

EDUCATIONAL-TEACHING PRACTICES AND ACHIEVEMENT TIMSS – MATHEMATICS

Chryssa Sofianopoulou, University of Athens, Greece

Ntelikou Maria, University of Athens, Greece

Dimitris Boulamatsis, University of Athens, Greece

Abstract

This paper examines the IEA's Third International Mathematics and Science Study (TIMSS) data for Greece and more specifically POP2 (8th grade). The paper focuses on the teacher's educational-teaching practices in the classrooms and analyses these with factor analysis. We also investigate the relationship between teaching practices and student achievement with regression analysis. Educational / teaching practices in the field of mathematics have acquired increasing importance. They are of high interest as a research subject as they are considered an essential parameter in the process of learning. In the 1990's the "mathematics education population", meaning students and teachers, constituted the main research focus. This paper explores students' perceptions of their teachers' practices in the classroom. Factor analysis resulted in eight factors, including innovative as well as traditional teaching practices. The regression analysis explored if and how these practices are related to the student achievement in mathematics. In the final model it appears that traditional and pragmatic teaching practices are positively correlated to student achievement, while the remaining six factors identifying practices such as *innovative teaching, emphasis on the new theme* are negatively correlated.

INTRODUCTION

This paper analyzes data from the IEA's Third International Mathematics and Science Study (TIMSS). More specifically, we examine the answers of the 8th grade Greek students on questions concerning their educational experience.

The paper aims to explore the relationship between educational-teaching practices and student achievement in mathematics. The effort to record, understand and study what goes on in education on the basis of the research question: "how is student achievement in mathematics related to teaching practices that are applied in school" renders exploration of this relationship very important. Moreover, the hierarchical

results of student achievement in mathematics must also be studied in relation to those factors that formulate this achievement at the school system level as well as the classroom level (Kontogiannopoulou-Polydorides, Solomon, Stamelos, 2000, p.3).

In order to investigate this relationship between achievement and educational-teaching practices in the classroom, factor analysis was performed on the various practices which indicated the frequency that these practices are applied during class and when a new theme is introduced. The extracted factors were related to student achievement using regression analysis, and more specifically, the non-automated best regression model selection. This method is used in exploring the relation between a qualitative variable and one or more qualitative or quantitative variables. For this specific study student achievement is the quantitative variable (as it was measured by TIMSS) while the factors presented in table 4, which express educational-teaching practices in class, were treated as qualitative variables.

We have taken into consideration all the characteristics that indicate the teachers' practices in mathematics class. We considered it important to include all the characteristics that are related to the teaching of mathematics according to *students' perceptions*. In order to explore the relationship between student achievement and educational-teaching practices, all ways of learning in mathematics should be studied, including teaching a "new theme". Baralos (2002), while presenting various teaching practices through relative studies (Crosswhite, 1987, Lapointe, Mead & Askew, 1992, Robitaille, Taylor & Orpwood, 1996, Colgan & Harrison, 1997) mainly refers to the introduction to a new theme by the teacher.

DATA ANALYSIS

Factor analysis was performed on the nineteen teaching practices that led to the extraction of eight (factors) practices that are:

Before analyzing the data it is important to clarify two important meanings: *traditional* and *alternative*, as they characterize educational practices and the teachers who apply them in the context of this paper.

Tradition basically refers to every human practice, belief, institution or creation that is passed on from generation to generation (Abercrombie, Hill, Turner, 1992). In this paper, the term traditional educational-teaching practices signifies any type of teaching that contains elements of the previous generation's teacher culture. This term characterizes all educational-teaching practices that are included in the notion that ideas and values that have been cherished over time have acquired a certain degree of objectivity and constitute the substance of the culture to be passed on to new generations. According to this notion, teaching is the action of transmitting knowledge, theory and practice that are often organized in school material and cognitive fields (Bertrand, 1999). The terms "traditional" and "traditional teaching" (as they are used in this paper) refer to long-standing educational practices, some of which have occasionally been questioned while others have received much support. Furthermore, the use of these terms is influenced by Giddens' views (2002): "Traditions have always incorporated power whether their construction was deliberate or not. [...] Those who follow a tradition do not feel the need to look for alternative practices. [...] Tradition offers a frame of action that is, to a large extent, considered uncontradictable. [...] Tradition's specific distinction is solemnity and repetition".

