

Teachers' views on creativity in mathematics education: an international survey

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Abstract The survey described in this paper was developed in order to gain an understanding of culturally-based aspects of creativity associated with secondary school mathematics across six participating countries. All participating countries acknowledge the importance of creativity in mathematics, yet the data show that they take very different approaches to teaching creatively and enhancing students' creativity. Approximately 1,100 teachers from six countries (Cyprus, India, Israel, Latvia, Mexico, and Romania) participated in a 100-item questionnaire addressing teachers' conceptions about: (1) Who is a creative student in mathematics, (2) Who is a creative mathematics teacher, (3) In what way is creativity in mathematics related to culture, and (4) Who is a creative person. We present responses to each conception focusing on differences between teachers from different countries. We also analyze relationships among

teachers' conceptions of creativity and their experience, and educational level. Based on factor analysis of the collected data we discuss relevant relationships among different components of teachers' conceptions of creativity as they emerge in countries with different cultures.

Keywords Teachers' creativity · Students' creativity · International perspective · Culturally related characteristics

1 Rationale

This study is a product of a collective effort on the part of researchers who participated in an International Workshop entitled, "Intercultural Aspects of Creativity in Mathematics and Science" that took place in Haifa, Israel in February 2008 with the support of the John Templeton Foundation (Leikin and Berman 2010). The workshop focused on culturally-specific aspects of creativity in mathematics and science teaching. The purpose of the survey was to gain a better understanding of culturally-based and intercultural aspects of creativity in secondary school mathematics. Approximately 1,100 teachers from six countries (Cyprus, India, Israel, Latvia, Mexico, and Romania) participated in the survey.

2 Background

2.1 Varying perspectives on creativity

Several definitions have been proposed for creativity, some of which focus on process while others emphasize the creative product (Haylock 1987). For instance, creativity can be considered a mental process involving the

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generation of new ideas or concepts, or the result of new associations between existing ideas or concepts. Further, we distinguish between creativity and innovation. Creativity typically refers to the act of producing new ideas, approaches, or actions. It is manifested in the production of creative outcomes (for example, a new work of art or a scientific hypothesis) that are both *original* and *useful*. Innovation is the process of both generating *and applying such creative ideas in some specific contexts*.

A large body of research has been devoted to studying creativity (e.g., Feldman 1999; Gardner 1983, 1997; Gruber 1986; Guilford 1967; Hilgard 1980; Sternberg 2000). Guilford (1967), who first instigated widespread interest in the topic, draws a distinction between convergent and divergent thinking. Convergent thinking, according to Guilford, involves aiming for a single, correct solution to a problem, whereas divergent thinking involves creative generation of multiple answers or multiple solution strategies to a problem.

Feldman et al. (1994) proposed that creativity emerges as an interactive system involving the individual (the creator), the symbol system she or he is engaged in (the domain), and the surrounding social system (the field). Therefore, it appears necessary to frame creativity within specific domains. That is, an individual has creative potential in a certain domain. In the research literature we also find a distinction between general and specific creativity (Piiro 1999), in which specific creativity is expressed in the clear and distinct ability to create in one area, for example mathematics (Leikin 2010).

The concept of creativity in mathematics is a topic of interest for many researchers. For example, Hadamard (1954) theorized that mathematicians' creative processes follow the four-stage Gestalt model of *preparation–incubation–illumination–verification*. He conducted an informal inquiry among prominent mathematicians and scientists, including George Birkhoff, George Polya, and Albert Einstein, investigating the mental images they used in doing mathematics. He described his own mathematical thinking as largely wordless, often accompanied by mental images that represented the entire solution to a problem. Similar thinking has been reported in the literature by others, including Hardy (1940). Liljedahl's (2009) recent results both confirm and extend the work of Hadamard on the inventive process, mathematical creativity, and the phenomenon of the AHA! experience. Burton (2001) interviewed 70 practicing research mathematicians concerning their personal thinking processes while in the process of discovering mathematical facts, principles, theorems, or proofs. She found that, frequently, mathematicians explain their own problem solving as either inserting the last piece in a jigsaw puzzle or a geographical journey, map, or view. Burton (2001) developed five

categories of analysis describing the way in which research mathematicians come to discover mathematics: person- and cultural-social relatedness, aesthetics, intuition and insight, styles of thinking, and connectivities. Exploring the characteristics of mathematical creativity through a qualitative study involving five creative mathematicians, Sriraman (2004) found that, in general, social interaction, imagery, heuristics, intuition, and proof were common characteristics.

Liljedahl and Sriraman (2006) suggested that professional-level mathematical creativity can be defined as “the ability to produce original work that significantly extends the body of knowledge (which could also include significant syntheses and extensions of known ideas)” or “opens up avenues of new questions for other mathematicians” (p. 18). For Sriraman (2005) and Erynck (1991), mathematical creativity is a central quality held by research mathematicians (Sriraman 2005). Erynck (1991) connected mathematical creativity with advanced mathematical thinking, defining it as the ability to raise important mathematical questions and find inherent relationships among them.

2.2 Creativity in the mathematics class and teachers' perspectives on creativity

Bloom's retrospective study of elite mathematicians (1985) sheds light on responses from a thought experiment developed by Subotnik et al. (2010). According to Bloom, the development of talent in mathematics is generated through a series of instructional experiences. The first stage involves encounters with a teacher who helps young people to fall in love with mathematics. The second stage involves teaching and learning the central rules, concepts, and values associated with creative mathematics. In the course of this phase, students start to identify themselves as young mathematicians. Finally, in the third stage, a teacher helps his or her students to negotiate how to be successful in the field and find a personal niche, and provides guidance and insider knowledge. Notably, according to Bloom, it is rare for one teacher to serve at every level of this model. Over time students would move developmentally to a teacher most suited to the task at hand. Also, Bloom (1985) realized that this type of talent development is too rarely conducted in schools, and most often happens outside of schools in the form of clubs or summer programs.

Several recent publications have been devoted to teachers' conceptions of creativity in teaching mathematics. As a result of analyzing discussions with prospective mathematics teachers, Shriki (2009) argues that teacher knowledge about creativity is insufficient. However, teachers considered themselves as a key factor in developing mathematical creativity (Kattou et al. 2009), without holding themselves

accountable for concurrently hindering creativity. When it comes to inhibiting creativity, teachers are more likely to blame the educational system. Lithner (2008) suggests analyzing mathematical activities in the classroom through the lens of creative thinking as opposed to imitative thinking. Bolden et al. (2010) analyzed written questionnaires and semi-structured interviews with prospective elementary school teachers about their conceptions of creativity, and showed that these conceptions were narrow and associated with their own unique actions.

