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Professional Development Through Technology-Integrated Problem Solving: From InterMath to T-Math

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The ability to integrate technology into instruction is among the characteristics of a competent mathematics teacher. Research indicates that the vast majority of teachers in Turkey believe the use of computers in education is important, but have limited knowledge and experience on how to use technology in their instruction. This paper describes the T-Math project (http://www.t-math.org), which adapted the InterMath (http://intermath.coe.uga.edu) knowledge base for mathematics teachers in the United States and developed relevant resources for professional development of Turkish mathematics teachers to guide them in constructing useful strategies for their students while developing as expert mathematics teachers. Examples of mathematical investigations adopted and developed in the T-Math project are presented as well as the anticipated challenges and subsequent strategies for integration.

Schools throughout the world recognize the need, but still struggle, to integrate technology into mathematics education. The development of teachers who can flexibly adapt technology into their teaching of mathematics is crucial for technology to have a positive impact on student performance. In order to develop teachers' flexibility in selecting instructional alternatives, technology should be integrated as a central aspect of teacher education programs (Sudzina, 1993).

The InterMath project promotes such an approach with an Internet-based (http://intermath.coe.uga.edu) professional development effort with the goal of designing and implementing a series of workshops and ongoing support programs that feature contemporary applications of technology and mathematics pedagogy in the middle-grades. It focuses on building teachers' mathematical content knowledge through mathematical investigations that are supported by technology. As a result of working on the InterMath project and seeing firsthand how teachers become better mathematics educators through completing technology-rich mathematical investigations, the first author of this paper sought to adapt InterMath for professional development of mathematics teachers in Turkey. An international extension of the InterMath project was a natural consequence, because e-mail communications and web hits suggested that InterMath's knowledge base and resources were already being used widely, both in the United States of America (USA) and internationally.

Before delving further into T-Math, we will look at some of the most evident similarities and differences between the educational systems in the USA and Turkey to better understand the adaptation of T-Math. Unlike the USA, the Turkish school system and curricula are centralized. All educational institutions are under the control of the Turkish Ministry of National Education (MNE). All important policy and administrative decisions, including the appointment of teachers and administrators, the selection of textbooks, the selection of subjects for the curriculum, and the management of in-service teacher education, are made by the MNE. A national mathematics curriculum is

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followed in every school and supervisors assigned by the MNE control all educational activities in schools.

In both Turkey and the USA, pre-service mathematics teachers are required to have an undergraduate degree. Unlike the United States, Turkey has a unified system of higher education under the umbrella of the Higher Education Council of Turkey, which is responsible for the planning, coordination, and supervision of higher education. Teacher education programs in different universities usually require the coursework suggested by the Higher Education Council of Turkey (Yükseköğretim Kurumu, 1998).

As for similarities between the educational systems, high stakes tests are an important issue in both Turkey and the USA. In Turkey, nationwide examinations for university and high school entrance are very important factors that influence what mathematics teachers do in the classrooms. The pressure these exams put on students, parents, and teachers easily changes the perception of "good teaching" in schools. Teaching to the test and solving as many multiple-choice questions as possible are highly valued teaching behaviors by most of the stakeholders. This results in appreciation of such student behaviors in mathematics classes as solving mathematics questions as quickly as possible, or remembering the rules that will help them reach quick solutions. In Turkey, due to the centralized education system, such tests have an extensive nationwide impact in almost all schools.

Similar to the impacts of *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000) in reforming mathematics education in the USA, the development of new elementary and secondary school mathematics curricula in Turkey supported the idea of adopting InterMath in a Turkish context. The new Turkish curriculum deviates from its precursor, and includes a larger emphasis on learner-centered instruction, problem solving, open-ended explorations, modeling real-life situations, and the use of technology as a tool to support mathematics learning (MNE, 2005a, 2005b). In Turkey, most teachers neither have experienced such instructional approaches as learners nor used them in their teaching. T-Math, like InterMath, aims to address the concern of, "How can teachers teach a mathematics that they never learned, in ways that they never experienced?" (Cohen & Ball, 1990, p. 238).

