FEATURED ARTICLES

AMCT'S PROFESSIONAL DEVELOPMENT MODEL: A STRATEGY FOR IMPROVING THE TEACHING AND LEARNING OF MATHEMATICS AND SCIENCE IN ELEMENTARY SCHOOLS OF PUERTO RICO

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Abstract

The objective of this research was to design and implement a model for teacher professional development. The model was implemented by the Turabo Mathematics and Science Alliance project (AMCT, Spanish acronym), which trains teachers. To test the model, a quasi-experimental design with a comparison group was followed. Pre- and post-tests were administered to both, the participants and the comparison group, through three years of implementation (2008-2011). The participating teachers in the experimental group, elementary school teachers (4th to 6th grade), showed significant improvements in their mastering of content knowledge, providing evidence to support the claim that the AMCT model for professional development is effective for the population of elementary school teachers of Puerto Rico. This model stems from a needs assessment, utilizes the state standards and, at its core, coordinates implementation with the faculty, emphasizing connections to the real world and promoting the assignment of, at least, 50% of each workshop to practice.

Keywords: teacher professional development, learning models, teaching strategies

Resumen

El objetivo de esta investigación fue el diseño e implementación de un modelo para el desarrollo profesional de maestros. El modelo fue implementado por el proyecto Alianza de Matemáticas y Ciencias del Turabo (AMCT), el cual entrena maestros. Para evaluar el modelo, se siguió un diseño cuasi-experimental con grupo de comparación. Pre- y pos-pruebas fueron administradas a ambos, los participantes y el grupo de comparación, a través de tres años de implementación (2008-2011). Los participantes del grupo experimental, maestros de nivel elemental (4to a 6to grado), mostraron mejorías significativas en su dominio de contenido, evidencia que apoya la aseveración de que el modelo de desarrollo profesional de AMCT es efectivo para la población de maestros de nivel elemental de Puerto Rico. Este modelo surge de un estudio de necesidades, utiliza los estándares estatales, y, en su parte medular, coordina la implementación con la facultad, enfatizando conexiones con el mundo real y promoviendo la asignación de, al menos, 50% de cada taller a la práctica.

Palabras claves: desarrollo profesional de maestros, modelos de aprendizaje, estrategias de enseñanza

INTRODUCTION

The Turabo Mathematics and Science Alliance (AMCT, Spanish acronym) is a project administered by the School of Engineering at University of Turabo (UT), a higher education institution in Puerto Rico. The AMCT provides content training in science, mathematics, as well as, research methodologies to elementary (4^{th} to 6^{th} grade) and secondary (7^{th} to 12^{th} grade) school teachers, according to the content standards and expectations of the Department of Education of Puerto Rico (DEPR). The project has been sponsored by federal funds from the Title II-B "No Child Left Behind Act" (NCLB) and the Mathematics and Science Partnership (MSP) Program of the Department of Education. The purpose of this paper was to present a model for professional development developed and tested by the authors by using it to design and deliver professional development workshops to teachers. Initially, the paper presents the theoretical foundations of the model, the teaching-learning strategies and tools that accompany its implementation, and the support activities necessary to implement the model. The final section contains the experimental design and final discussion.

PROFESSIONAL DEVELOPMENT MODEL OF THE AMCT

The NCLB law establishes that students must have the opportunities to attain academic success and that teachers must take the learning process to its highest level. This is a difficult mission to carry out given that in our society the volume of information grows at vertiginous speeds and continuous training is the main strategy for reflection (Montecinos, 2003; Watt et al., 2006).

Knowledge is evolving constantly; from a mathematical standpoint, what is known is supported by axioms and theorems that were proposed centuries ago. Consequently, evolution is seen in terms of the capacity to solve practical problems and establish interdisciplinary relationships with other areas of learning (Ernst, 1998; Godino et al., 2003). In terms of the sciences, educators visualize knowledge as fluctuating and progressive; however, at the basic levels, scientific knowledge is still represented as something done, observed and formed solely on the basis of finalized concepts (Calixto, 2000; Sawyer, 2006). Therefore, it should come as no surprise that, in the United States, as well as, in Puerto Rico, the students' academic achievement in these areas of knowledge was below the considered levels of proficiency or excellence (National Science Board, 2004). The results of the Academic Achievement Puerto Rican Test (PPAA for its Spanish abbreviation) showed that, during the academic year 2009-2010, only 13% of the high school students reached the proficient level in mathematics and only 17% were proficient in science.