However, analysis of research literature devoted to deep analysis of teachers' conceptions of creativity in teaching mathematics clearly demonstrates that this issue is underdeveloped in mathematics education research (Leikin 2009, 2010, 2011). Lev-Zamir and Leikin (2011) devised a model of teachers' conceptions of creativity. They further demonstrated that distinctions between teacher-oriented and student-oriented conceptions explain differences that they consider to be creative in teachers' practice. In the current study we address both teacher-oriented and student-oriented conceptions of creativity held by mathematics teachers from different countries.

2.3 International perspective

This study, considered from the international perspective, aimed at gaining deeper understanding of intercultural and culturally dependent aspects of mathematics teachers' conceptions of creativity in mathematics teaching. The importance of such a study is rooted in the evidence-based argument about the cultural nature of teaching (Stigler and Hiebert 1999) and about sociocultural contexts of mathematics teaching and learning in schools (Bishop 1994; Schmidt et al. 1997). Multicultural views on mathematical creativity is an additional area overlooked in the mathematics education research.

In line with this argument, Subotnik et al. (2010) described an exploratory study that focused on the role of context, individual differences, and motivation as related to creativity in school mathematics across several countries. They asked leading professionals in mathematics education from six nations to take part in a thought experiment focusing on the following task: *Imagine you are a policy maker (e.g., minister of education in charge of mathematics) hoping to elicit more creativity on the part of mathematics students in your country's schools.* The outcomes of the study responses demonstrate differences among countries as related to multiple relationships between creativity and motivation within a society and which are manifested in the labor market and in the community at large.

Subotnik et al. (2010) argue that societal norms and values induce the values, norms, and routines of the educational system at both the structural and the content level.

For example, social contexts encourage youth to pursue certain domains of study that are associated with socioeconomic progress at a certain moment. The results of the thought experiment highlighted the limits and possibilities of developing creativity in mathematics within an educational system, and left the authors with a number of questions that might be pursued by additional conversations with our participants as well as through formal education or policy research.

In the previous study we examined the views of experts in mathematics education on the role of creativity in school mathematics. In this study we focus our attention on teachers' views of creativity in school mathematics. We also move from the qualitative methodology that integrated a thought experiment to the results of an international survey on teachers' views of creativity in general and creativity in mathematics in particular.

3 The study

3.1 The mathematics teacher questionnaire

The questionnaire that served as the central instrument of this study was designed collectively by the members of the survey's research team, thus guaranteeing content validity of the tool. It included two sections:

Section A of the questionnaire aimed at collecting personal details of participating teachers. This allowed for making good cross-country comparisons of outcomes.

Section B of the questionnaire aimed at collecting data on the topic of the current study. It included 100 items divided into four main parts. The main categories of the questionnaire are depicted in Fig. 1.

For Q1, Q2, and Q4 participants were asked to express their agreement with each item of the questionnaire from "strongly disagree" (scored with 1) to "strongly agree" (scored with 6). For Q3, participants were asked to evaluate how often factors described in the questionnaire items are discussed in mathematics classrooms ranging from "never" (scored with 1) to "always" (scored with 6).

The questionnaire's internal reliability was examined using Chronbach's alpha, and was found to be sufficiently high to perform statistical analysis for all categories. The results of the study are reported according to these categories.

3.2 Study population

Of the mathematics teachers who participated in the study, 1,089 completed the survey questionnaire in such a way that allowed for conducting the analyses presented below. The majority of the teachers also provided information about their educational background and gender.

Fig. 1 Main categories in Section B and internal reliability of the questionnaire

	Categories	Chronbach's alpha
Q1	Who is a creative student in mathematics?	0.930
1.1	He or she uses his or her ability in unique ways	0.799
1.2	He or she comes up with unique outcomes (solutions or new problems)	0.750
1.3	He or she is motivated and enjoys engaging with mathematics	0.880
Q2	Who is a creative mathematics teacher?	0.943
2.1	She or he enjoys mathematics	0.730
2.2	He or she regularly applies strong background knowledge in mathematics	0.830
2.3	He or she uses instructional skills optimally	0.859
2.4	He or she elicits creativity on the part of students	0.860
2.5	He or she values creativity on the part of students	0.802
Q3	How is creativity in mathematics related to culture?	0.922
3.1	Mathematics and religion/tradition	0.780
3.2	Mathematics and arts/architecture	0.801
3.3	Mathematics and sciences, including social sciences	0.857
3.4	Mathematics and argumentation	$r=.288^{***}$
Q4	Who is a creative person?	0.906
4.1	He or she is born that way (innate)	0.740
4.2	He or she has a creative personality or way of being	0.731
4.3	He or she is creative in the processes of solving problems	0.739
4.4	He or she has rich background knowledge	0.793
4.5	He or she demonstrates success in professions that require original contributions	0.839

Table 1 depicts differences in educational levels and gender of participating teachers in different countries. The highest educational level of the participants in this study was in the sample of teachers from India (58 % M.A. or M.Sc. degree either in mathematics or mathematics education and 15 % with Ph.D. degree). The other five countries were more similar to one another in terms of the education level of the respondents.

3.3 Correlations of the responses with the respondents' highest level of education

Multivariate analysis of the correlation between teachers' highest level of education in the different countries and the teachers' views on creativity in mathematics (MANOVA followed by ANOVA with Bonferroni adjustment for significant variables) did not reveal any relationship between teachers' highest level of education and their views on creativity in school mathematics.

3.4 Gender differences

There were no gender differences in teachers' responses except for responses provided by the participants from India to the following statements (with higher level of agreement expressed by male participants): Students are creative if they use their ability in unique ways, produce

Table 1 Survey participants

Country	N	Degree (reported)			Gender (reported)	
		B.A./B.Sc.	M.A./M.Sc.	Ph.D.	F	M
Cyprus	101	58	34	3	60	40
		61 %	36 %	3 %	60 %	40 %
India	264	71	153	38	97	169
		27 %	58 %	15 %	36 %	64 %
Israel	182	90	80	5	136	28
		51 %	46 %	3 %	83 %	17 %
Latvia	59	33	25	0	58	1
		57 %	43 %	0 %	98 %	2 %
Mexico	65	33	26	5	30	35
		52 %	41 %	8 %	46 %	54 %
Romania	418	271	107	4	323	95
		71 %	28 %	1 %	77 %	23 %
Total	1,089	556	425	55	704	199
		54 %	36 %	6 %	78 %	22 %
		1,036 ^a			903 ^a	

^a Some participants did not report their degree or gender

unique outcomes, and enjoy engaging with mathematics; mathematics teachers are creative if they enjoy dealing with mathematics, use instructional skills effectively, elicit creativity in students, and value students' creativity; A

creative person is successful in his/her profession; discussions about relationships between mathematics and tradition, between mathematics and arts, and between mathematics and science should be incorporated in mathematics lessons. Based on these analyses we argue that these differences between the samples of teachers from different countries did not have an effect on the study results.

