult for students who defend a perspective that goes against the one promoted in TE (Altet, 2013). In the final year, however, the acquisition of a more substantial theoretical and practical background brings more confidence to students whose professional identity is better defined (Hanin & Cambier, 2023). Students are much more assertive in their convictions. This can be seen in their reaffirmation of their opposition to an open conception of mathematics and the promotion of critical thinking, as well as in their positioning in favor of the transmissive approach. The formal conception and that promoting the application of procedures show a different evolution: the coloration by the experiences lived in initial training is only felt in the last year. Regarding the formal conception, if it is hard to uproot, it is probably because of the strong emphasis put by teachers in compulsory education (during the students' own school career) on the use of symbolism, language, and mathematical vocabulary with an often excessive rigor and undoubtedly also due to the image of mathematics conveyed by society (Beswick & Fraser, 2019; Cratty, 2012). As for the promotion of the application of procedures, several studies have highlighted that novice teachers focus on classroom management (rather than on the management of learning; Bernal Gonzalez

et al., 2018) which may explain a marked position in favor of practices that maintain control of the classroom (Hanin et al., 2021; Mukamurera, 2011).

As regards the evolution of the proportion of students embracing the anti-socioconstructivist/pro-traditional profile, a slight decrease can be observed throughout the training. This supports the hypothesis that beliefs are permeable to teacher education experiences.

Evolution of the Flexible Profile During Training

At the beginning of their training, students with a flexible profile (23.5% of the cohort) adhere to a procedural vision of mathematics, reject vehemently a formal vision of the discipline and very modestly the open conception. In terms of their conception of teaching and learning, they position themselves in favor of the development of critical thinking, the application of procedures and a transmissive approach, with a decreasing intensity. Like previous work (Gravé et al., 2020; Voss et al., 2013), this profile highlights that constructivist and transmissive beliefs are not mutually exclusive dimensions, but rather that they can be reconciled within the same belief system. Second-year students (24.7% of the cohort) advocate with the same strength as their predecessors a procedural conception of mathematics as well as the application of procedures and a transmissive approach. However, they defend with more fervor the promotion of critical thinking. They also distinguish themselves from first-year students by claiming, albeit modestly, a formal vision of mathematics and a strong open view of the discipline. If there is indeed a reconciliation of the two dual educational conceptions, a slight leaning toward the constructivist conception seems to emerge. As for the final year students (21.7% of the cohort), as their direct predecessors, they are still in favor of a procedural and an open view of mathematics, and promote critical thinking practices, but in a less fervent way. They defend with the same intensity as second-year students a formal conception of mathematics and the application of procedures. Finally, contrary to the students of the previous two years, they reject the transmissive approach.

Like the previous profile, when they enter training, the flexibles hold conceptions about the nature of mathematics, its teaching and learning that are strongly influenced by their own experiences as students. Our results support, once again, the influence of initial training experiences on students' initial beliefs. However, this influence seems to operate differently with students who have a mixed profile of conceptions.

The socioconstructivist paradigm conveyed in training seems to influence above all the open conception of mathematics and the promotion of critical thinking. Contrary to anti-socioconstructivists, students who are

able to make a priori contradictory conceptions cohabit are not destabilized and do not question their other conceptions when they are enculturated in a socioconstructivist vision of education. This is seen in particular through the promotion of the application of procedures that do not break down during training. The situation is slightly different for the procedural vision of mathematics and the transmissive approach which evolve in the last year, most probably thanks to the accumulation of practical experience. On that point, it is important to note that if the application of procedures is still in force in elementary classrooms, particularly in the run-up to the end-of-year certification tests and evaluations, transmissive teaching is in sharp decline (Topping, 2011). A result that runs somewhat counter to the above is that concerning the formal conception of mathematics: first rejected, it is then defended. The flexibles are the only ones who enter initial training with no concern for this dimension. Yet, both trainers and associate teachers consider it important that future teachers demonstrate a minimum of rigor in the use of symbolism, language, and mathematical vocabulary (Hanin et al., 2022; Dejemeppe, 2018).

The distribution of the students throughout the training is almost constant. Meanwhile, the above analysis points to differences from 1 year to the next that attest of a coloring of future teachers' initial beliefs by their experiences in teacher education and allow us to go one step further in our understanding of this relationship. Work to date talks about changing less pedagogically supportive conceptions of future teachers through TE (Liljedahl et al., 2019; Voss & Kunter, 2019) and the structural difficulty of combining traditional and constructivist conceptions without isolating them into distinct belief clusters (Beswick et al., 2019; Cross Francis, 2015). Our results nuance these conclusions by highlighting, on the one hand, the capacity of teacher education to broaden students' vision, to make it integrative and thus to develop students' adaptability to the educational situations they encounter on a daily basis and, on the other hand, the presence of mixed conceptions.