Table 1: Factor Analysis On Teaching Practices

	<i>During mathematics calss...</i>	<i>F1</i>	<i>F2</i>	<i>F3</i>	<i>F4</i>	<i>F5</i>	<i>F6</i>	<i>F7</i>	<i>F8</i>
Alternative teaching practices	Use of calculators	0.8							
	Use of computers	0.8							
	Students work in pairs or small groups	0.6						0.3	
	New theme-work in pairs or small rroups	0.4	0.3	0.3				0.3	
Emphasis on new theme	New theme-previous knowledge		0.7						
	New theme-follow the textbook		0.7						
	New theme-examples		0.7						
Feedback	Students check each other's homework			0.8					
	Discussion about homework			0.8					
Pragmatic approach	Problem solving with every day life examples				0.8				
	New theme-relation with every day life				0.8				
Traditional teaching 1	New theme-explaining the rules					0.7			
	Homework assignment					0.7			
Traditional teaching 2	Students copy from the board						0.9		
	The teacher shows how to solve problems					0.3	0.6		
Testing and evaluation	Take written quizzes or tests							0.7	0.3
	The teacher checks homework			0.3		0.4		0.6	
Projects, homework	Students begin homework in class								0.7
	Papers, projects						0.3		0.6
	% of variance	9.4	8.4	8.1	7.7	7.6	6.8	6.4	6.0
	Total variance explained	60.4							

Extraction Method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalization.

Source: IEA, Third International Mathematics and Science Study (TIMSS), 1994-95, Hellenic Coordinating Center of IEA, University of Athens (HCC/IEA).

The term *alternative teaching practices* characterizes educational-teaching practices that focus on the students' activity. It is the students who, with their teachers' incentive, select, analyze and organize the facts in order to construct new knowledge. In this case neither the teacher nor the textbook constitutes authority in the classroom. Baralos (2002) claims that teachers who have social constructivist opinions view their role in class as facilitators; i.e., they present problems that provide incentives to create an environment that favors exploration, and offers students opportunities to discuss their emerging understandings.

Thus, whenever the term "alternative teaching" is mentioned, it will refer to teaching that is not merely a transmission of facts and knowledge. Rather, it is the students who construct, explore, conclude, control and, at the same time, share and discuss their thoughts with their teacher and their schoolmates. This notion, of course, includes the use of technology (computers, calculators, etc.).

In our effort to explore which of the above eight practices (Table 1) are related to achievement and *in what way*, we performed regression analysis (more specifically, the non-automated model selection). Regression analysis was chosen because it is the method that provides more information, not only about the statistical significance between two independent variables, but about their correlation to the dependent variable as well. This means that regression analysis can explore which independent variable is more related, in what way (positively or negatively), and can determine which model is final. Furthermore, the linear correlation between the independent variables and the variable we examine (dependent) is estimated. In this particular analysis, achievement was entered as the dependent variable, while the educational-teaching practices (factors) that are presented in Table 1 were the independent variables. The final equation of the regression analysis, in which all factors were entered, is presented in the following tables, 2 through 6.

Table 2: Regression – Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	Pragmatic teaching, Feedback, Testing and evaluation, Emphasis on new theme, Papers, projects, Traditional teaching 2, Traditional teaching 1,	,	Enter

All requested variables entered
Dependent Variable: Achievement in Mathematics

Table 3: Regression – Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R. Square Change	Change Statistics			
						F	df1	df2	Sig. F
1	0.373	0.139	0.137	81.256	0.139	65.166	8	3216	0.000

Predictors: (Constant), Pragmatic teaching, Feedback, Testing and evaluation, Emphasis on new them, Papers, projects, Traditional teaching 2, Traditional teaching 1, Alternative teaching practices

Table 4: Regression – ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	3442086.3	8	430260,78	65,166	0,000
Residual	21236264.7	3216	6602,519		
Total	24678350,9	3224			

Predictors: (Constant), Pragmatic teaching, Feedback, Testing and evaluation, Emphasis on new theme, Papers, projects, Traditional teaching 2, Traditional teaching 1, Alternative teaching practices

Table 5: Regression - Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	St. Error	Beta			Tolerance	VIF
1 (Constant)	487,370	1,433		340,116	0,000		
Emphasis on new theme	18,517	1,429	0,212	12,954	0,000	1,000	1,000
Papers, projects	15,436	1,444	0,175	10,686	0,000	1,000	1,000
Traditional teaching 1	-14,862	1,471	-0,165	-10,103	0,000	0,999	1,101
Traditional teaching 2	-9,151	1,450	-0,103	-6,310	0,000	0,999	1,001
Testing and evaluation	8,363	1,431	0,096	5,846	0,000	1,000	1,000
Alternative teaching practices	8,548	1,458	0,096	5,862	0,000	0,999	1,001
Feedback	6,250	1,430	0,072	4,372	0,000	1,000	1,000
Pragmatic teaching	-5,145	1,430	-0,059	-3,599	0,000	0,999	1,001