4 Findings

In this section we present a summary of the findings according to the categories addressed in the study questionnaire. Each section includes statistical analyses of the data and descriptions relevant for making comparisons. Our interpretations and explanations of the findings are presented in the Summary section.

4.1 The highest degree of teacher agreement

We start by reporting descriptive statistics. Table 2 depicts means and standard deviations for all the participating countries in response to the four study questions from the questionnaire. The boxes with grey background depict, for each category, the highest degree of teachers' agreement among the countries in the form of a score on a Likert scale. The boxes shaded in light gray depict responses with high degrees of teachers' agreement (>5 , between agree and strongly agree), and the boxes shaded in dark gray depict a lower degree of teacher agreement across countries (<4).

Participants from Romania expressed the highest (among the countries) degree of agreement with the majority of the suggested characteristics of creativity in Research Question 1 (Who is a creative student in mathematics?), Research Question 2 (Who is a creative mathematics teacher?), and Research Question 4 (Who is a creative person?). Participants from India and Mexico expressed the highest degree of agreement (among the teachers from different countries) about the ways in which creativity in mathematics are related to culture (see Table 2).

The highest degree of agreement among teachers across the countries was found in the following areas:

- Unique use of abilities as an indication of students' creativity in mathematics ($M = 5.10$, $SD = 0.62$)
- Characterization of creative mathematics teachers in the form of their
 - own enjoyment of mathematics ($M = 5.13$, $SD = 0.83$),

- ability to elicit students' creativity ($M = 5.09$, $SD = 0.59$),
- inclination to value creativity in students ($M = 5.23$, $SD = 0.77$)
- Creative problem solving as a characteristic of a creative person ($M = 5.13$, $SD = 0.64$).

The lowest degree of teacher agreement in the form of their scores on a Likert scale was recorded in response to "Mathematics and tradition", as related to creativity and culture in school mathematics.

4.2 Differences in responses between countries on different sections of the questionnaire

Although the variation around the mean is relatively small, the diversity is relevant. This needs to be studied further because it indicates significant and interesting cultural differences.

Table 3 features outcomes with significant differences in attitudes of teachers from different countries. In the sections below we report on these significant differences only.

4.2.1 Characteristics of creative students in mathematics

Romanian teachers expressed the greatest agreement with items about mathematically creative students associated with Research Question 1. Their responses were significantly different from those of teachers from Cyprus, India, Latvia, Israel, and Mexico. Teachers from the Romanian sample consistently considered the main cognitive characteristics of a creative student, as well as the capacity to initiate and enjoy investigations being common attributes associated with school math creativity.

Participants from Cyprus demonstrated significantly higher agreement than Indian participants regarding the relationship between students' mathematical creativity and their ability to provide unique outcomes. They showed significantly stronger agreement than participants from Mexico regarding relationships between students' mathematical creativity and their motivation for and engagement with mathematics.

Participants from India evaluated the relationship between students' mathematical creativity and their motivation and enjoyment derived from engaging with mathematics more strongly than participants from Mexico. Israeli teachers expressed higher agreement than teachers from India and Mexico with statements about the relationship between students' mathematical creativity and their ability to provide unique outcomes.

Table 2 Descriptive statistics

Country		Cyprus	India	Israel	Latvia	Mexico	Romania	Total
Q1	N	101	264	182	58	65	418	1123
Unique use of ability	Mean (SD)	5.01 (0.49)	4.87 (0.64)	4.93 (0.71)	4.96 (0.65)	4.87 (0.84)	5.39 (0.43)	5.10 (0.62)
Unique outcomes	Mean (SD)	4.72 (0.56)	4.46 (0.65)	4.76 (0.68)	4.60 (0.62)	4.50 (0.76)	5.12 (0.44)	4.80 (0.63)
Students' enjoyment	Mean (SD)	4.83 (0.61)	4.69 (0.68)	4.61 (0.87)	4.63 (0.78)	4.37 (0.92)	5.12 (0.57)	4.83 (0.73)
Q2	N	102	265	182	58	65	418	1123
Teachers' enjoyment	Mean (SD)	4.78 (0.86)	5.17 (0.82)	4.64 (0.98)	5.01 (0.80)	5.27 (0.89)	5.41 (0.58)	5.13 (0.83)
Strong knowledge	Mean (SD)	4.81 (0.66)	4.83 (0.60)	4.68 (0.70)	4.72 (0.52)	4.77 (0.67)	4.78 (0.56)	4.77 (0.61)
Instructional skills	Mean (SD)	4.84 (0.59)	4.81 (0.56)	4.68 (0.69)	4.82 (0.54)	5.00 (0.63)	5.05 (0.50)	4.90 (0.58)
Eliciting creativity in students	Mean (SD)	4.96 (0.54)	4.97 (0.64)	4.89 (0.63)	4.90 (0.63)	5.12 (0.58)	5.31 (0.46)	5.09 (0.59)
Valuing students' creativity	Mean (SD)	5.11 (0.70)	4.90 (0.89)	5.08 (0.88)	5.19 (0.73)	5.19 (0.82)	5.52 (0.52)	5.23 (0.77)
Q3	N	101	264	180	58	64	418	1117
Mathematics and tradition	Mean (SD)	3.87 (1.04)	4.42 (0.93)	3.51 (1.22)	3.70 (0.86)	4.45 (0.93)	3.88 (1.02)	3.96 (1.08)
Math and arts	Mean (SD)	3.97 (0.97)	4.79 (0.96)	3.77 (1.24)	4.09 (0.82)	4.74 (0.92)	4.09 (1.03)	4.22 (1.10)
Math and science	Mean (SD)	4.45 (0.56)	4.73 (0.64)	4.35 (0.59)	4.29 (0.51)	4.54 (0.56)	4.49 (0.54)	4.50 (0.59)
Math and argumentation	Mean (SD)	4.21 (0.97)	4.42 (1.02)	3.97 (1.25)	4.10 (0.84)	4.42 (0.90)	4.21 (0.90)	4.20 (1.02)
Q4	N	102	257	177	58	64	418	1106
Creativity as a gift	Mean (SD)	4.19 (0.85)	4.26 (0.95)	4.11 (0.95)	4.19 (0.72)	3.48 (1.05)	4.40 (0.86)	4.23 (0.92)
Creative personality or way of being	Mean (SD)	4.42 (0.68)	4.57 (0.68)	4.27 (0.68)	4.34 (0.64)	4.34 (0.78)	4.58 (0.64)	4.49 (0.68)
Creative problem solving	Mean (SD)	5.14 (0.53)	5.02 (0.67)	4.90 (0.71)	4.81 (0.72)	5.17 (0.64)	5.35 (0.53)	5.13 (0.64)
Rich knowledge	Mean (SD)	4.56 (0.95)	4.22 (1.21)	4.13 (1.07)	4.23 (0.92)	3.80 (1.28)	4.48 (0.90)	4.32 (1.06)
Professional success	Mean (SD)	4.04 (0.81)	3.98 (0.96)	4.00 (1.02)	4.16 (0.98)	3.68 (1.11)	4.42 (0.78)	4.15 (0.93)
Country		Cyprus	India	Israel	Latvia	Mexico	Romania	Total