In value-added modeling (VAM) tests, a significant relationship has been determined between the students' grades and the teachers' efficiency. It has also been proven that enhancing the teachers' education is an important variable in order to achieve high academic performance among students (Darling-Hammond, 2000; Rowe, 2003; Darling-Hammond and Loewenberg, 2007; Darling-Hammond, 2010; Baker et al., 2010). Furthermore, it has been established that effective teachers are able to inspire their students in a significant way. However, the characteristics that make teachers effective are still under discussion and, therefore, one turns to the domain of measurable variables. Certifications, academic qualifications, and years of experience are also taken into account. Most of these variables are linked to the students' scores, but, as a whole, only account for a fraction of a teacher's caliber (Rivkin et al., 2005). This research presents a model for teacher professional development and shows its positive impact on elementary school teachers. The Professional Development Model of the AMCT (MDP-AMCT, Spanish acronym) has three core components: i) theoretical foundations, ii) teaching-learning strategies and tools, and iii) support activities (Figure 1).

Theoretical Foundations

The selection of topics for each training workshop emerges from a needs assessment, as well as, from topics identified by the DEPR. A needs assessment survey is administered once a year to the participating teachers. Each training workshop must have theoretical foundations and must be aligned with the standards and expectations of the DEPR. With these criteria, the project curriculum specialists design a syllabus for each workshop identifying: i) the standards that will be covered, ii) the topics and subtopics that will be developed, along with their respective suggestions regarding methodology and application, iii) the suggested distribution of time, iv) a set of assessment items, and v) recommended bibliography.

The syllabus is at the core of the trainings since it embodies the structure and design of the MDP-AMCT and guarantees the fulfillment of the project's requirements. With this syllabus, the faculty develops the workshop. Likewise, the syllabus outlines essential topics and the faculty is urged to address concepts from an interdisciplinary perspective; that is, each workshop searches for possible integrations with other disciplines, such as, connecting physics to mathematics, chemistry, biology, or earth sciences.