The Pebbly Road to Technology Integration in Teaching and Learning of Mathematics

Integrating technology into mathematics education is not easy or straightforward, and many barriers exist. Such barriers include the lack of a unified meaning of integration of technology (Willis & Mehlinger, 1996); common teacher perception that technology and its integration would not have a positive impact on student learning (Coffland, 2000; Ertmer, Addison, Lane, Ross, & Woods, 1999; Ertmer & Hruskocy, 1999; Slough & Chamblee, 2000); lack of access to technology and related resources (Hadley & Sheingold, 1993; Manouchehri, 1999; Parr, 1999); lack of training and support in both pre-service and in-service teacher education programs (Ertmer & Hruskocy, 1999; Wetzel, Zambo, & Buss, 1996); and discouraging school environments, curriculum requirements, and heavy teacher course-load (Coffland, 2000; Manouchehri, 1999). In addition, research has shown that teachers teach in the same manner in which they have been taught, making the integration of technology quite difficult, since most teachers have never used technology as a tool for meaningful learning (Ball, 1990; Frank, 1990; Quinn, 1998; Trueblood, 1986; Vannatta & Fordham, 2004).

In Turkey, the integration of technology into school mathematics is moving at a very slow pace compared to other countries in the Organization for Economic Co-operation and Development (2005), and barriers to integration are similar to the ones in the USA. For example, strict curriculum requirements, heavy content of mathematics lessons, and a lack of time to integrate technology into teaching are some of the obstacles that teachers in Turkey have to overcome (Cakiroglu, Cagiltay, Cakiroglu, & Cagiltay, 2001). Further, tests given nationwide at the end of primary education (i.e., High School Entrance Examination) and secondary education (i.e., Student Selection Exam for University Programs) may result in teachers focusing mainly on test preparation, which makes the implementation of technologically-oriented applications and problem solving even more challenging (Kellecioglu, 2002). Many teachers think that using calculators or computers in a mathematics course, before students have mastered basic concepts and skills may limit their cognitive abilities and hinder their computational skills (Fleener, 1995). Nevertheless, other research shows that some teachers do see technology as a tool to develop their students' critical thinking processes (Aloff, 1999; Hembree & Dessart, 1992; Yoder, 2000).

Similar to research in the USA, Turkish studies indicate that a majority of teachers believe the use of computers in education is important, but they have limited knowledge and experience on how to use this technology in their teaching (e.g. Cakiroglu et al., 2001; Cakiroglu & Haser, 2002). Two more major obstacles to the use of technology were the lack of hardware and the lack of teachers' knowledge about using computers (Cakiroglu et al., 2001). Teachers expressed concern about classroom management, including issues such as keeping track of student progress and maintaining control of the lesson (Cakiroglu & Haser, 2002). Further, teachers felt that they had a more "passive" role in lessons when computers were involved and that students were less "serious" when using computers (Cakiroglu & Haser, 2002).

Further, these negative perceptions of computer use (or other technologies such as graphing calculators) in mathematics influence whether technology is integrated into their teaching (Norton, McRobbie, & Cooper, 2000). Other studies on technology use suggest that, even if the computers are available and accessible, mathematics teachers tend not to use computers in their classrooms (Rosen & Weil, 1995).

Need for Professional Development

Providing professional development activities for teachers who do not feel prepared to integrate technology into their instructional practices is crucial for supporting technology integration into mathematics classrooms (Liu, 2001). As part of their education reforms, the MNE has attempted to improve the technological infrastructure (e.g. hardware and Internet access) in Turkish schools and has mandated that teachers must learn how to use technology and integrate it into their teaching (MNE, 2005c). Technology-related teacher competencies defined by the MNE can be seen in the Appendix. Despite these visions, Turkish teachers, like American teachers, typically only learn about the basic uses of technology (e.g., how to operate a computer, how to use Microsoft Office programs, and how to do basic computer programming), rather than learning how to use these technologies to enhance their teaching. External factors, such as poor administrative support, lack of access, limited or no budget, inadequate training on the use of hardware and software, additional work and preparation time that technology may demand from teachers, curriculum requirements, and teachers' insufficient pedagogical content knowledge, also inhibit the implementation of technology-rich activities (Halpin & Kossegi, 1996; Hanks, 2002; Mouza, 2003; Tozoglu & Varank, 2001).

A new vision of school mathematics requires a new vision of teacher education. For a successful implementation of recent curriculum changes in Turkey, there is a need for professional development efforts aiming to influence teachers' beliefs about, improve knowledge of, and increase comfort with technologies that are likely to enhance student learning. As Ball (1990) suggested, professional development can be achieved by having teachers fully immersed in a context of professional development where they can experience the use of technology, first as a learner in investigating problems for improving their understanding of mathematics, and then as a teacher in their actual instructional practices. This would be an effective way of having teachers improve themselves for better implementation of the recent curriculum changes and serve to mediate between reform dictations and classroom implementations. The existing in-service teacher education programs in Turkey are far from addressing such expectations (Cakiroglu et al., 2001). Thus, we are in the process of adapting InterMath into T-Math, which aims to utilize the principles explained above to come up with effective professional development activities for Turkish mathematics teachers.