Evolution of the Anti-Traditional / pro-socioconstructivist Profile During Training

The first-year students (37.5% of the cohort) take a stand against the traditional approach of the nature of mathematics, its teaching and learning. They reject the procedural vision of mathematics and the transmissive approach and, more modestly, the application of procedures. They defend an open vision of the discipline, but are almost neutral on the promotion of critical thinking. More surprisingly, they are in favor of a formal conception of mathematics. Their second-year counterparts

(38.4% of the cohort) define themselves by firmly rejecting a traditional conception of mathematics, its teaching and learning. This is evidenced by a marked opposition to a procedural and formal view of mathematics, and to teaching based on the application of procedures and transmissive practices. The perspective defended (i.e., open vision of the discipline and promotion of critical thinking) are much less fervently affirmed. Unlike their predecessors, final year students (41.9% of the cohort) defend more assertively an open conception of the discipline and critical thinking practices, that is a socioconstructivist view. Additionally, they are still firmly opposed to the procedural conception of mathematics and the application of procedures. They reject the transmissive approach with the same intensity as second year students but are more modestly opposed to the formal conception of the discipline.

Several hypotheses can be formulated to shed light on these results. The presence, among the first-year students, of a formal conception of mathematics, such as, defending a certain rigor in the use of symbolism, language, and mathematical vocabulary is to be interpreted, in our opinion, as a vestige of the school experience of these future teachers and also of the image of mathematics conveyed by society (Beswick & Fraser, 2019; Cratty, 2012). Author and colleague (2020) note that stronger mathematics future teachers sometimes believe that a procedure is all that is needed based on their own school experiences. The significant change that can be observed between the first and second year is to be linked to the enculturation of future teachers in a socioconstructivist paradigm, as previously mentioned (Dejemeppe, 2018). This influence is also visible through a stronger rejection of the procedural approach and the application of procedures. At the same time, second-year students make the practical experience that promoting an open view of the discipline and critical thinking are much more demanding in terms of class control. Studies point to a temporary shaking of the teacher's identity as a result of the initial confrontations with the profession (Henry, 2016; Meijer et al., 2011). As previously stated, second-year students are in the midst of constructing their professional identity. This can be seen in the fact that they define themselves in opposition to a series of conceptions without affirming what they stand for. In the final year, with a better knowledge of the different facets of the profession, more practical experiences, and therefore a more stable professional identity and sense of competence, final-year students seem to revert to their initial conceptions of the profession.

About the distribution of the students, it follows the reverse curve of the anti-socioconstructivist profile, that is a slight increase throughout the training which supports the thesis of the permeability of initial conceptions to pre-service experiences.

Evolution of Pedagogical Practices Favored by the Three Profiles Throughout the Training

As a recall, three pedagogical practices were investigated: student-centered practices, regulation by the teacher, and differentiation. A first general observation that emerges from our analyses is a consistency between the conceptions defended and the pedagogical practices promoted.

More precisely, regarding student centered practices, our results indicate a certain stability of the relationship between conceptions and practices throughout the training. Anti-traditionalists/pro-socioconstructivist and flexible teachers use this type of practice significantly more than anti-socioconstructivist/pro-traditional teachers. A small specificity in the second year: the flexibles say that they put more emphasis on the student than the anti-traditionals. This finding is quite consistent with what we have observed in terms of the characteristics of these two profiles. On this point, in the second year, the flexible profile defends a more socioconstructivist vision than the anti-traditional profile, which defines itself more in opposition to the traditional approach. With regard to the regulation of learning by the teacher, the anti-traditionalists distinguished themselves, throughout the training, from the other two profiles by using them less. Note, however, that in the second year the difference with the flexibles is no more significant. This can again be explained by the more "socioconstructivist" coloration of the flexible profile in the second year, compared to the other two years of the training. Finally, regarding the differentiation practices, the same distinctions were observed throughout the training, that is, a lesser use by the anti-socioconstructivists/pro-traditionals compared to both the flexibles and the anti-traditionals/pro-socioconstructivists.

Conclusion

This contribution highlights some encouraging results. At the end of training, less than 40% of the sample defends a traditional conception of the nature of mathematics, its teaching and learning. More than 40% defend a socioconstructivist approach and approximately one fifth of the sample adopt a flexible perspective. The dominant conceptions observed in the last year of training (i.e., an open vision of mathematics promoting diversity of reasoning and artifact-based learning; the promotion of critical thinking; a conception of learning where the student is at the center) are very much in line with the evolution of society's needs in terms of literacies and skills (Darling-Hammond, 2017; Okogbaa, 2017). Societal developments require citizens capable of analyzing and resolving complex situations, that is, mobilizing their knowledge in situations in a relevant, flexible and creative way.

Our results provide new insights to existing knowledge. First, the beliefs' profiles of mathematics future

teachers are more complex than the commonly accepted binary model. Not only is there the presence of an intermediate profile, but the anti-socioconstructivist/pro-traditional and anti-traditional/pro-socioconstructivist profiles are not as clear-cut as that.