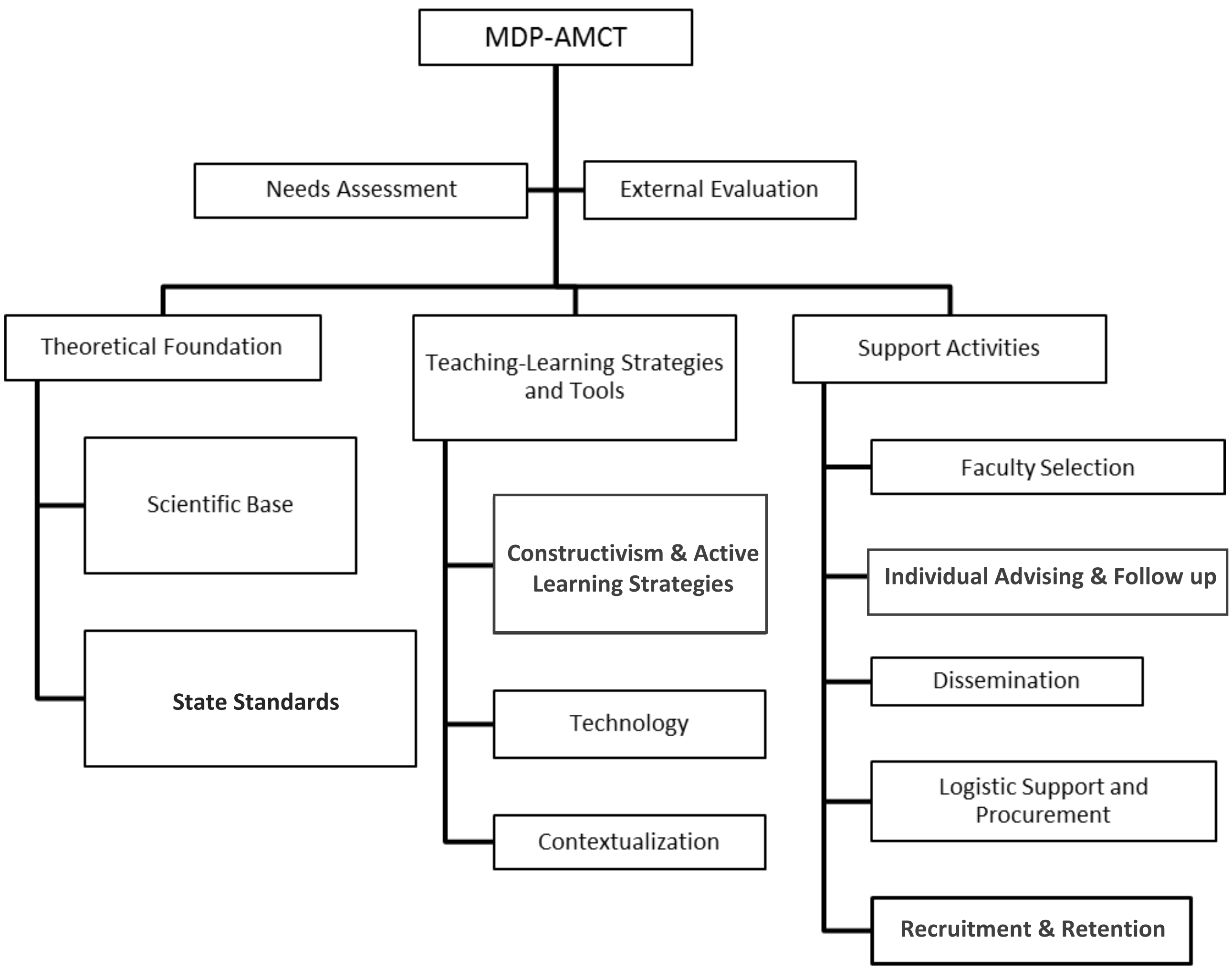

Figure 1. Professional Development Model for the Turabo Mathematics and Science Alliance (MDP-AMCT)

Teaching-Learning Strategies and Tools

The teaching-learning strategies are based on active pedagogical philosophies. The constructivist focus of the workshops promotes the conceptual analysis of mathematics and science by solving problems from other areas of learning and finding applications within everyday situations. Moreover, the use of engineering projects has been a successful strategy for the integration of science and mathematics, making it possible for teachers to acknowledge the interdisciplinary aspect of the courses they teach.

The MDP-AMCT emphasizes the use of technology, both of information and communication technology (ICT), as well as, of the technology available in the laboratories at the UT (e.g., robots, machine-shop, electric circuits, chemistry, biology, and physics labs). In terms of the emphasis on active methodologies, the MDP-AMCT model proposes the use of time in a dynamic way, that is, time is distributed, approximately, 40% for the revision of theory (e.g., concepts, demonstrations) and 60% for practical activities (e.g., problem solving, projects, team work, laboratories).

Support Activities

The logistics of the training workshops begins with the selection of the faculty, taking into account their specialty, experience, and communication skills. In most cases, the faculty is part of the School of Engineering or the School of Science and Technology of the UT, who hold master or doctoral degrees. Following each workshop, the faculty is evaluated by the teachers; subsequently, being the recipient of an excellent evaluation is a criterion which will determine whether or not one can return as a project faculty.

The second group of activities is the Individual Advising and Follow-up, executed with the help of the educational consultant. Each teacher receives a maximum of four visits during the academic year. While the visits focus on topics or activities in which the teacher requires counseling, each visit has specific objectives: i) the first one is the "exploration visit" and helps to identify the topics in which the teachers require support; ii) the second visit is the "mentoring visit", and its purpose is to provide mentorship in the topics previously indicated, as well as, in the search or selection of activities and materials. During this visit, the educational consultant submits the rubric that will be used to observe the teacher's performance during a sample class; iii) the third visit is the "observation visit" of the teaching exercise; teachers that opt out from being observed, may choose further mentoring, and iv) the fourth and last visit, designated to be the "impact visit", serves to compile data or evidence of content transfer to the classroom.

