PARENTAL ENGAGEMENT IN MODELING-BASED LEARNING IN MATHEMATICS: AN INVESTIGATION OF TEACHERS' AND PARENTS' BELIEFS

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As part of a larger project aimed at promoting mathematical modeling as an inquiry based approach to mathematics and science, this study aimed: (a) to describe teachers' and parents' beliefs about inquiry-based mathematical modeling and parental engagement and (b) to explore the impact of a modeling-based learning environment on enhancing parental engagement. The research involved three sixth-grade teachers and 32 parents from one elementary school. Teachers reported positive beliefs on parental engagement and parents' potential positive role in implementing innovative problem solving activities. Parents expressed strong beliefs on their engagement and welcomed the modeling approach. Implications for parental engagement in mathematics learning and further research are discussed.

Keywords: Parental engagement, teacher beliefs, modeling, interdisciplinary problems, model eliciting activities.

INTRODUCTION

The study argues for an inquiry-based approach in the teaching and learning (IBL) of mathematics, one that is based on a models and modeling perspective (Lesh & Doerr, 2003). A modeling inquiry-based approach can serve as an appropriate means for bridging complex real world problem solving with schools mathematics (English & Mousoulides, 2011). While complexity gradually appears in all forms of the society, the economy, and the education and the new technologies have been integrated in all forms of work, new forms of mathematical and scientific thinking are needed (English & Sriraman, 2010). With this into account, researchers and educational policy makers highlight the need to promote an inquiry-based approach in mathematics and science, one that enhances students' abilities in designing experiments, predicting complex systems, manipulating variables, working in teams, and effectively communicating with others (Lesh & Zawojewski, 2007; Mousoulides, Sriraman, & Lesh, 2008).

Integrating such innovative approaches in mathematics and science is not a straightforward process. It conflicts with various factors, including national curriculum requirements, the need for more time and resources, teachers' beliefs and practices, and parents' beliefs and attitudes towards such innovations. The significance of parents' role in mathematics education has been documented in a number of studies (see Epstein et al., 2009). Parental engagement has been documented as a positive influence on children's achievement, attitudes, and behaviour, regardless of cultural background, ethnicity, and socioeconomic status. From the teacher perspective, teachers have not only to realise that parents play an integral role in their children's education and they should act as full partners with teachers, but also to find appropriate methods to involve them, especially when it comes to use innovative methods, like mathematical modeling, in the mathematics classroom (Deslandes & Bertrand, 2005).

There is a lack of studies focusing their research agenda on the role parents might play during the implementation of innovations in mathematics teaching and learning, and especially in mathematical modeling. To this end, the present study focuses on designing a teaching experiment on mathematical modeling, one that also involves parents, in an attempt to create an environment for engaging parents and creating a relationship between teachers and parents. The study further explores teachers' and parents' beliefs while working on a real world modeling activity, in further improving parental engagement and communication between parents and school.

THEORETICAL FRAMEWORK

The theoretical framework review focuses on two strands: (a) instructional interventions to promote mathematical inquiry through a modeling perspective, and (b) parental engagement in the mathematics and science classrooms with an emphasis on teachers' and parents' beliefs.

A Modeling Perspective in Inquiry Based Learning in Mathematics and Science

In successfully working with complex systems in elementary school, students need to develop new abilities for conceptualization, collaboration, and communication (Kaiser & Sriraman, 2006; English & Sriraman, 2010). In achieving these abilities, a number of researchers propose the use of an inquiry-based approach in the teaching of mathematics, one that builds on future-oriented, interdisciplinary problem-solving experiences that mirror the modeling principles (Haines, Galbraith, Blum, & Khan, 2007; English & Mousoulides, 2011). Specifically, the present study proposes introducing Engineering Model-Eliciting Activities (EngMEAs) within the mathematics and science curriculum; realistic, client-driven problems based on the theoretical framework of models and modeling (Haines, et al., 2007; Lesh & Doerr, 2003).