4.2.2 Characteristics of creative mathematics teachers

Romanian teachers associated more strongly than teachers from other countries the characteristics of a creative mathematics teacher with the features described in items about enjoying mathematics, using instructional skills in an optimal way, eliciting students' creativity, and valuing students' creativity. The level of agreement with statements in these categories demonstrated by Romanian teachers was significantly higher than that revealed by the

teachers from Cyprus, India, and Israel. Similar differences were found between the attitudes of Romanian teachers and the attitudes of teachers from Latvia with respect to enjoying mathematics, eliciting students' creativity, and valuing students' creativity. Additionally, participants from Romania were significantly more likely to report stronger associations than Mexican participants regarding connections between teachers' creativity and their ability to value students' creativity. The vast majority of the Romanian respondents consider that when a teacher displays a

Table 3 Differences between the countries

Lower agreement Higher agreement	Cyprus	India	Israel	Latvia	Mexico	Romania
Cyprus		Q1. 2*	Q4.3, Q4.4	Q4.3	Q1.3 Q4.1, Q4.4	
India	Q2.1 Q3. 1, Q3.2, Q3.3		Q2.1 Q3.1, Q3.2, Q3.3, Q3.4 Q4.2	Q3.1, Q3.2, Q3.3	Q1.3 Q4.1	Q3.1, Q3.2, Q3.3
Israel					Q4.1	
Latvia			Q2.1		Q4.1	
Mexico	Q2. 1 Q3.1, Q3.2		Q2.1, Q2.3 Q3.1, Q3.2, Q3.4	Q3.1, Q3.2 Q4.3		Q3.1, Q3.2
Romania	Q1.1, Q1.2, Q1.3 Q2.1, Q2.3, Q2.4, Q2.5 Q4.3, Q4.5	Q1.1, Q1.2, Q1.3 Q2.1, Q2.3, Q2.4, Q2.5 Q4.3, Q4.4, Q4.5	Q1.1, Q1.2, Q1.3 Q2.1, Q2.3, Q2.4, Q2.5 Q3.1, Q3. 2 Q4.1, Q4.2, Q4.3, Q4.4, Q4.5	Q1.1, Q1.2, Q1.3 Q2.1, Q2.4, Q2.5 Q4.3	Q1.1, Q1.2, Q1.3 Q2.5 Q4.1, Q4.4, Q4.5	

MANOVA tests followed by ANOVA tests adjusted for all pair-wise comparisons within a row of each innermost sub-table using the Bonferroni correction. Results are based on two-sided tests assuming equal variances with significance level 0.05

^a Coding of each question (e.g., Q2.1) is in accordance with coding in Fig. 1

creative personality, she or he obviously enjoys solving problems and, with even greater percentages, she or he exhibits genuine interest in mathematics. To be creative, the teacher should design original instructional activities. These findings can be attributed to the word original, which is naturally associated with creativity. Teachers in the Romanian sample believe that a creative teacher should use real-life situations for mathematical problem solving.

With respect to connections between *teachers' creativity and their enjoyment of mathematics*, Indian teachers exhibited significantly higher levels of agreement relative to teachers from Cyprus and Israel; Likert scale ratings by teachers from Latvia and Mexico are higher than those from Israel; and teachers from Mexico elicited higher ratings than teachers from Cyprus. Teachers from Mexico responded with higher degree of agreement than teachers from Israel with respect to *the use of instructional skills as an indication for teachers' creativity in mathematics*.

4.2.3 Creativity in mathematics related to culture

In this questionnaire the teachers were asked how often (in their opinion) the relationship between mathematical creativity and culture was discussed in mathematics classrooms in their country. The major differences in teachers' opinions about this issue are found in the responses from participants from India and Mexico.

According to the responses, relationships between mathematics and religion/tradition, mathematics and arts, and mathematics and science were discussed significantly more often in Indian mathematics classes than in mathematics classes in Cyprus, Israel, Latvia, and Romania.

Mexican teachers focus classroom discussions on issues related to connections between mathematics and religion, and between mathematics and arts, significantly more often than teachers from all other countries (except India). As reported, the relationship between mathematics and argumentation is a topic of discussion in Mexican mathematics classrooms more frequently than in Israeli classes.

The Romanian teachers discuss different issues related to connections between mathematics and religion and mathematics and arts with their students more often than Israeli teachers appear to do.

4.2.4 Characteristics of a creative person

Romanian teachers agreed more strongly with the categories suggested in Research Question 4. Cypriot teachers held stronger beliefs that creative problem solving is a characteristic of the creative person compared with teachers from Israel and Latvia. The participants from Cyprus viewed the relationship between depth of knowledge and personal creativity significantly more strongly than Israeli and Mexican teachers.

Thus Israeli teachers expressed less agreement with characteristics of creative personality as suggested in the questionnaire than teachers from India and Romania.

Mexican teachers were least likely to consider creativity as a gift, significantly less so than the teachers from Cyprus, India, Israel, Latvia, and Romania. Mexican teachers responded with the lowest association between a person's creativity and his/her professional success.

4.3 On the similarities and differences in the responses to main factors by country

As reported earlier, the questionnaire was designed by the group of experts who pre-determined the main categories (that appeared to have high internal consistency). We applied factor analysis to the data in order to elicit additional connections among different items in the questionnaire as reflected in the responses by the teachers from different countries. Through factor analysis we identified some identical connections for all the countries and some connections that are specific to different countries, thus demonstrating the presence of both international and national factors related to creativity in teaching mathematics. In what follows below we present comparisons of some of the main factors and theoretical constructs about the nature and structure of mathematics teachers' conceptions about creativity in teaching mathematics. Factor analyses are presented for India ($N = 264$), Israel ($N = 182$), Cyprus ($N = 101$), and Romania ($N = 418$) since the number of participants who completed questionnaires in these countries allowed performance of factor analysis. Whereas analysis of the results in the previous section of this paper was performed according to the categories of the items (Fig. 1), this section presents relationships between the items in each one of the parts of the questionnaire related directly to teaching mathematics (Q1, Q2, and Q3) across the categories.

4.3.1 Who is a creative student in mathematics?

Teacher responses from all the countries demonstrated strong connections among the role of *ability to raise mathematical conjectures*, *ability to discover mathematical patterns*, and *ability to think independently* as related to students' mathematical creativity. All these categories are indicators of students' **investigative abilities**.