Secondly, both the analysis of these profiles and of the pedagogical practices promoted by the future teachers of our sample support the non-linearity of the beliefs-practices relationship. Our findings are consistent with, and complementary to, research that has shown the role played by pre-service experiences in this relationship (Gravé et al., 2020; Yang et al., 2020). While most research focuses on the practical aspect of training and reports a perception of the uselessness of theoretical content and, consequently, its distancing by students, our results indicate a sensitivity of initial conceptions also to the theoretical aspect of training (as changes can already be seen at the start of the second year of training). Moreover, this coloration would differ according to the student's conception profile. On this point, flexibles switch from a neutral position to a pro-socioconstructivist tendency between the first and second year of training, and maintain this inclination, albeit slight, in the final year. This can also be seen in the practices they promote: in second year, they use significantly more student-centered practices than the anti-traditionalists and reduce their use of teacher regulation (compared to their first year counterparts), reaching the level of the anti-traditionalists. Anti-traditionals, under the influence of a pro-socioconstructivist paradigm, firmly reject the traditional approach in the second year. On the other hand, in the last year, following longer practical experiences and with a more stable and defined professional identity, they more explicitly defend an open view of mathematics and the promotion of critical thinking. With respect to the anti-socioconstructivists/pro-traditionals, between the first and second year of training, they move from a firm opposition to a socioconstructivist vision of the discipline and a strong position in favor of a traditional approach to a quasi-neutral position on the procedural vision of math and a much less pronounced interest in transmissive approaches. They are also neutral on the open view of mathematics. The socioconstructivist bath in which they have been immersed for a year and a half has turned their identity markers upside down, sowing doubt and questioning in their initial conceptions of the profession. In the third year, progress in the definition of their teaching identity and practical experiences lead them to reject more firmly the socioconstructivist approaches and to express their interest in a procedural vision of the discipline and in transmissive practices.

While many studies have shown that pedagogical practices based on the transmission of knowledge and the

application of procedures are deleterious to quality learning (Behlol et al., 2018; Noreen & Ranan, 2019), we agree with Voss et al. (2013) who defend the adaptability of practices to circumstances. We support a more balanced approach to the teaching and learning of mathematics instead of a desire to be on either end of the continuum. According to this perspective, traditional practices are not to be avoided completely and socioconstructivist practices to be invested in permanently, it is rather a matter of being able to identify the most adequate approach given the contextual characteristics of the situation (e.g., class group, mathematical object treated, and time of the sequence). We believe that training as it is currently conceived (at least in French-speaking Belgium) does not encourage a hybridization of practices. This is important in order to be able to deal with the growing complexity of the teaching profession (Standal et al., 2014; Voss & Kunter, 2019). On the contrary, it tends to demonize traditional approaches and to "indoctrinate" FE with socioconstructivist ideas and practices, which seems to have the effect of reinforcing the pro-traditionalists in their initial conception. Some individuals continue to hold to the practice that if a more traditional form of teaching worked for me, it will work for others (Hanin et al., 2022). In order to encourage these individuals to hybridize their conceptions and practices, and thus to develop more appropriate teaching practices, we believe that, in initial training, we should favor a variety of pedagogical approaches and, above all, develop the critical spirit of pre-service teachers with regard to these different approaches so that they can make judicious choices according to each situation. This nuanced look at different pedagogical approaches is equally important for socioconstructivists. By questioning the feasibility of socioconstructivist proposals in training, the "shock" of reality should be mitigated. Also, the development of a capacity for pedagogical analysis would enable them not to opt for traditional approaches in order to maintain control of the class, but for pedagogical reasons (e.g., more complex mathematical contents require a little more guidance from the teacher).

This hybridization of both conceptions and practices by the decentration that it requires from the future teachers is a source of instability and discomfort. It is not a simple assimilation in the Piagetian sense, but it requires a real conceptual restructuring (accommodation; Coburn & Woulfin, 2012). The establishment of a secure and supportive framework is therefore not enough. As our results attest, novice teachers' inordinate preoccupation with classroom management may impede this restructuring process. One suggestion for focusing the attention of pre-service teachers on the pedagogical dimension of teaching might be to assess only this dimension during one or two of their practical experiences.

Future Perspective and Limitations

Several limitations to the present study provide new avenues of research that can be pinpointed. First, the use of a self-report questionnaire to tap teachers' beliefs allows access only to the beliefs that are conscious. This is why many researchers recommend cross-referencing such data collection with discourse analysis and real class observation that allow inferring of beliefs from what people say, intend, and do (Cross Francis, 2015; Curtiss, 2017; Safrudiannur & Rott, 2021). The results of the present research can be cross-referenced with the results from the qualitative study based on the same theoretical model and conducted with final-year students with the same characteristics as those who participated here (Hanin & Cambier, 2023), in order to grasp the phenomenon under study in all its complexity. It would also be interesting to conduct a similar qualitative study with first- and second-year students. Second, a methodological point, it is necessary to validate the structure resulting from the exploratory factor analysis through SEM analysis with another sample presenting the same characteristics. Third, it would be informative to document how these profiles differ regarding future teachers' actual instructional practices. In concrete terms, two complementary options can be considered. The first would consist in collecting teachers' self-reports of their practices, with the advantages and biases that such a survey entails, and the second would consist in carrying out observational studies of the professional actions of teacher candidates when they are in classrooms. In the same vein, it would be interesting to cross-reference our results with an observational study of the teaching practices of trainers working in Pedagogical School. Such a study, which would complement our contribution, would shed new light on the impact of training on the conceptions of future teachers. Fourth, in order to better guide continuing education and thus more effectively support in-service teachers' professional development, it would be

advisable to carry out a similar study among in-service secondary school teachers. In this respect, given that in-service teachers move through specific developmental stages (Lunenberg et al., 2014; Mukamurera, 2014; Nault, 1999; Sprott, 2019), it would be interesting to identify specific profiles for each of these stages. Finally, as previous research has pointed to a connection between beliefs and knowledge of mathematics (Holm and Kajander, 2012) or that stronger mathematics understandings might promote a more pro-traditional view (Hanin et al., 2022), it would be beneficial to also consider the knowledge that pre-service teachers hold about mathematics in conjunction with their beliefs.