The third group of activities that provide support is the one related to dissemination. Among these are the production of an information bulletin, leaflets regarding content, the publication of newspaper articles showcasing the project, and the publication of articles in specialized peer-reviewed journals, in which the project shares accomplishments and models. These materials, as well as, those designed by the workshop lecturers, are published on the project's web page: http://www.suagm.edu/turabo/amct_incio.asp. All participating teachers have access to this page, and they are free to use the published materials for the development of their classes, as well as, for student consultations.

The fourth group of activities is the Logistics Support and Procurement. Basically, these consists on the specific support to the AMCT faculty, before and during the trainings, which comprises acquisition of materials, and technical and logistic support, and the purchasing and distribution of teaching materials to the participating teachers. These materials remain at the teachers' schools. The project assigns these materials based on the actual amount of contact hours per training workshops that the participants have attended. The final group of activities is the Recruitment and Retention of participants and control group.

METHODS

The MDP-AMCT is the result of an empirical and research process that underwent multiple revisions and adjustments. The AMCT project evaluation follows a mixed design, including formative and summative evaluation, and consists of qualitative, as well as, quantitative aspects. Without delving into the formative and summative evaluations carried out by the DEPR, composed of quarterly reports, desk monitoring reviews, and final annual performance reports, the AMCT project, as well as, each of the MDP-AMCT components, have been subjected to independent external evaluations, all of which confirm that, throughout the years herein reported, the objectives of the project have been consistently achieved. This section describes the project's experimental design, along with a description of the participants in the experimental group, as well as, of those in the control group.

Experimental Design

The design implemented was quasi-experimental with comparison group. The project's impact was measured directly by way of the elementary teachers' performance in a pre-test and post-test, designed for each area (i.e., mathematics and science) and, indirectly, by way of the performance of their students in the standardized state test, i.e., "Pruebas Puertorriqueñas de Aprovechamiento Académico" (PPAA, Spanish acronym). The pre- and post-tests were designed by the AMCT project and were subjected to a validation process and reliability measurement. As a result of the process of validation, the tests were modified and some items were eliminated or rewritten. Reliability was measured by the Cronbach's Alpha coefficient, which was higher than 0.65.

Sample Description

A total of 412 teachers have participated in the training workshops during the three years of implementation that were the subject of this analysis. In Puerto Rico, elementary and middle school education is a profession mostly undertaken by women: 91% of the experimental group and 79% of the control group are women. Seventy-one percent (71%) of the experimental group's and 59% of the control group's ages range between 20 and 45 years old. Table 1 summarizes the characteristics of the teachers in the experimental group and the control group that have participated in the AMCT project from 2008 to 2011.

Table 1. Demographic Characteristics of Teachers by Group and Year

Year	Participants (E/C)	Participants' Gender		Age Groups			
		Female (E/C)	Male (E/C)	20-25 (E/C)	26-35 (E/C)	36-45 (E/C)	46-55 (E/C)
2008-2009	141 / 29	125 / 22	16 / 7	22 / 2	37 / 8	40 / 7	35 / 10
2009-2010	133 / 25	123 / 20	10 / 5	25 / 1	35 / 5	34 / 12	34 / 7
2010-2011	138 / 24	128 / 21	10 / 3	26 / 0	38 / 5	33 / 6	35 / 12
Total	**412 / 78**	**376 / 62**	**36 / 16**	**73 / 3**	**110 / 18**	**107 / 25**	**104 / 29**
%	**100 / 100**	**91 / 79**	**9 / 21**	**18 / 4**	**27 / 23**	**26 / 32**	**25 / 37**

E: Participants in the experimental group   C: Participants in the control group

The distribution of the participants according to the subjects they teach, mathematics or science, has been similar during the three years analyzed. The distribution of the sample according to grade level indicates that 51% of the AMCT participants were elementary school teachers (Table 2). The distribution of the participants in the experimental and control groups according to the years of work experience dedicated to education is presented in Figure 2. As can be observed, 35% of the participants in the experimental group and 30% of those in the control group reported having six or more years of teaching experience. In Table 3, the sample of teachers was distributed according to the highest academic level completed; 51.2% of the teachers in the experimental group have a bachelor's degree while 61% of the teachers in the control group have a master's degree. During the period from 2010-2011, more than 50% of the participating teachers attended between 61 and 90 hours of professional development training (160 hours per year were offered by the AMCT project). The attendance of the participants can be observed in Figure 3.