Responses from all the participating teachers revealed a sense of connection between indicators of students' **mathematical flexibility** such as *students' ability to solve mathematics problems in multiple ways* and *the use of a variety of strategies when solving mathematical problems*. Interestingly, teachers from India, Cyprus, Romania, and Israel connected mathematical flexibility with another

factor that included **affective characteristics of problem solving** such as *enjoyment from investigating mathematical problems* and *initiation of mathematical investigations* (for teachers). For teachers from India and Cyprus the former factor **included also** *students' motivation to search for elegant solutions*, *their enjoyment in solving mathematical problems at various levels of difficulty*, and *searching for new information*.

An additional factor—**success in problem solving and proving**—as an indicator of students' creativity in mathematics was found for teachers from Cyprus and Israel. It included *success in solving unconventional problems*, *proving a new theorem that will be studied during the next lesson*, *success in solving Olympiad problems*, *enjoyment of solving Olympiad problems*, and *students' ability to provide original solutions during participation in mathematical competitions*. Surprisingly, we discovered that **mathematical originality** expressed in *students' ability to produce unconventional solutions* appeared in different factors identified for the responses provided by teachers from different countries. For example, teachers from India connected this ability with *mathematical discoveries* and *mathematical investigations*, teachers from Romania with *success in solving unconventional problems*, and teachers from Cyprus with *asking questions that are difficult to answer*.

4.3.2 Who is a creative mathematics teacher?

There was wide variability by country in factors associated with this question.

The first factor found for Q2 demonstrated that teachers associated **teachers' enjoyment from doing mathematics** with teachers' creativity. This factor included different items for teachers from different countries. For example, significant correlations were found between *exhibiting genuine interest in mathematics and encouraging students' initiative during the lesson* (teachers from India, Romania, and Cyprus); *teachers' enjoyment derived from solving mathematical problems* and *their inclination to ask interesting mathematical questions* (teachers from Cyprus and Romania); *teachers' excitement derived from original solutions* found either *by the teacher or by his/her students* with *enjoyment of students' unpredicted answers* (teachers from Israel and Romania).

The second factor in Q2 demonstrated that teachers' conceptions of a creative mathematics teacher are related to their **tendency to encourage student initiative**. The factors demonstrated that teachers in different countries encourage student initiative in different ways: by *using historical facts* in lessons, by *asking for alternative explanations*, and *using real-life examples* in India, by explicitly *valuing students' curiosity* in Cyprus and Israel,

and additionally by *adapting the lesson plan to unpredicted student ideas* and by *the analysis of students' thinking processes on the spot* in Cyprus, by asking students *not to simply repeat what the teacher does in class* and by the *involvement of students in proving new theorems* in Romania.

The data did not reveal connections between *encouraging students' initiative* and **teachers' didactical creativity**. For all countries (except Latvia) this factor included two main items: *design of original instructional activities by the teacher* and *having many didactical ideas*. For teachers from Cyprus this factor also included *using mathematics software*, and *implementing many visuals* as means to lead students *not to simply repeat what he/she does in class*. For teachers from Israel didactical creativity also included *teachers' inclination to analyze students' thinking processes on the spot* and *preparing different mathematical tasks for students with different abilities*.

Another factor addressed **teachers' ability to connect mathematical content from the curriculum with other areas of art and science**. Teachers from all the countries who participated in our survey saw expression of teachers' creativity in mathematics teaching in making *connections between mathematical content and architecture* and *connections between mathematical content and arts*. The factors that included these two items were different for different countries. The items correlated significantly: with *connections between mathematical content and the history of mathematics* (teachers from Cyprus, Romania and India); with *describing patterns in nature mathematically* (teachers from Israel and Romania); with *organization of role plays during the mathematics lessons* (teachers from India and Romania); and *using historical facts in mathematics lessons* (teachers from Cyprus and Romania). Only teachers from Cyprus included the *use of Olympiad problems* in the lessons as a component of this factor. This may be due to the fact that in some cases the context of the Olympiad problems is taken from areas of arts and science. For Israeli teachers this included also *mathematically describing patterns in nature* as well as *using real-life situations for mathematical problem solving*.

4.3.3 How is creativity in mathematics related to culture?

Factor analysis of teachers' responses to Q3 revealed three factors for each one of the countries. We found clear similarity between the factors attained for Cyprus, Israel, and Romania. The factors derived from the responses of teachers from India were different.

The first factor revealed in Q3 was similar to the initially determined category **mathematics and religion**: *religious holidays can serve as a context for mathematical investigations*; *religious texts can be analyzed mathematically*;

there are many mathematical facts in religious books. This factor for all the countries included also such items as *differences between different cultures may be described mathematically* and *in geography there are many facts that can be described mathematically*. For teachers from India this factor additionally included the item *economics is a wonderful context for learning mathematics*. For Israeli teachers this factor also included relationships between *mathematics and drawing* and *existence of mathematical patterns in music*.

The second factor derived from participants' responses from Cyprus, Romania, and Israel included three items that connect creativity in mathematics and **creative aspects in geometry**: *the golden section as a part of many objects in nature and science*; *symmetry as a fundamental interdisciplinary mathematical concept*; and *mathematical (geometrical) objects in architecture*. For Romanian and Israeli teachers this factor also included *mathematics as language*. The Romanian curriculum contains explicit sections dedicated to communication within mathematics lessons while in Israel this issue is emphasized in courses for mathematics teachers. Teachers from India connected mathematics as language with *mathematical patterns in music* and *the golden section*.

The last factor that we describe here relates to **mathematics in real life**. For Indian teachers, this is the biggest factor in the category creativity in mathematics as related to culture. This factor included teachers' opinion that *our everyday life is full of mathematics*; *mathematics is present in geography, drawing, and architecture*; *mathematics helps to describe differences in economics*; *mathematics strengthens ability to justify an opinion*. In contrast, for teachers from Israel mathematics in everyday life appeared to be connected to two items related to *economics as context for learning mathematics* and *mathematics as a way of describing differences between economics in different countries*.

5 Creativity-related features of mathematics education in Cyprus, Mexico, and Romania

In this section we explain differences and similarities revealed in the study by focusing on three countries where the most meaningful differences were found.

5.1 Mathematics education in Cyprus

5.1.1 The mathematics curriculum

The mathematics curriculum that teachers who participated in this study were implementing at the time that the survey

was conducted made no reference to creativity (Ministry of Education and Culture of Cyprus, n.d.). Nor were there references to interdisciplinary approaches to mathematics. The curriculum mainly presented a list of mathematical topics that teachers had to cover every academic year.

Another reason why creativity may not be given appropriate attention in Cypriot mathematics classes is because creativity is never assessed or examined in final mathematics examinations. Examinations most often include procedural tasks and sometimes conceptual tasks that do not require much creativity. Therefore, teachers often “train students to the test” and emphasize the procedures and concepts that will allow their students to succeed in these examinations.