Appendix A

Professional Competences Defined in the Decree Defining Initial Teacher Training.

1. To communicate adequately in the language of instruction in the various contexts related to the profession (FWB, 2022).
2. To respect a deontological framework and adopt an ethical approach in a democratic and responsible perspective.
3. To work in teams, maintain partnerships with families, institutions and, more broadly, to act as a social and cultural actor in society.
4. To develop a critical and autonomous relationship with scientific knowledge, and to innovate.
5. To develop expertise in the contents taught and in the methodology of teaching.
6. To design, implement, regulate and evaluate learning situations that aim to develop each student in all dimensions.
7. To create and develop an environment that stimulates social interaction and the sharing of common experiences, where everyone feels accepted.

Appendix B

Table B1. Means, Standard Deviations, Skewness, Kurtosis, and Correlation Matrix for the Assessed Variables for the First Year of Training ($n = 272$).

	M	SD	S	K	1	2	3	4	5	6	7	8	9
Cluster													
1. Procedural	2.43	.42	.14	2.06	I								
2. Formal	2.63	.59	-.21	.01	.01	I							
3. Open	3.19	.41	-.27	-.18	-.35**	-.13	I						
4. Promotion of critical thinking	3.32	.47	-.30	.05	-.21**	-.10	.43**	I					
5. Promotion of procedures' application	2.54	.42	-.26	.21	.43**	.24**	-.06	-.04	I				
6. Transmissive approach	1.93	.30	.22	-.26	.21**	-.07	-.27**	-.44**	-.06	I			
Pedagogical practices													
7. Student-centered	3.38	.37	-.07	-.83	-.10	-.02	.39**	.61**	.10	-.33**	I		
8. Regulation by the teacher	2.81	.54	.23	-.16	.18*	-.02	-.06	.05	.49**	-.02	.22**	I	
9. Differentiation	3.27	.27	.18	-.66	-.20**	-.13	.29**	.51**	-.13	-.20**	.71**	.17*	I

* $p < .05$. ** $p < .01$.

Table B2. Means, Standard Deviations, Skewness, Kurtosis, and Correlation Matrix for the Assessed Variables for the Second Year of Training ($n = 184$).

	M	SD	S	K	1	2	3	4	5	6	7	8	9
Cluster													
1. Procedural	2.26	.41	.20	.07	I								
2. Formal	2.57	.53	.10	-.26	.26**	I							
3. Open	3.29	.37	-.06	-.60	-.07	.13	I						
4. Promotion of critical thinking	3.40	.42	-.05	-1.00	-.06	-.01	.37**	I					
5. Promotion of procedures' application	2.53	.48	-.17	-.04	.55**	.41**	.06	-.15*	I				
6. Transmissive approach	1.97	.31	.78	1.71	.30**	.33**	.02	.02	.28**	I			
Pedagogical practices													
7. Student-centered	3.43	.37	-.14	-1.04	-.19*	-.11	.33**	.41**	.00	-.12	I		
8. Regulation by the teacher	2.79	.57	-.15	-.33	.24**	.19**	.07	.01	.35**	.32**	.14	I	
9. Differentiation	3.34	.40	.20	-.99	-.18*	-.12	.28**	.40**	-.13	-.08	.63**	.15*	I

* $p < .05$. ** $p < .01$.**Table B3.** Means, Standard Deviations, Skewness, Kurtosis, and Correlation Matrix for the Assessed Variables for the Third Year of Training ($n = 190$).

	M	SD	S	K	1	2	3	4	5	6	7	8	9
Cluster													
1. Procedural	2.20	.51	.08	.94	I								
2. Formal	2.56	.64	-.55	.08	.29**	I							
3. Open	3.36	.36	-.28	.26	.07	-.02	I						
4. Promotion of critical thinking	3.31	.45	-.23	-.46	-.13*	-.13*	.17**	I					
5. Promotion of procedures' application	2.61	.39	.29	-.25	.38**	-.00	-.30**	-.03	I				
6. Transmissive approach	1.99	.32	.20	.15	.14*	.01	-.26**	-.17**	.10	I			
Pedagogical practices													
7. Student-centered	3.47	.37	-.40	-.50	-.20**	-.03	.28**	.41**	-.15*	-.18**	I		
8. Regulation by the teacher	2.81	.54	.08	.20	.21**	-.10	.08	-.06	.17**	.08	.25**	I	
9. Differentiation	3.24	.44	-.20	-.25	-.27	-.03	.41**	.43**	-.25**	-.21**	.65**	.26**	I

* $p < .05$. ** $p < .01$.

Appendix C

Table C1. Summary of Goodness-of-Fit Statistics for the Previous Models.