Dependent Variable: Achievement in Mathematics

Table 6: Regression – Collinearity Diagnostics

Model	Dimension	Eigenvalue	Condition Index	(Constant)	Emphasis on new theme	Papers, projects	Traditional teaching 1	Traditional teaching 2	Testing and evaluation	Alternative teaching practices	Feedback	Pragmatic teaching
1	1	1,047	1,000	0,43	0,01	0,01	0,27	0,16	0,00	0,02	0,00	0,05
	2	1,034	1,006	0,02	0,03	0,01	0,16	0,02	0,12	0,55	0,01	0,06
	3	1,026	1,010	0,08	0,15	0,38	0,09	0,00	0,04	0,00	0,03	0,19
	4	1,020	1,014	0,04	0,24	0,01	0,02	0,29	0,01	0,02	0,32	0,01
	5	0,999	1,024	0,05	0,03	0,03	0,00	0,00	0,53	0,02	0,02	0,32
	6	0,995	1,026	0,00	0,16	0,16	0,03	0,07	0,00	0,02	0,54	0,02
	7	0,983	1,032	0,03	0,07	0,23	0,02	0,03	0,29	0,10	0,01	0,23
	8	0,973	1,037	0,00	0,31	0,12	0,17	0,36	0,00	0,00	0,02	0,04
	9	0,923	1,065	0,34	0,00	0,04	0,23	0,06	0,00	0,27	0,06	0,07

Achievement in Mathematics

The practice that shows the strongest relation with achievement and, more specifically, is positively related to it, is "traditional teaching 1" (factor 5). Thus, it appears that students who have higher achievement report that their teachers use the following practices: explain rules and definitions while presenting a new theme, and assign homework.

The next factor that is positively related to student achievement is "traditional teaching 2" (factor 6). The students who copy notes from the board and whose teachers demonstrate how to solve problems seem to have higher achievement.

At this point it is important to refer to Flato (1993), who claims that students who are considered gifted in mathematics are not really those with the best real abilities in this field. That is to say that the educational system, which is founded on selection based on mathematics, has for the majority of students encouraged the development of memorization and assimilation of knowledge, which the most truly gifted students dislike. Most often the children who are considered gifted, or genius are really no more than obedient spirits who study hard and build up an ability to memorize formulas or meanings (Flato, 1993, p. 25).

Bertrant (1999, p. 183) also points out that in the case of traditional teaching, the goals set for students are externally defined, and their papers and projects have been determined by someone else, i.e., the teacher. During these kinds of learning activities, pre-constructed learning methods or conventional rules are generally acquired, and have been learned and memorized in an automated way.

Despite these views on traditional teaching we cannot doubt the fact that the TIMSS data analysis illustrates that both types of traditional teaching are positively correlated with student achievement in mathematics.

The pragmatic approach of the teacher (according to the students) is also essential to teaching mathematics. Student achievement is positively differentiated when the teacher frequently connects the problem or lesson to every day life. Integration of empirical situations in the context of school action reveals a particular ideological approach of the school towards meanings such as autonomy, participation, collectivity (Chrysafidis, 1994). Freedom of action, work, thought, organizing, and expression is, according to Dewey, an essential condition, for students to understand their experience. This characterizes people who are self-administered, self-organized and self-expressed (Fragos, 1984, p.334). Such "empirical teaching"¹ is clearly student-oriented.

And indeed, we observe in the results of this research that student achievement is positively differentiated -"improvement of the outcome of the learning process" (Chrysafidis, 1994, p. 33) - when reference to experience and planning of a communication procedure are practiced. Moreover, mathematical concepts are not to be found in natural objects or predefined activities in the classroom, but in what students do and experience (Noble et al., 2001). The theory of incorporated mathematics (Lakoff, Nunez, 2000) provides an epistemological basis which can be summarised into the following basic principles:

- a) Mathematics is a natural part of human existence. It emerges from our body movement, our brain and our daily experience of the world.
- b) Mathematics' effectiveness results from a combination of mathematics knowledge and its connection with the world. This connection is realized inside the human brain.
- c) Meanings like change, proportion, size, rotation, probability, etc., are everyday concepts that derive from mathematization, which is a common human activity.