Finally, a majority of secondary schoolteachers in Cyprus claim that they have a vast number of topics to cover and very limited time. According to data presented in the Trends in International Mathematics and Science Study (TIMSS), Cyprus is one of the countries with the fewest teaching hours devoted to mathematics in Grade 8. Overall, in Grade 8 and Grade 11 mathematics is taught for only three 45-min sessions every week. In Grades, 7, 9, and 10 it is taught for four 45-min sessions, and in Grade 12 for two 45-min sessions. The number of mathematics teaching hours increases in Grades 11 and Grade 12 for students who choose mathematics as an elective subject. In that case, the number of teaching hours becomes seven 45-min lessons in Grade 11 and six 45-min lessons in Grade 12 every week. The time pressure on mathematics teachers in secondary schools appears to restrict them from presenting their students with tasks designed to elicit creativity or tasks that relate mathematics to other disciplines. It is well known in the literature that creativity tasks as well as tasks linking mathematics to other disciplines typically require more time to be completed.

5.1.2 Instructional materials and equipment

In Cyprus a common series of mathematics textbooks is used in all public secondary schools. The mathematics textbooks that were used by the secondary school teachers who participated in the study presented hardly any activities that promoted creative thinking. Nor did they emphasize the relationship between mathematics and other areas such science, cultural tradition, or art. This probably explains why Cypriot teachers appeared to discuss these issues significantly less often than teachers from India and Mexico.

Given the fact that these mathematics textbooks offer hardly any activities promoting mathematical creativity and connections with other disciplines, we may assume that teachers do not have any instructional guidance in how to do this. Instead, students are encouraged to find a correct solution (mainly a single solution) without considering

different paths/methods/concepts that might lead to the solution.

Further, neither in the mathematics curriculum nor in the mathematics textbooks are any suggestions made for the integration of technology. The use of technology in mathematics teaching is limited and is based on teachers' own interest and knowledge. Moreover, in each class there is only one computer and in each school there is usually no more than a small computer lab'.

5.1.3 Teachers and teacher education

All mathematics teachers in Cyprus that are currently working in secondary education have a degree in mathematics, with an emphasis on pure mathematics, applied mathematics, or statistics. As shown by the data presented in Table 1 a significant proportion of the mathematics teachers possess a Master's degree, and a small proportion holds a Ph.D. During their studies for the completion of a Bachelor's degree these mathematics teachers develop their subject matter knowledge but not their pedagogical knowledge. Additionally, teachers in Cyprus have to complete a postgraduate certificate in education in order to be granted the license to teach. During these studies, teachers have to attend lessons related to educational psychology, pedagogy, didactics of mathematics, and mathematical content.

5.1.4 Interpreting connections between the Cypriot educational scene and mathematical creativity

Teachers from Cyprus consider themselves to have a key role in the enhancement of students' creativity. Due to the lack of opportunities provided by the Cyprus mathematics curriculum and books, teachers feel responsible for organizing activities that engage students in creative thinking. Thus, students' creativity depends mainly on their teachers' creativity.

Teachers from Cyprus who participated in this study reflected on the fact that in recent years there has been a number of public discussions and presentations about the importance of the use of mathematics software in the mathematics classroom. Teachers seem to believe that new instructional or didactical ideas may come through designing original activities using mathematical software and visual aids. This is reflected in Cypriot teachers' responses to the question regarding teachers' didactical creativity, where they claimed, in a significantly higher percentage than teachers from other countries, that mathematics software and visual aids are indicative of teachers' didactical creativity.

It is also interesting that Cypriot teachers saw expressions of creativity in mathematics teaching in the ability to

make connections between mathematics and history to a significantly higher degree than teachers from other countries. This is probably due to Cypriot teachers' Greek heritage and the fact that references to Greek mathematicians and their work, such as Pythagoras, Euclid, and Thales, are made in Cypriot textbooks.

Furthermore, only teachers from Cyprus saw the inclusion of Olympiad problems in mathematics lessons as an expression of teachers' creativity. This may be due to the fact that in Cyprus there is a very active Mathematical Society in which a large proportion of the mathematics teachers are members. This Mathematical Society organizes the Mathematics Olympiads. Thus a large proportion of the Cypriot mathematics teachers come across mathematical problems that are used in the Olympiads. Without teacher intervention, the type of mathematics problem presented in the Cyprus Mathematics Olympiads is rarely encountered by Cypriot students in their mathematics classrooms. It appears that Cypriot teachers believe that mathematical creativity is needed to solve these problems, since one has to combine different pieces of prior knowledge to address them.

5.2 Mathematics education in Romania

5.2.1 The mathematics curriculum

According to the Romanian national curriculum (Singer and Voica 2004), learning mathematics is based on understanding the nature of mathematics as a corpus of knowledge and problem-solving procedures that can be approached by exploration; and as a dynamic discipline relevant to everyday life and to science, technology, and social sciences.

Curriculum reform that started in 1998 recommended some major shifts in the way teachers think about their classroom activity (Singer 1999). These shifts refer to: putting more emphasis on problem-solving activities involving trial-and-error; active participation in practical learning activities; search for solutions beyond the given frame of school knowledge while relying less on memorizing rules and computing; focus on formulating questions, analyzing the steps, and motivating decisions in problem solving more than merely solving problems/exercises that have a unique answer; using various manipulative activities to help learning, instead of merely "pen and pencil" (or "chalk and blackboard") math; a teacher acting as a facilitator of learning, who challenges students to work in teams frequently, instead of acting as an information provider for passive students that work alone; and, finally, viewing assessment as a part of learning that stimulates classroom activities instead of using assessment just for labeling students. Unfortunately,

various changes of educational policies in Romania in the last decade affected the consistency of implementation of the curriculum reform. Consequently, these educational initiatives did not actually reach a critical mass of teachers and students and they have not yet effectively pervaded students' learning experiences.

5.2.2 Instructional materials and equipment

In primary and secondary education, teachers are responsible for selecting the textbook to be used in every class, from a list approved by the Ministry of Education. Although many of the new textbooks display a gamut of learning activities, most teachers use these books in class just for practicing problem solving.

Various resources may be used in mathematics teaching: objects, shapes, drawings, computers—but not calculators. The systematic use of Information and Communication Technology (ICT) in instruction is relatively limited. There are some national programs focusing on technology integration as well as educational software for teaching mathematics and science. However, the average school does not have enough equipment for one-on-one instruction, and frequently there are problems with maintaining existing equipment. Consequently, the use of computers in teaching/learning/assessment is dependent on local resources. Given this situation, we can deduce from teachers' answers a real desire for more creative approaches, where technology can play an important role.

5.2.3 Teachers and teacher education

The minimum requirement for teaching in primary education used to be graduation from a pedagogical high school. This policy was recently replaced by the need for a Bachelor's degree and 60 credits in a psycho-pedagogical field program. The professional development of teachers is a process made up of several stages beginning with confirmation as a teacher and continues on to teaching degree II and teaching degree I, and in-service training programs that are compulsory every 5 years.