Models	Epistemological conceptions	Learning conceptions	Teaching conceptions	Pedagogical practices
RMSEA	0.09	0.09	0.10	0.09
CFI	0.71	0.81	0.60	0.80
TLI	0.60	0.70	0.54	0.75
SRMR	0.07	0.06	0.11	0.07

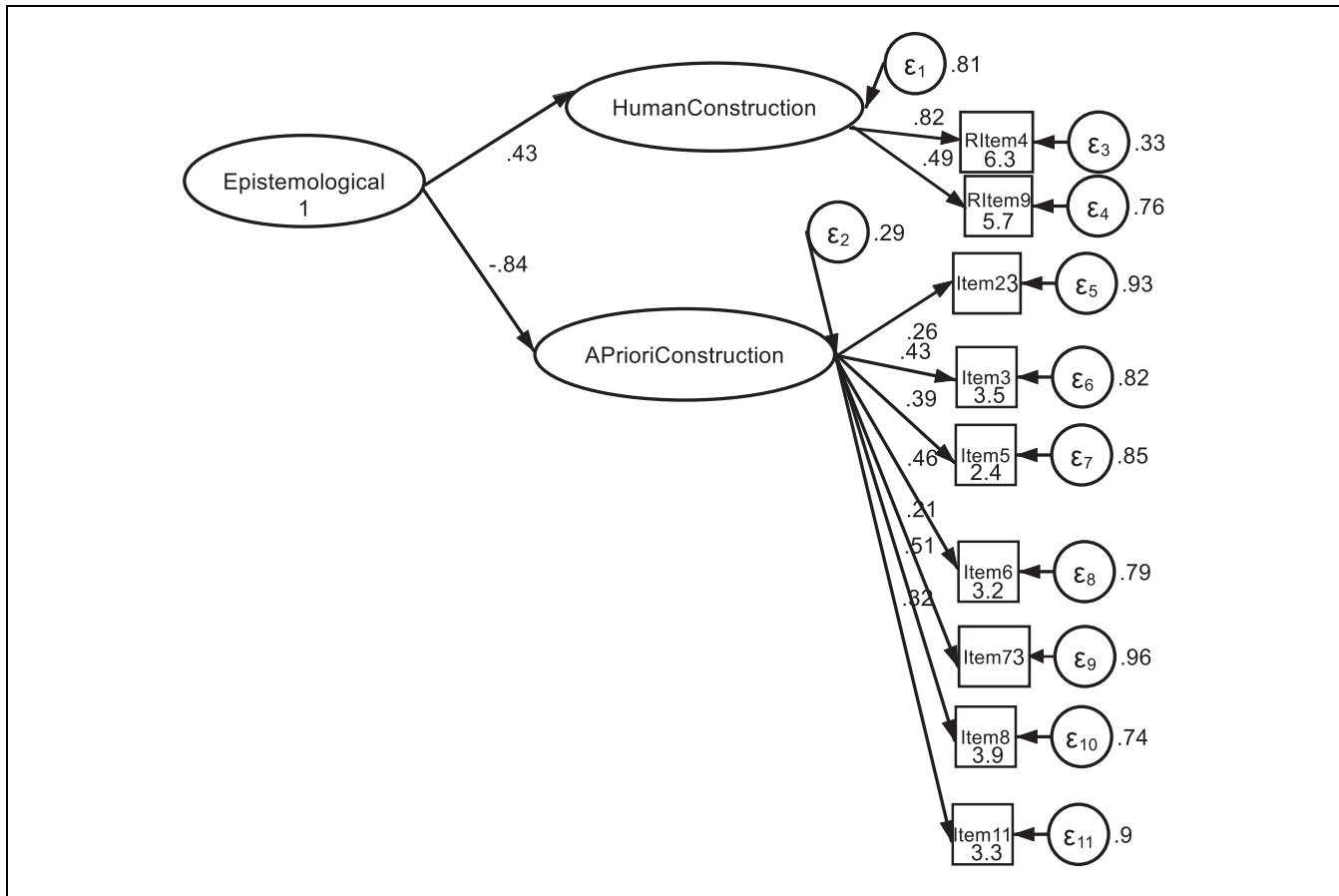


Figure C1. Epistemological conceptions model according to Gattuso and Bednarz (2000).

Note. Loadings are standardized.