Engineering Model Eliciting Activities (EngMEAs) has been in the focus of our work for the last few years (see Mousoulides, Sriraman, & Lesh, 2008; English & Mousoulides, 2011). EngMEAs provides an enriched modeling approach by offering students opportunities to repeatedly express, test, and refine or revise their current ways of thinking as they endeavor to create a structurally significant product for solving a complex engineering problem (Mousoulides et al., 2008). The development of the models necessary to solve the EngMEAs has been described by Lesh and Zawojewski (2007) in terms of four key, iterative activities, namely: (a) Understanding the context of the problem and the system to be modelled, (b) Expressing / testing / revising a working model, (c) Evaluating the model under conditions of its intended application, and (d) Documenting the model throughout the development process. The cyclic process is repeated until the model or design meets the constraints specified by the problem. The content students experience differs significantly from what is taught traditionally in the mathematics and science curriculum for their respective grade level. For instance, in the modeling activity presented here, the types of quantities needed in this problem include accumulations, frequencies, and ranks, while the required operations include sorting, selecting, quantifying, and transforming data sets (Lesh & Zawojewski, 2007).

Parental Engagement

Parental engagement has been documented as a positive influence on children's achievement in mathematics and science, regardless of cultural background, ethnicity, and socioeconomic status (Epstein et al., 2009). A significant body of research provides solid support for building parental engagement, by reporting a constant correlation between increase in parental engagement and increase in student achievement and overall success of the student, socially, emotionally and academically (Cutler, 2000; Epstein et al., 2009).

Active parental engagement, however, is quite difficult to be maintained. Therefore, programs of parental engagement should be carefully designed and implemented, taking into account all related variables and barriers (Musti-Rao & Cartledge, 2004). Musti-Rao and Cartledge (2004) argue that schools should be less concerned about parental engagement in schools, and more concerned about determining what role parents can play so that parents may most productively involve themselves in their children's education. They suggested inviting parents' experiences in science, technology, and engineering into discussion, and including parental engagement strategies in teacher professional development courses. They also proposed a number of strategies for engaging parents, such as mathematic and science fairs, community involvement utilizing science and engineering experts, and the establishment of a clear communication between teachers and parents, in an attempt to bridge teachers' and parents' beliefs and expectations (Musti-Rao & Cartledge, 2004).

Epstein and Van Voorhis (2001) have identified that one barrier to creating effective relationships between the home and school may be teacher beliefs. They reported that teacher beliefs could impact the relationship between parents and teachers. Teachers enter the teaching profession with personal (positive and negative) beliefs about parental engagement that may not be addressed until they interact with the families of their students and that might result in not involving parents and other community members in the classroom. Teachers who believe that parental engagement could contribute to positive learning outcomes for students are more likely than those with negative views to be involved in parental engagement practices.

Teachers' beliefs on the significance of parental engagement on students' achievement might also impact parental engagement (Epstein, et al., 2009). The interpretation of parent involvement is dependent on the individual beliefs and expectations of each person concerned. Often teachers might have a negative situation or encounter with a parent that can lead to stereotypes regarding the relationship between a teacher and parents. Teachers may also view parents as adversaries when parents become adamant about what they want for their child (Cutler, 2000; Epstein, et al., 2009).

THE PRESENT STUDY

The Purpose of the Study

The aim of this study was to explore teachers' and parents' beliefs on parental engagement in mathematics teaching, with a focus on implementing an engineering based modeling activity. The study investigated teachers' and parents' beliefs on parental engagement during the implementation of a modeling activity, and examined the impact of Twitter®, a contemporary technological tool, as a means to facilitate: (a) parental engagement and (b) the interactions between the students, the teacher, and the parents.

Participants and Procedures

The larger research design includes: (a) inquiry-based mathematics and science instruction, (b) integration of engineering model-eliciting activities as a part of the mathematics and science instruction, and (c) examination of various forms of parental engagement, including workshop participation, participation in classroom activities, and communication with teachers. During their participation in *PRIMAS*, a longitudinal four-year project on Inquiry and Modeling Based Learning in Mathematics and Science, 62 elementary and secondary school teachers in Cyprus participated in workshops on inquiry- and modeling-based teaching and learning in mathematics and science. During workshops teachers were provided with appropriate student and teacher materials for integrating modeling in their day-to-day practices.