Table 2. Distribution of Participants by Group, Subject, Level, and Year

Year	Participants by Subject				Participants' Grade Level
	Science		Mathematics		Elementary*
	E	C	E	C	E
2008-2009	62	13	79	16	70
2009-2010	53	10	80	15	70
2010-2011	56	9	82	15	72
Total	**171**	**32**	**241**	**46**	**212**
%	**42**	**41**	**58**	**59**	**51**

E: Participants in the experimental group C: Participants in the control group
* Elementary level comprises grades 4^{th} through 6^{th}

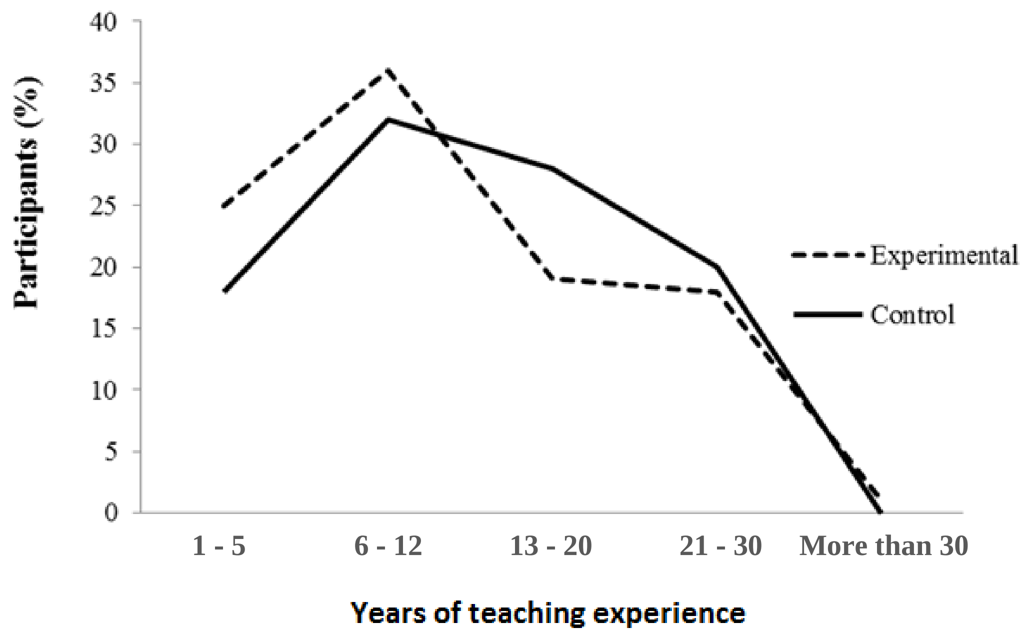

Figure 2. Participants by Group and Years of Teaching Experience

Table 3. Distribution of Academic Degree by Group and Year

Year	Academic Degree			
	PhD (E / C)	**Master (E / C)**	**Bachelor (E / C)**	**Associate (E / C)**
2008-2009	0 / 0	61 / 19	75 / 10	5 / 0
2009-2010	1 / 0	59 / 15	71 / 10	2 / 0
2010-2011	1 / 1	70 / 13	65 / 10	2 / 0
Total	**2 / 1**	**190 / 47**	**211 / 30**	**9 / 0**
%	**0.5 / 1.2**	**46.1/ 61**	**51.2 / 38**	**2.2/ 0**