This background preparation is reflected by our sample: about 8 % graduated from pedagogical high school; the highest level of formal education completed by the majority of Romanian respondents is the Bachelor's degree (65 %), though a quarter of them have earned a Master's degree as well.

According to a new education law, a Master's degree will become compulsory for a teaching career. Recently, a few universities have developed Master's degree programs for teacher training. The most successful has proved to be a four-semester program that takes place in a blended learning environment which combines face-to-face with

online activities (Singer and Sarivan 2011). This graduate program is innovative in curriculum design. Subjects are grouped into: a core curricular area (that offers fundamental knowledge of the specific teaching subject, for example mathematics); a specialized curricular area (which includes didactics of algebra, didactics of geometry, etc.); and a functional curricular area (subjects derived from the specific social needs of the contemporary society: Communication, ICT, Entrepreneurship, and Management of Values). A tutorial for educational research and another for preparing the paper required for graduation is also included (Singer and Stoicescu 2011).

Other attempts to update pre-service teacher training come from innovations in organizing didactical courses delivered by each university for its prospective teachers. For example, in a few universities, the teaching of the Didactics of Mathematics delivered in the second year of university studies was based on monitoring teacher candidates as they implement small-scale research projects in their practice schools (Voica and Singer 2011). The use of projects has proved quite efficient for acquiring teaching knowledge and understanding.

These attempts show that within the educational system a variety of old and new practices coexist, with the idea of impacting change in teaching and teachers' mentalities. For a long time, a typical highly appreciated math teacher in Romania was a person that served as a coach for gifted/high achieving students, during and beyond the class. The results of the survey confirm that this perception is still valid.

5.2.4 *Interpreting connections between the Romanian educational scene and mathematical creativity*

In contrast with other countries (e.g., Cyprus and Israel) whose educational systems started emphasizing creativity in school mathematics during the last decade, a certain type of mathematical creativity has always been of great interest for Romanian mathematics teachers. Romanian teachers' attitudes reflected in this study might be explained by their focus on training students for mathematical competitions. For them, creativity mostly equals high scores in math contests. During the 1980s, the school system was oriented towards obtaining high ranking in math competitions and consequently most of the learning activities were devoted to high achievers in math. This vision is still strong in the educational system today, although more and more voices argue that teaching must take into account all levels of students' abilities.

The Romanian sample is consistent in considering that attributes associated with school math creativity are cognitive characteristics of a creative student, such as: the generation of multiple solutions and strategies in problem

solving; the novelty of solutions; and success in solving unknown problems. Taking into account the fact that there is no focus on open-ended problems or exploratory activities in the current practice of the Romanian teachers, we can conclude that when they refer to creative students they mean high achievers, able to solve well-defined difficult problems. Implicitly, in order to be creative, a student has to have a high level of mathematical performance.

The teachers' answers to the questionnaire also reflect a vision that is influenced by some old ideological tendencies. The data suggest that concrete ways to implement creative approaches in the classroom are less valued compared with a general interest in creativity (which might be ideological in nature). For example, more than 90 % of the Romanian sample (53 % strongly agree and 40 % agree) believes that a creative teacher is one who uses real-life situations for mathematical problem solving. However, it is not a usual practice in teaching and learning. This fact becomes more obvious when observing that the high degree of agreement decreases when it comes to: describing patterns in nature mathematically (28 % strongly agree and 52 % agree); connecting mathematical content to the history of mathematics (15 % strongly agree and 41 % agree); connecting mathematics and architecture (12 % strongly agree and 42 % agree); and using historical facts in the lessons (10 % strongly agree and 56 % agree).

Concerning the relationship between mathematics and religion, the answers provided by the Romanian sample reflect the secular orientation of the old school system and the mentality induced by the communist regime still present in the teachers' minds 20 years after the fall of communism. Although today 1 hour of religion per week is compulsory from K to 12, the frequency of religious connections to the math class is rather sparse.

Romanian society still perceives the best teachers as those with great success in coaching students for national or international competitions. As a consequence of this attitude, creativity is frequently seen from the perspective of problem solving. Problem posing, open-ended problems, and explorations of a multiplicity of solutions and learning approaches are less common in teaching practice. However, the high scores accorded to creative features might express the desire of Romanian teachers for having more open and diverse creative experiences in the school context after almost two decades of searching for a new identity in a democratic world.

5.3 Mathematics education in Mexico

5.3.1 *The mathematics curriculum*

The Mexican curriculum underwent reform starting in 2004 with pre-school education and ending in 2011 with

high-school education. The new curriculum relies on a series of pedagogical principles (Secretary of Public Education, Mexico, 2012a). The first principle focuses on: life-long learning designed to develop students' disposition and ability for learning, developing critical thinking and higher order thinking in order to solve problems, and analyzing situations from different knowledge domains. The second principle reinforces the role of the teacher by asking them to plan proper learning sequences to facilitate student learning and the development of competencies. The third principle requires teachers to create contexts for learning in which communication and interactions facilitate learning. This puts an accent on collaborative learning, use of instructional materials, and proper assessment modalities associated with curricular standards and expected learning outcomes.

Mathematical thinking is a basic element of the curriculum spanning pre-school to the end of secondary school. Pre-school consists of 3 years of learning with the last 2 years as mandatory for attending school, followed by 6 years of primary school and 3 years of high school. According to the Mexican curriculum, mathematics has to be focused on problem solving, on building arguments to explain results, and on designing strategies for decision making (Secretary of Public Education, Mexico, 2012a). Students are responsible for developing new knowledge based on previous experiences, formulating and validating conjectures, formulating new questions, searching for interesting problems related to everyday life, looking for multiple solutions, and using diverse techniques in an efficient way.

5.3.2 Instructional materials and equipment

The Secretary of Public Education is the sole authority in Mexico for creating and maintaining up-to-date textbooks used by all children in primary education. With regard to the use of computers in the classroom, there are big differences depending on the region of the country.

Since 2000, an initiative between the Secretary of Public Education, the National Pedagogic Institute, and National Autonomous University of Mexico built *Enciclomedia*, an e-learning system having at its core free textbooks and multimedia resources (Secretary of Public Education, Mexico, 2012b). There has been a sustained effort to distribute computers, white boards, and projectors, so teachers can have access to the resources in order to plan, organize, and evaluate the teaching/learning process. The same system allows teachers to integrate their own questions and answers into the system. It has to be said that this project generated a lot of controversy: particularly about copyright issues, but also about priorities given to the concrete problems schools face.

An interesting issue to mention is the role of distance education in Mexico. In the last four decades there has been an increasing effort to help students finish their mandatory schooling. The Tele-Secundaria or distance education for high school is an option available for those in rural regions or those who, for various reasons, cannot attend school, and even for Mexicans living outside of Mexico (Secretary of Public Education, Mexico, 2012c).