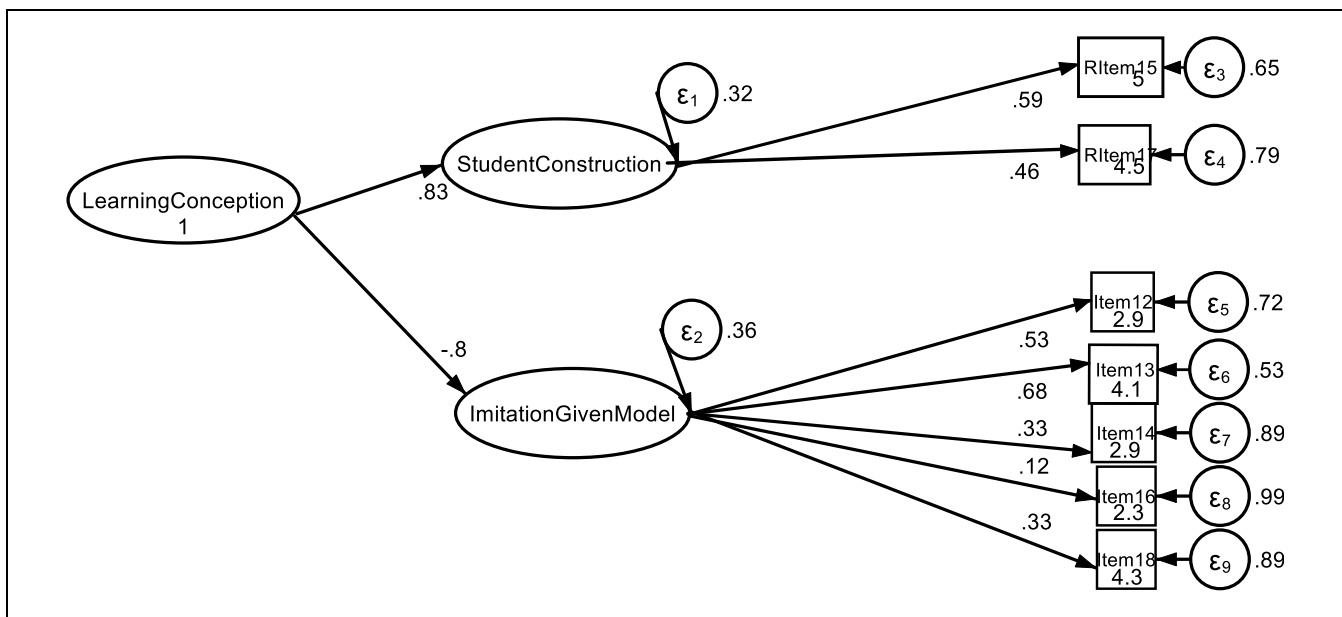


Figure C2. Learning conceptions model according to Gattuso and Bednarz (2000).

Note. Loadings are standardized.

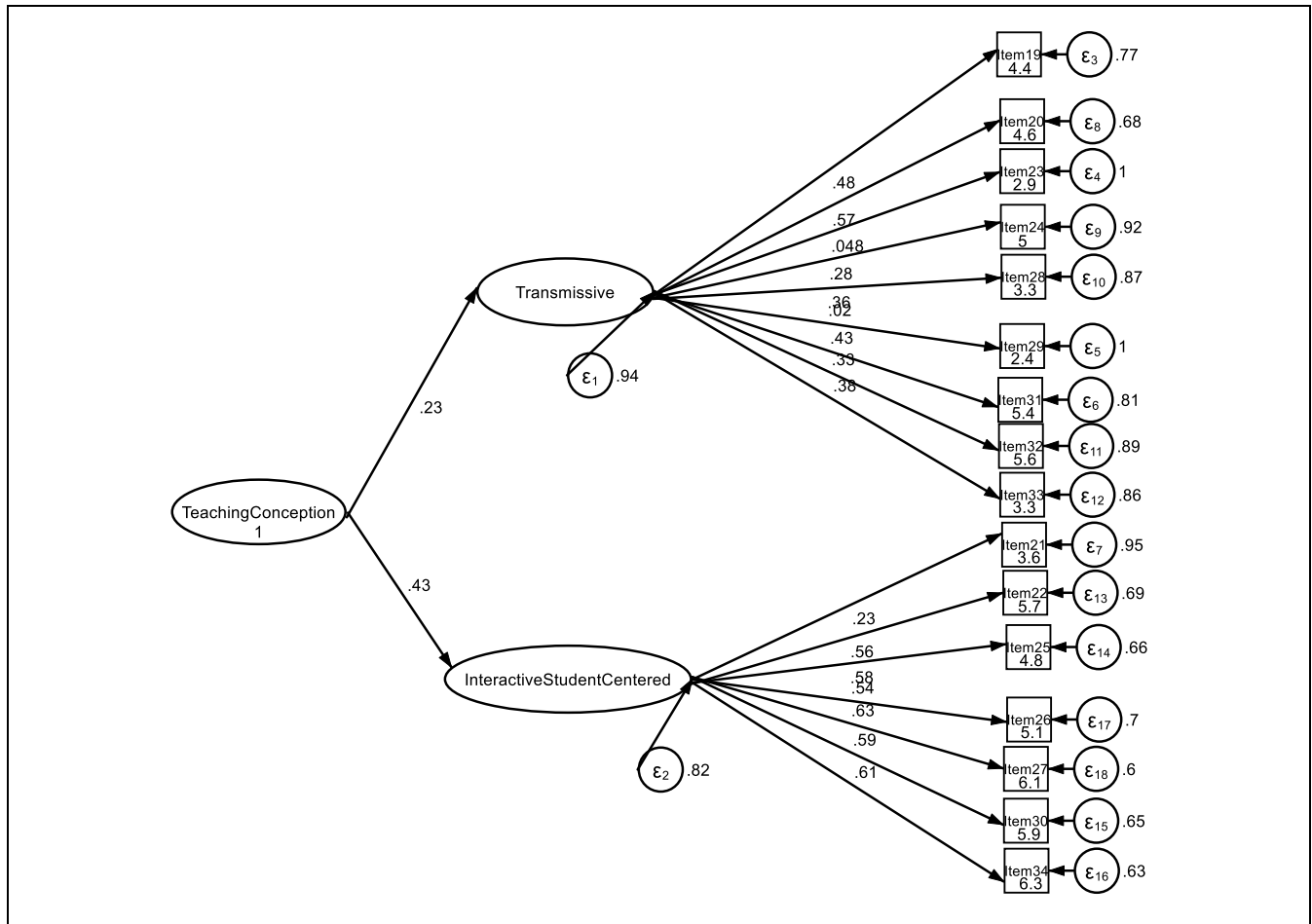


Figure C3. Teaching conceptions model according to Gattuso and Bednarz (2000).
 Note. Loadings are standardized.