E: Participants in the experimental group C: Participants in the control group

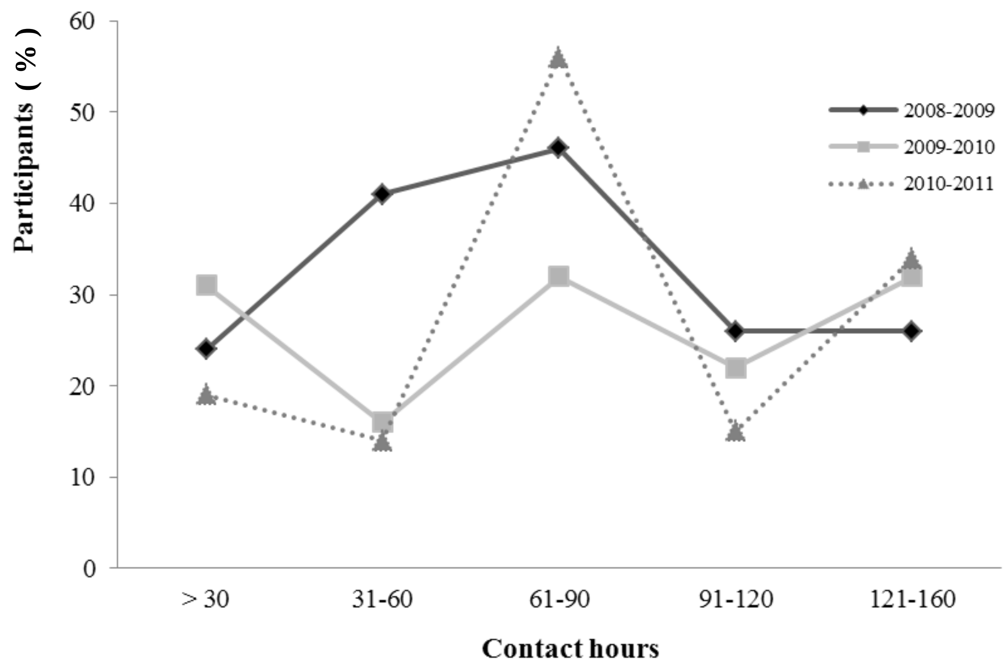

Figure 3. Participating Teachers' Contact Hours by Year

RESULTS

In order to determine the impact of the professional development workshops on elementary school teachers, a test was administered prior to and after the workshops concluded. The results indicated that, in the three years analyzed, the teachers in the experimental group who taught at the elementary level, those who taught science, as well as, those who taught mathematics, improved their performance in the post-tests. The paired t-test shows highly significant *p* values, below 0.017 in the three years analyzed (Table 4). Similar tests were applied to the teachers in the control group showing no statistically significant differences between the pre- and post-tests (Table 5).

Upon comparing the performance in the PPAA of students of teachers in the experimental group with the performance of students of teachers in the control group, the results were: i) in 2008-2009, there were no significant differences between the experimental group and the control group (t=1.61, p=0.055); ii) in 2009-2010, the control group had a better performance (t=3.67, p<0.01); iii) in 2010-2011, the experimental group performed better (t=1.7, p=0.04). These results showed that the results of the PPAA during the years analyzed were erratic. One possible explanation is that the topics covered during an academic year by the AMCT project may or not correspond to the topics evaluated in said test.

Table 4. Participating Teachers Test Results by Elementary Level, Subject, and Year

Year	Experimental Group Results					
	Elementary Science			Elementary Mathematics		
	Pre-test	Post-test	Gain / p-value	Pre-test	Post-test	Gain / p-value
2008-2009	29.36	39.00	9.64 / 0.005	28.9	52.59	23.69 / 0.001
2009-2010	102.8	118.0	5.2 / 0.003	114.8	129.1	14.3 / 0.001
2010-2011	92.4	99.3	6.9 / 0.017	119	135.6	16.6 / 0.0035

Table 5. Control Group Test Results by Elementary Level, Subject, and Year

Year	Control Group Results					
	Elementary Science			Elementary Mathematics		
	Pre-test	Post-test	Gain / p-value	Pre-test	Post-test	Gain / p-value
2008-2009	31.25	29.75	- 2.0 / NA	50.16	51.83	1.67 / 0.29
2009-2010	98.3	106.1	7.8 / 0.083	125.8	120.2	5.6 / 0.18
2010-2011	90.9	84.6	-6.3 / NA	132.7	134.4	1.7 / 0.37

DISCUSSION

In order to verify the effects produced by the AMCT Professional Development Model (MDP-AMCT), the experimental design contemplated the use of two groups, an experimental group and a control group, to which the same pre- and post-test was administered. The pre-test also represented a point of reference in order to discern the teachers' initial knowledge, adjust the content of the professional development program, and schedule the pertinent workshops according to the needs of the majority of the participants. This research provided statistical evidence to support the claim that the experimental group at the elementary level obtained better results than the control group, which can be attributed to the MDP-AMCT professional development program.