This study follows three of these teachers who implemented modeling activities in their classrooms. The teachers were from one public K-6 elementary school in the urban area of Nicosia, the capital of Cyprus. One teacher used to teach both mathematics and science in one class, while the other two teachers used to teach mathematics and science respectively in a second class in the same school. The two classes (22 and 19 eleven-year old students), their parents and the three teachers worked on the *Water Shortage* activity, during the second year of the *PRIMAS* project.

Prior implementing modeling activities in their classrooms, the three teachers attended three five-hour workshops on afternoon or Saturday sessions. An additional workshop on the use of Twitter® and on parental engagement good practices, also took place. In one of the first three workshops and in the additional workshop, one parent from each student family was also invited to participate. Twenty-eight out of the 41 parents accepted the invitation and participated in the two workshops, which were conducted by *PRIMAS* personnel.

The three workshops provided some insights on inquiry modeling based mathematics instruction and on parental engagement in mathematics. An introduction to the *Water Shortage* activity took place in the last workshop. During the second part of the workshop teachers and parents were introduced to Twitter® and on the possibilities it provided for the mathematics classroom. Accounts were also created for all parents and teachers. Twitter® is an online technological tool which can break down the rigid classroom schedule barriers and allow teachers, students, and parents to collaborate. Teachers were actively engaged during the workshops, as they shared questions, suggestions, and examples from their own practices and beliefs.

The Implementation of the Water Shortage activity

The *Water Shortage* model eliciting activity entailed: (a) a warm-up task comprising a mathematically rich newspaper article, designed to familiarize the students with the context of the modeling activity, (b) "readiness" questions to be answered about the article, and (c) the problem to be solved, including tables of data (see Table 1). The activity asked students to assist the local authorities in finding the best country for supplying Cyprus with water.

The problem was implemented by the teachers and the author. Working in groups of three to four, the students spent five 40-minute sessions on the activity. During the first two sessions the students worked on the newspaper article and the readiness questions and familiarized themselves with Google Earth and spreadsheet software. In group discussions students identified the significance of the problem and submitted a relevant tweet (one Twitter® account was created for each group of students). Twelve parents commented on students' tweets, by emphasizing that water shortage was among the country's most important problems. Some parents further provided additional sources of information. During the second session students reviewed their parents' comments and suggestions that were provided through Twitter®.

Country	Water Supply per week (m^3)	Water Price (m^3)	Tanker Capacity (m^3)	Tanker Oil cost per 100 km	Port Facilities for Tankers
Egypt	3 000 000	€ 4.00	30 000	€ 20 000	Average
Greece	4 000 000	€ 2.00	50 000	€ 25 000	Very Good
Lebanon	2 000 000	€ 5.20	30 000	€ 20 000	Average
Syria	3 000 000	€ 5.00	30 000	€ 20 000	Good

Table 1: The provided data for the four countries

In the next two sessions students worked on solving the problem. They developed a number of appropriate models for solving the problem, and shared these problems with their teachers and parents. During model development students were prompted by teachers to share their ideas with their parents. To facilitate model sharing, a public Wiki was created, in which students could easily upload their files. Student then shared the links to their models with their parents, using appropriate tweets. Twenty-six out of the 28 parents that participated in the implementation of the activity followed their children's tweets and provided feedback and suggestions to their models. In total, during model development parents and teachers send more than eighty tweets. However, a significant number of these tweets just encouraged students to continue the good work, while only a few tweets actually provided constructive feedback and identified weaknesses in students' models. During the last session students wrote letters to local authorities (as indicated in the activity), explaining and documenting their models/solutions. Finally, a class focused on the key mathematical ideas and relationships students had generated.