The ways in which teachers present and emphasize a new theme in mathematics seem to be related to achievement in a different way. Students with higher achievement are those –according to their educational experience- whose teachers do not demand that they have pre-existing relative knowledge, follow the textbook and try to answer in examples. Of course this is contrary to the views presented in the mid 1970s, and illustrates a specific perspective: children’s ideas. Here we refer specifically to the variable "pre-existing relative knowledge" which reflects the ideas, perceptions, representations of the world that children have formulated (a) before entering the school mechanism and (b) based on previous school experience. Kouzelis (1999) presented the Anglo-Saxon discourse to the Epistemology Faculty in the mid 1960s, with Kuhn’s book *The Structure of Scientific Revolutions* as a landmark, and spoke of the authoritarian turn in the field of Didactics. Instead of the autocracy and inefficiency of traditional practices, the suggestion was to focus on the world of children. Respect their ideas, their culture and their personality as well, "to focus perhaps on an effort to strengthen those particular concepts and meanings by which each child experiences and interprets the world" (Kouzelis, 1999, p.160). This direction aimed at challenging the "replacement" model, according to which traditional practices aim to replace children’s ideas – that are considered mistaken – with the equivalent scientific meanings. According to this model, scientific knowledge can be constructed regardless of empirical knowledge and it can be imprinted in the mind of the learners without any preparatory work (Kouzelis, 1999). Of course children’s ideas cannot be replaced; however we should not be limited to them. And, according to Kouzelis, instructive intervention should organize the way in which students, "with the help of the tools offered by scientific fields and that are systematically placed at their disposal, critically process their original ideas of the world and refute them. They challenge their original ideas in order to reconstruct them with new concepts and a new context of meanings". This applies to Science and Mathematics as well, with a representative theoretical hypothesis: the principal of reinvention of mathematical concepts through the mathematization processes.

As far as this study is concerned, we are able to present two alternative interpretations concerning the reference to pre-existing knowledge or relative examples:

- (a) they are not systematically practiced by the teachers
- (b) they do not have a specific educational goal

It appears that teachers do not try to lead their students’ ideas to either a dead-end or to the construction of knowledge. And this perhaps justifies the negative relation of this practice to achievement. However, it should be noted that teachers are not the only ones responsible for the approach of this particular educational-teaching practice. Curriculum and textbook have their share of responsibility as well.

Student papers in mathematics show a similar correlation. When students execute various papers in mathematics, there is often no positive relation with achievement. This could be interpreted in various ways:

- a) Student papers in mathematics are of general interest and thus are not related to specific subject knowledge; and/or
- b) Students do not work particularly hard on them so that they could enrich their knowledge and consolidate their skills in mathematics; and/or
- c) These papers assigned by teachers do not aim at the improvement of achievement and therefore regression analysis correlates them negatively.

Results for the remaining factors related to achievement are interesting. The use of technology, working in groups, checking of homework either by teachers or by students show positive correlation when teachers use them rarely. This means that students who do not experience the above educational-teaching practices have higher achievement. At this point we have traced three alternative interpretations for the negative cross-correlation of these practices with achievement:

- a) These practices are applied in a formal way, perhaps because they are imposed by the curriculum, and thus do not offer anything regarding knowledge-achievement to students; and/or
- b) Teachers apply these practices more often when they address students with low achievement in order to help them improve; and/or
- c) Students with high achievement are in a position to evaluate the above activities and their frequency and therefore they just answer this question precisely.

DISCUSSION

Teachers seem to prefer traditional teaching, which appears to be effective. It clearly appears that the application of alternative practices is not related positively with student achievement. Teaching practices using papers, working in groups, technology, connection to previous knowledge, students checking their homework, do not appear to constitute "effective" practices in mathematics.

However, we would like to point out that personal teaching experience in class has led to interpretations that support the notion that mathematics can be taught through alternative educational action, but teachers and their culture are not yet ready to accept them.

Although teachers commented (in relative studies like Chionidou, 2001) positively on mathematics practices that are a part of a constructivist approach to teaching and learning, they could not reach a model, where students are given opportunities, through suitably selected activities, to direct themselves to new concepts, recall to memory informal pre-existing knowledge, reconstruct new concepts, apply them, and finally reflect and extend this knowledge with the help of their teachers. According to Chionidou (2001), teachers acknowledge other teaching approaches in Mathematics as well, but do not "dare" – as they say – suggest or apply them.

In Greece, the mathematics curriculum (as suggested by the Greek Ministry of Education), which follows the Western European model, obviously is not accepted by teachers. The educational institution and the culture (of teachers and students) are involved; therefore the expected results are not feasible.

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NOTE

1. Chrysafidis (1994) defines empirical teaching as a “web of teaching processes that derive from empirical situations. Meaning children’s needs, problems and questions derived from every day life and experience, and concerns that are created in the social surroundings, that the children live and and are a part of”.