Many articles have been written in the United States, as well as, in other parts of the world, with the purpose of determining the characteristics of an efficient professional development program. A great number of researchers agree on that teachers' need to improve their mastering of content knowledge; consequently, these researchers developed their work based on quasi-experimental designs, with the application of tests before and after the intervention of professional development (Weiss et al., 2001, Corcoran and Foley, 2003; Guskey, 2003; Supovitz, 2003; Gerber et al., 2011). The results indicated that, in all cases, the teachers' scores reflect improved results in the post-tests with *p* values oscillating between 0.035 and 0.042 in science, and between 0.0001 and 0.0008 in mathematics. In regards to this, research conducted by Desimone et al. (2002 and 2003) determined that professional development that focuses on increasing the teachers' content knowledge improved their pedagogical practices. However, these researches were based on self-reporting presented by the teachers and not on the direct observation of the teachers' practices.

Although the teachers' gains in the post-tests can be an indication of the effectiveness of the professional development models, many researchers prefer to observe results based on the gains achieved by the students in standardized tests, such as the Northwest Evaluation Association (NWEA), the Middle Grades Integrated Process Skill Test (MIPT), the Iowa Test of Basic Skills (ITBS), or, as in the case of this study, the PPAA. Similarly to the results obtained in this research, other researchers attempting to link professional development with students' learning achievements have produced mixed results. For example, Yoon et al. (2007) examined nine investigations and found that students whose teachers had received an average of 49 hours of professional development performed better in the standardized tests than those students whose teachers had never attended a professional development program. Another study designed by Garet et al. (2008) determined that the achievements reached by teachers in professional development programs did not necessarily translate into achievements on the part of the students, and many of the abilities developed were managed only for a short term and, as a result, did not have a lasting effect.

Teachers need to know how to teach (pedagogical component), as well as, what to teach (academic component), especially when the "information society" demands an increase in the amount of citizens with high levels of education, who are able to keep up with the current technological developments and to propel to the future innovations in science and technology (Imbernon et al., 1999). Hence, the importance of professional development programs for teachers is evident, as a strategy to face the challenges of modern society (Castells, 2000; Lieberman and Miller, 2001). In response to this demand, the MDP-AMCT designs and offers professional development workshops, providing a more profound study of fundamental topics, with the assistance of selected faculty who, by sharing their knowledge and strategies, stimulates teachers to improve their teaching practices.

Considering that previous professional development programs that the teachers have received were rarely directed toward putting into practice what was learned (Lüdke, 2006), the core of the MDP-AMCT model consists of the development of workshops in which approximately 60% of the time is dedicated to practical application. This percentage has been determined by empirical experience, as a result of the work between the UT and the teachers, and responds to the amount of new information that the participants are able to process in a session of intense workshops, of no less than 7 hours per day.

Another relevant aspect of the MDP-AMCT is the construction of knowledge based on the solution of problems from everyday life. In order to implement this strategy, the teachers' previously held concepts are taken into account. In the workshops, the teachers establish relationships between the information they possessed and the new information available. Moreover, they visualize new relationships between theory and practice. Wenglinski (2000) stated that a good professional development program for teachers should acknowledge the characteristics of the teacher population that is the object of the study. According to the author, knowing the gender, age, years of teaching experience, degree of education, as well as, the population that they teach, are some of the aspects that help to provide a more accurate and contextualized understanding regarding the characteristics and professional development needs of teachers. As was observed in Table 1, women comprise 91% of the population that receives the AMCT professional development workshops. Information from different countries confirms that, except at technical schools and universities, teaching is predominantly a woman's profession. Women represent almost all the preschool teachers, three fourths of the elementary school teachers, and half of the high school teachers (Bonder 1994; Valdivieso 2010). In the same Table 1, it was determined that 71% of the AMCT's participating teachers are between 20 and 45 years old. Similar results have been reported by Bernard (2010). These researchers analyzed demographic variables of the teaching population in Puerto Rico, finding that 60% of the public school teachers are within this age range. This is an important variable to consider in professional development programs because, since the methodological strategies that a teacher uses are directly related to how he or she was taught (Loucks-Horsley and Stiles, 2001), it is a powerful predictive of the teaching-learning styles of the teachers.