Interviews

All three teachers (two females and one male) and six parents (three females and three males), selected randomly out of the 28 parents that were involved in the study, participated in individual semi-structured interviews. Three areas of interest investigated: (a) participant's (teacher or parent) beliefs on mathematical modeling and the implementation of the EngMEA, (b) parental engagement, and (c) their experiences during the EngMEA implementation with regard to collaboration and communication. The interviews were either conducted right after school or in the early evening. Each interview lasted between 45 to 60 minutes and all interviews were audio recorded and later transcribed. Data from the semi-structured interviews were summarized through sequential analysis. A grounded theory approach was adopted. Themes were identified and clustered through axial coding, which was conducted in AtlasTI software.

RESULTS

Results are based on the qualitative analysis of interviews. The results are presented in terms of the themes that arose from the sequential analysis of teachers' beliefs and practices and parents' beliefs, with regard to mathematical modeling and parental engagement.

Teachers' beliefs

Teachers' responses could be summarized in three broad categories: student cognitive goals and teaching effectiveness, student affective goals, and constrains of using a modeling based approach. Teachers had positive beliefs on the impact of inquiry-modeling-based approaches in students' cognitive gains. "This open approach get the children to think critically, set their own questions to reach the solution, and become independent in solving quite complex problems", a teacher commented. A second teacher added: "I really enjoy teaching [in a setting like this]. This is the only way to teach higher order thinking skills and problem solving skills." Teachers were also emphatic in commenting on the affective goals of using a modeling approach. They claimed that such approaches could help students develop "a love for mathematics and science". A teacher reported: "Some students rarely participate in more traditional lessons. Now, they repeatedly said that they like those activities [Primas modeling] very much". Teachers were also concerned with the constrains related to mathematical modeling, and especially with time: "There is so little time for extra curriculum activities … modeling activities require a lot of time and efforts; how can you complete, even a part of it [activity], in 45 minutes?" Another dimension of teachers' comments was the use of Twitter®: "At the beginning I was sceptical … but then I was impressed by parents' involvement and how it [involvement] benefited students' work … I will continue using it [Twitter®] in my lessons, when possible. Well, this is obvious from the number of my tweets!" Another teacher added: "I love it! It is great when students and parents are involved. I had the impression that the lesson was on going; 24 hours a day. This is teaching!"

Teachers explicitly underlined the importance of parental active engagement. One commented: "Parents have good ideas to discuss with their children … there was a fruitful interaction between parents and children at home … we had [in class] almost everyday discussions … based on the interactions with their parents at home". Another teacher added: "Workshops helped parents to be involved and to realise that everyone was valued and that their role was crucial to the success of the activity. But of course that was not easy; only half of parents participated, right? And I am not sure how many of them spent much time at home finding resources and providing accurate feedback to students' solutions". Another teacher shared the same belief, that for fruitful parental engagement careful planning and organization were needed.

Another theme that arose during teachers' interviews was the impact of parental engagement in students' growth and involvement. Teachers reported that the activity could not be the same without parental engagement, which was clearly positive and constructive. Teachers also proposed that: "This approach was a good example and we clearly need more good examples in engaging parents in mathematics, which, I believe, is beneficial for students' achievement". Another teacher pointed: "Is there a better way to engage parents both at school and home? I do not think so. And I am confident that such appropriate engagement will help children improving their grades and attitudes towards mathematics and science".

Parents' beliefs

Parents were enthusiast and welcomed the modeling activity. They found the activity interesting and challenging not only for their children, but also for them. A parent, who was actively involved throughout the activity, commented: "I have been always good in maths … but the activity opened new horizons for me … I frequently visited the Wiki and commented on students' tweets. It was great!" Another parent said: "Such activities will help our children to develop important skills, needed beyond school … I am very happy that we use such approaches in our school". Although interesting, activity was also found to be difficult. A parent mentioned: "Well, I could not know for sure that the solution was correct, and that was somehow annoying. Perhaps more guidance could help".

All six parents explicitly commented on the partnership climate that was generated. "I had the feeling that we [parents and teachers] were equal partners", one parent commented. She said: "It was far better than sitting at the back [in the classroom] and watching a lesson. We were actively involved and had constant communication with our children and the teacher. It was really good". Another parent added: "I was following teacher's comments and suggestions and I tried to build on these, by discussing at home with my child the problem … Yes, it helped our communication".