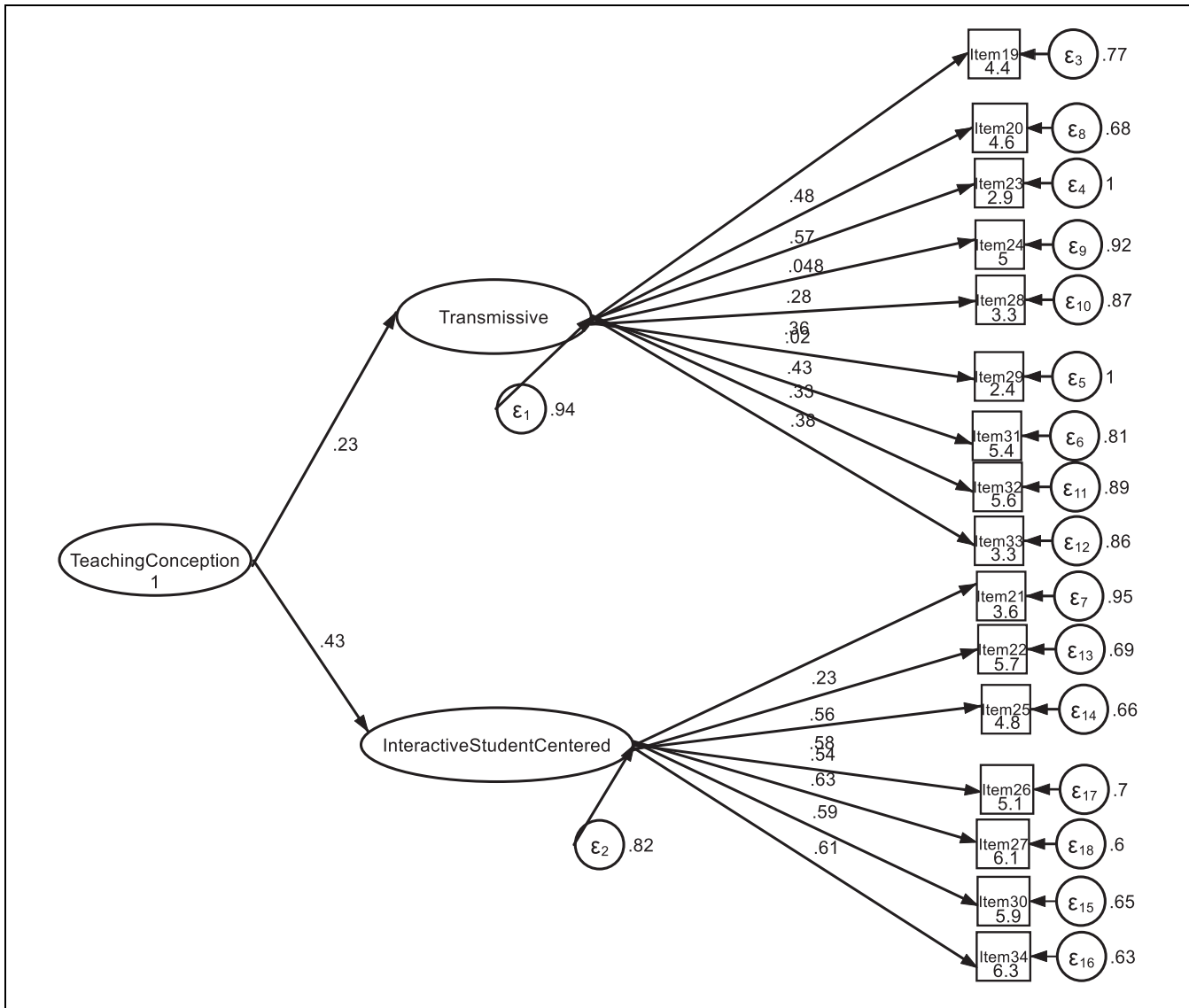


Figure C4. Pedagogical practices model according to Gattuso and Bednarz (2000).

Note. Loadings are standardized.

Appendix D

Table D1. Most Significant Item Saturation Coefficients by Factors for the Beliefs About *Mathematics*.