In Figure 2, it was observed that most teachers comprising the MDP-AMCT have less than 12 years teaching experience. Programs like the AMCT have greater acceptance among teachers, especially among those with little work experience. This is consistent with other research where it is mentioned that, while newly graduated teachers have the basic initial training, this does not necessarily enable them to manage themselves sufficiently well in the work force (Darling-Hammond, 2000; Vezub, 2007). Blanco et al. (2008) adds that newly graduated teachers do not feel well prepared. Bullough (2000) maintains that newly graduated teachers' initial contact with their teaching practice will quickly lead them to adopt the abiding school structures and routines. Hence, the need of a professional development program, such as the one designed by the AMCT, where the expertise and knowledge of the most experienced teachers is available, to help reduce the perpetual gap between knowledge and practice. In the aforementioned Figure 2, it can also be surmised that the teaching practice implies a lifelong learning process. Regardless of their years of experience, teachers come to training programs not because they consider it a right, but because they consider it a requisite of the profession; this is so because a distinguishing characteristic of the teaching practice is that it involves a specialized activity in which the problems to be solved are constantly changing. In this sense, the content of the teacher's practice changes with time, as occurs with the objects of study in the sciences (Avalos, 2006). Aligned with this rationale is the needs assessment, where teachers are asked to determine the nature of the topics they wish to be addressed in each academic cycle.

A criterion for being selected as a teacher by the DEPR is having received a formal education in teaching and possessing the corresponding certification in the subject one wishes to teach. Not all teachers fit the expected profile since a percentage of the participating teachers at the AMCT, albeit a small one (2.2%), only possesses an associate degree. In Table 3, it is noted that most of the teachers in the experimental group have completed a bachelor's degree (51.2%) and a high percentage of them possesses a master's degree (46.1%). Given this seemingly solid academic background, it would seem that the need for professional development is minor. However, it has been detected that, besides content matters, teachers need to improve basic skills in communication, critical thinking, and technological literacy; qualities which they, surely, can improve when they participate in professional development programs (Garet et al., 2001; Hiebert et al., 2002; Miranda, 2003).

During years 2008-2009 and 2010-2011, nearly 50% or more of the teachers attended between 61 to 90 contact hours of training (Figure 3), despite the fact that the training workshops take place during the summer (during the school recess) and on Saturdays (during the academic year). Data provided by Darling-Hammond (1999) indicates that the United States is among the developed countries that provide the least amount of time to their teachers to be dedicated to professional development, since schools and parents expect the teacher to be in his or her classroom at all times. This information contrasts with the data reported for European and Asian countries, where teachers spend between 15 and 20 hours a week in the classroom and dedicate the rest of the time to preparing lessons, talking to parents, advising students, conducting research projects or attending professional development programs.

CONCLUSION

The attainment of quality education is a challenge in which a myriad of variables converge. The AMCT recognizes that one of the essential variables is the teachers, and how they commit to transferring to the classroom the concepts learned in professional development activities. In light of the results produced by the implementation of the MDP-AMCT, there is evidence to support the claim that the AMCT model for professional development is effective and pertinent to the population of elementary school teachers of Puerto Rico. The evidence shows that detailed planning of professional development activities, to the point of suggesting the use of active learning methodologies, allocating time to practice (more than 50% of a workshop), and using a variety of strategies, tools and technology, produce statistically significant results in the teachers' mastering of content knowledge in mathematics and sciences.

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