To improve parental engagement in schools, parents seemed to unanimously agree that good communication and active engagement was the key. Parents suggested that a variety of engagement strategies could assist all parents to be engaged. One parent noted: "Attending lessons is not bad, but it cannot be the only way of engaging. I enjoyed the two workshops very much, although I had to leave work early. We should have workshops more often". Another parent mentioned a strategy currently employed in the school: "Last year children had to work on two projects. Those projects were not focused on maths, but required some maths and science. I would like to see more projects like these, in which I can work with my children at home".

Although quite satisfied with the situation, parents explicitly mentioned that it was expected from school and teachers to do more, in order to enhance their (parental) engagement. It was revealed that school's climate had a significant impact on the overall effectiveness of parental engagement. From parents' responses a number of factors were uncovered, showing what schools should do in order to encourage and enhance parental engagement. A parent mentioned that schools should promote parental engagement using various methods, and not only expect from parents to be engaged. She said: "Schools and teachers must actively seek and promote the parental engagement. Not all parents are engaged by default". The importance to implement activities and initiatives that engage students was also mentioned by two parents. One of them mentioned: "Such activities [referred to the Water Shortage activity] are one of the best ways to engage parents, because their children are also engaged. When children are excited and discuss their mathematics work, parents are more inclined to be engaged in mathematics".

DISCUSSION

The purpose of this study was to examine teachers' and parents' beliefs on parental engagement in mathematics teaching and learning, with a focus on modeling as a problem based approach. The results supported the expectation that such an approach is likely to positively affect teachers-parents' partnership and possibly student outcomes (Epstein, et al., 2009). The environment generated, provided opportunities for parents and teachers to establish appropriate communication and collaboration venues, which resulted in improved students' models (English & Mousoulides, 2011). The modeling activity implementation as a means to engage parents in school mathematics could be considered successful; teachers were increasingly refocusing their teaching to incorporate and respond to students' ideas and needs, and parents were responding positively to their new roles as engaging partners in their children learning. With regard to Twitter®, results revealed that Twitter® assisted in generating a safe, shared knowledge space in which teachers and parents gained insights into students' learning, helped students to develop better solutions, and provided more opportunities for reflection and discussion.

During interviews, teachers expressed positive beliefs towards modeling, although they identified challenges and demands in their knowledge and other institutional constrains (Epstein et al., 2009). Using a modeling perspective in mathematics and science teaching, teachers have opportunities to adopt a more interdisciplinary, real world based approach, in which students' role is central and parents' impact have the potential to be very positive. Clearly, teachers' beliefs are important in determining parental engagement in their classroom. Positive teachers' beliefs and attitudes are needed to maintain the best possible parental engagement and to build mutual understandings and collaboration for the improvement of mathematics and science teaching (Cutler, 2000).

Interviews with parents revealed that they hold positive beliefs and attitudes towards innovations in the mathematics and science classrooms, like a models and modeling perspective. Parents also reported significant positive beliefs towards their engagement in schools, indicated at the same time the necessity for the school and teachers to take actions. Parents identified that a clear and constant bidirectional communication venue is urgently needed and they stressed that the modeling environment could be a successful method to achieve this goal (Epstein & Van Voorhis, 2001). Parents also commented that many schools might focus their partnership activities on forms of engagement, like classrooms observations and formal meetings with teachers, although these were not perceived to be the most effective form of engagement activities in mathematics and science.

The findings from this study suggest a need for researchers to expand our definitions of parental engagement in mathematics and science, beyond traditional ideas of school and classroom norms, to include a dimension related to active parental engagement and technology rich modeling environments. Despite its limitations, this study provides new insights into the importance of modeling related parental engagement practices in mathematics and science teaching. It suggests that teachers and schools that have positive beliefs towards parental engagement and facilitate the use of inquiry- modeling-based approaches are more likely to have positive active parental engagement and probably better students' learning results. Unquestionably, students need high-quality instruction to improve mathematics learning. However, if schools, teachers, and parents work together in creating appropriate, collaborative environments, they are more likely to see higher students' learning outcomes.

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