5.3.3 Teachers and teacher education

In Mexico the training of pre-school, primary, and secondary teachers happens in specialized higher education institutes where future teachers can obtain a Bachelor's degree. The duration of training is 4 years. For pre-school and primary teacher training the curriculum is organized around five lines: psychology (educational and developmental psychology, psychology of learning, and learning difficulties); social formation (Mexican educational system, social, economic and political issues in Mexico, etc.); pedagogy (design of instructional materials, educational models, academic contents, etc.); instrumental line (mathematics and statistics, educational theories, Spanish); line of specific content or complementary courses (creativity and scientific development, educational technology, children's literature, physical education, etc.). At pre- and primary school level, the main purpose in creativity training is to prepare prospective teachers to develop games or game-like situations to be used in teaching and to enhance their ability to create situations in which children's creativity can be stimulated mainly through movement, art, and drama. In some states of Mexico creativity training has been a central issue in teacher training for decades, leading to the generation of certificate courses in creativity for professional development of in-service teachers in addition to the creativity training for pre-service teachers. However, these workshops and courses are not domain-specific.

For high-school teachers, training happens in three main directions: domain-specific training, pedagogical formation (teaching methodologies), and practical training. However, it is common to have secondary teachers who completed university level training in a special domain (like mathematics or physics) even if they had no special (pedagogical and didactical) training. It is also true that due to the lack of teachers in many regions, this role is often filled by persons with little or no special training in a domain.

As far mathematics is concerned, the Association of Mathematics Teachers has annual reunions, publications, and workshops to help in-service mathematics teachers. The Mexican Mathematical Society also plays an active role in promoting mathematics by way of diverse publications (popular journals, problem collections, mathematical calendars), and also by organizing competitions,

mathematical camps, training sessions for all those interested in mathematics, and by offering scholarships to outstanding students.

5.3.4 *Interpreting connections between the Mexican educational scene and mathematical creativity*

Teachers from India and Mexico reported significantly more positive associations between creativity and culture than teachers from other participating countries. This finding may be related to the fact that educational systems in India and Mexico are less secular than in other countries.

In the Mexican educational system the teacher remains the main person responsible for creating a proper context for classroom learning. Documents from the Ministry of Education clearly state that the role of the teacher is to identify and select interesting problems and create mathematically complex and rich learning contexts—as opposed to offering simple explanations—so that by the analysis and exploration of those problems students can develop deep mathematical understanding. In this way, the focus is shifted from rote onto creating, adapting, and finding proper ways to put forward challenges that call for learning new mathematical concepts.

Some universities offer special courses on creative thinking in mathematics focusing mainly on recreational mathematics, advanced problems, and topics in geometry and number theory, and also on the use of technologies in mathematics. This type of course is included in the common core for different areas: informatics, chemistry, mathematics, and physics. The courses are designed to develop creative approaches to mathematical situations in order to generate multiple solutions, develop the taste for problem solving, and facilitate organizing and structuring ideas.

Emphasis is put in these courses on developing with a link between creativity and instructional practices in the various contexts of teaching, in both teacher preparation and professional development programs. This emphasis reinforces a view in which one can be trained to be creative (in the case of teaching). Results reported in Sect. 4.2.2, namely that Mexican teachers were the least likely to view creativity as a gift, but rather it is as a result of teachers' creative use of instructional skills, are concordant with the above view.

The study results speak to the importance Mexican teachers attribute to promoting the rich cultural inheritance of civilizations from the pre-conquest period. The outstanding achievements of Mayans in mathematics, astronomy, and arts offer a meeting point in discussing connections among these areas and reinforce cultural identity. The fact that today's physical space is indivisibly intertwined with vestiges from the past in many parts of

Mexico transforms the past into a continuous presence and facilitates references to it. Today's Mexico is home to more than 60 officially recognized indigenous populations whose language, religion, and traditions are integral parts of the society and there are ongoing efforts to bring awareness of this cultural amalgam by integrating it into the school curriculum and by developing special programs to promote it.

Divided opinion (as shown by a low mean and relatively high standard deviation) among Mexican teachers on the relationship between personal creativity and professional success finds an explanation in Mexican reality. Today's Mexico is hugely varied in socioeconomic status, a reality strongly reflected in the school system. Many public schools at the primary education level are struggling to keep students who have difficulty attending school due to low family income. In the last few years, there have been several coordinated efforts on federal and provincial levels to change this situation. In several provinces, a scholarship regime was installed in order to stimulate families sending and keeping their children at school. Sadly, however, even with financial stimulus, school attendance at the primary level has not improved. Concurrently, another segment of the population participates in a relatively expensive private school system. This enrollment in the private system occurs in spite of Mexican education being free of charge and accessible at every level of schooling, including several of Mexico's higher-level education institutes that are internationally recognized for the level of training they offer. Clearly, a teacher's professional experience will vary enormously depending on the location and level of the school where he or she works.

6 Summary

The results of the international survey presented in this paper highlight the fact that some of the variables associated with mathematical creativity in school are culturally dependent whereas other factors are intercultural. For example, attention provided to creativity in mathematics and teacher training directed to excellence in mathematics led teachers from Romania to agree more strongly than teachers from other countries with the majority of questionnaire items that describe the characteristics of mathematically creative students and teachers as well as of a creative person in general. Based on specific characteristics and national history, teachers from India and Mexico report more positive associations between creativity and culture than teachers from other participating countries.

In general, the variation among teachers from the different countries is relatively small. In spite of the differences in culture and tradition, many of the categories of

creativity in mathematics teaching appear to be intercultural. Among these categories are: the relationship between teachers' creativity and the depth of their mathematical knowledge; and the relationship between creativity and problem solving.

Factor analysis led to the identification of some factors that unify conceptions of teachers from different countries. Teachers consider students to be creative if they have investigative abilities, are mathematically flexible, and succeed in problem solving. Teachers from all the participating countries evaluated mathematics teachers as creative when reflected by student-directed mathematical flexibility (i.e., development of mathematical creativity in students) as well as teacher-directed didactical creativity (i.e., teachers' own ability to be flexible in planning and managing mathematics lessons) (Lev-Zamir and Leikin, 2011, this issue). Student-oriented conceptions of mathematical creativity appeared to be connected to teachers' own enjoyment derived from doing mathematics. Teachers' creativity is also considered by teachers from all the countries as related to teachers' ability to connect mathematical content with curriculum from other areas of art and science.

Analysis of the differences in creativity-related characteristics of mathematics education in different countries clearly shows that differences in educational systems are reflected in teachers' conceptions. Based on the findings of our study we argue that more attention should be given to creativity in school mathematics at the level of (1) educational policy, (2) instructional materials, and (3) teacher education.

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