Items	Factors		
	1	2	3
6. Résoudre des problèmes en maths, c'est trouver la bonne réponse.	0.66		
5. Faire des maths est une activité solitaire.	0.60		
8. Résoudre des problèmes en maths, c'est mettre en application des règles de calculs.	0.54		
3. Il y a toujours une règle à suivre pour résoudre des problèmes en maths.	0.54		
7. Sans le langage et le vocabulaire qui lui sont spécifiques, il n'y a pas de maths.		0.81	
2. Sans symbole, il n'y a pas de maths.		0.62	
11. Les maths reposent sur un ensemble de définitions qu'il faut connaître.		0.59	
9. Explorer une situation à l'aide d'un dessin, d'un schéma pour en découvrir la solution, ce n'est pas faire des maths ^a .			−0.73
4. Explorer une situation à l'aide de matériel concret, ce n'est pas faire des maths ^a .			−0.66
10. Résoudre des problèmes en maths, c'est principalement faire appel à l'intuition et à la créativité.			0.51
1. Il y a toujours plusieurs façons de résoudre des problèmes en maths.			0.50
Total variance explained: 55%			

Note. Factor 1 = procedural conception; Factor 2 = formal conception; Factor 3 = open conception.

Table D2. Most Significant Item Saturation Coefficients by Factors for the Beliefs About *Mathematics Learning and Teaching*.

Items	Factors		
	1	2	3
34. Enseigner les maths, c'est donner l'occasion aux élèves d'avoir un regard critique sur leurs démarches pour se corriger.	−0.80		
30. Enseigner les maths, c'est inviter les élèves à décrire leurs propres démarches de résolution, à comprendre les démarches développées par autrui et à en débattre.	−0.72		
27. Enseigner les maths, c'est encourager les élèves à découvrir plus d'une manière de résoudre un problème de math.	−0.70		
25. Enseigner les maths, c'est encourager les élèves à développer leurs propres démarches et procédures pour résoudre des problèmes.	−0.64		
19. Plus on fait d'exercices, plus on devient habile. Il faut donc donner beaucoup d'exercices à faire aux élèves.		0.69	
13. L'élève apprend les maths en suivant le modèle présenté par le professeur en le mettant en application dans différents problèmes ou exercices.		0.68	
20. Enseigner les maths, c'est démontrer les différentes étapes d'une procédure le plus clairement possible, puis inviter les élèves à appliquer cette procédure dans une série d'exercices ou de problèmes.		0.64	
14. La majorité des erreurs faites par les enfants en maths sont dues à l'inattention.		0.55	
12. Apprendre les maths est principalement une mémorisation de règles.		0.52	
28. Enseigner les maths, c'est expliquer la théorie (les nouvelles notions mathématiques) avant de proposer des exercices ou des problèmes à résoudre.		0.51	
16. On est bon ou on n'est pas bon en math, il n'y a rien à faire, on ne peut rien y changer.			0.74
29. Ce n'est pas une bonne idée que les élèves s'entraident en maths parce que ce sont les plus doués qui font tout le travail.			0.70
17. Quand l'enfant arrive à l'école, il faut tout lui montrer.			0.54
26. Enseigner les maths, c'est donner l'occasion aux élèves de travailler en petits groupes coopératifs. ^a			−0.50
23. Dans une activité d'exploration, les élèves n'en savent pas assez pour discuter entre eux d'idées mathématiques.			0.48
Total variance explained: 500.7%			

Note. Factor 1 = promotion of critical thinking; Factor 2 = promotion of procedures' application; Factor 3: transmissive approach.

^aReverse-coded for data analysis.

Table D3. Most Significant Item Saturation Coefficients by Factors for the *Pedagogical Practices*.

Items	Factors		
	1	2	3
49. D'encourager les élèves à poser des questions.	0.73		
58. De concentrer mes efforts à rendre mon enseignement clair, logique et précis.	0.73		
48. D'essayer de rendre mon cours vivant et excitant afin de stimuler la motivation et l'intérêt des élèves.	0.67		
59. D'encourager des discussions dans lesquelles les élèves, en petits groupes, peuvent comparer leurs stratégies, tirer des conclusions.	0.62		
54. D'encourager les élèves à participer aux discussions de classe et à exprimer leurs idées.	0.61		
51. De permettre aux élèves de s'exercer le plus possible.	0.57		
52. De proposer des activités de manipulation, d'exploration à l'aide de matériel.	0.56		
50. D'encourager chaque élève à chercher les raisons ou la logique derrière les procédures de résolution en maths.	0.43		
66. De travailler la métacognition au cours de math.		0.72	
57. D'utiliser diverses représentations dans la présentation d'un sujet, d'un concept.		0.64	
56. De donner un feedback aux élèves sur leur travail.		0.50	
55. De fournir la possibilité aux élèves de mettre en place différentes stratégies de résolution.		0.45	
63. De m'assurer que les élèves savent toujours très rapidement si leurs réponses sont bonnes ou mauvaises.			0.78
60. De m'assurer que les élèves ne font pas d'erreurs, ni de fautes dans leur travail.			0.72
61. De savoir parler les maths pour les rendre accessibles aux élèves.			0.51
Total variance explained: 51.5%			

Note. Factor 1 = student-centered practices; Factor 2 = regulation by the teacher; Factor 3 = differentiation.

*Reverse-coded for data analysis.

Acknowledgments

We would like to thank the students who participated in this project, as well as the two students in education who helped us collect the data.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethics Approval Statement

Participants were guaranteed anonymity and confidentiality. Participants gave written informed consent for this study.

Code Availability

We use SPSS Statistics 25.

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Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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