Goals of the T-Math Project

Derived from InterMath, the overall aim of T-Math is to provide a professional development environment for mathematics teachers. To attain this goal, three principles were considered as a basis for the main activities of T-Math (Figure 1). First, T-Math aims to help teachers experience the use of technology as learners in a problem-solving environment. Second, it facilitates teachers' reflections on their technology-based problem-solving experiences. Third, T-Math provides environments for teachers to collaborate with each other to establish a shared understanding of a technology-rich mathematics learning environment. T-Math aims to address all of these goals through the use of interactive and dynamic technologies. The expectation of T-Math is that teachers will construct their own understanding in a context where collaboration and problem-solving activities engage them in debating ideas, communicating with each other, transferring knowledge, making predictions, and deriving new questions (Cobb, 1994). T-Math employs a mixed approach that combines on-site workshops and

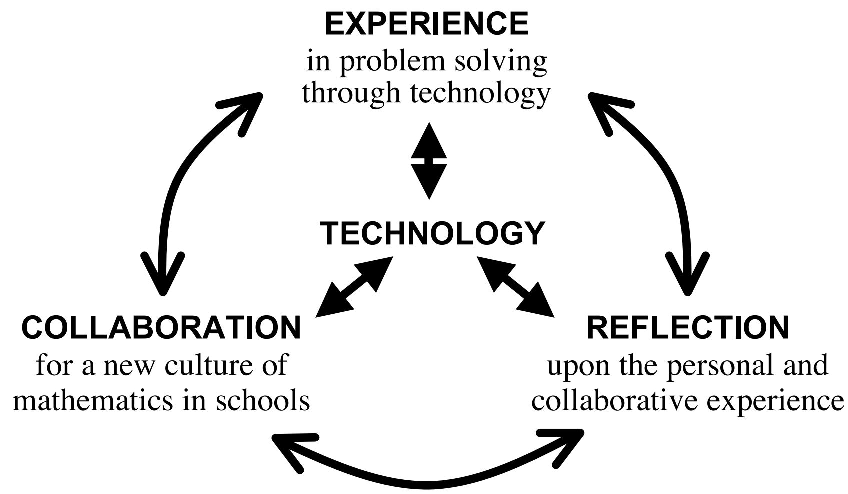

Figure 1. The professional development principles promoted in the T-Math project.

online help systems to facilitate the various activities. These activities are detailed below.

T-Math Investigations

Similar to InterMath, the face-to-face workshops of T-Math provide the opportunity for teachers to explore technology-rich investigations. These investigations allow teachers to develop their mathematics content knowledge, hone their technology skills in the context of doing mathematics, and experience learning mathematics in an investigative, learner-centered manner.

Integrating Technology-Rich Investigations

In addition to the goals described above, the workshops are expected to provide participant teachers with meaningful learning experiences and motivate them to adapt and use T-Math investigations, or integrate technology in general, into their instructions. Teachers in the InterMath workshops made progress in learning how to use technology and provided evidence that they saw technology as being important in their own learning of mathematics (Orrill, Polly, Ledford, Bleich, & Erbas, 2005). However, the majority of the participants believed that their students could not benefit from this use of technology because of logistical barriers or because the students had not yet developed an understanding that watching a demonstration provided a fundamentally different learning experience than engaging with the technology. Considering that InterMath courses had little focus on how a teacher can use the technology in their own classroom, these results were reasonable. In T-Math workshops, we intend to give more emphasis on classroom integration and give support to individual teachers in transferring what they learn into their classrooms. We anticipate that in this way teachers will be more willing to adapt T-Math and use technology for and with their students.

Addressing Beliefs about Technology Use and Integration

There is a growing body of research literature indicating that the beliefs teachers hold directly affect both their perceptions and strategies of teaching and learning interactions in the classroom, and that these, in turn, affect their teaching behaviors (Clark & Peterson, 1986; Clark & Yinger, 1987). Trumbull (1987) has shown, for instance, how teachers' beliefs limit their ability to find solutions to pedagogical problems. While teachers are trying to adopt innovations related to technology-integrated mathematical applications into their classrooms, negative attitudes towards technology impede both their teaching and their students' learning (Hazzan, 2002; Margerum-Leys & Marx, 1999). Teachers' negative beliefs and attitudes towards technology and its integration deriving from their lack of experience and knowledge would be addressed in T-Math workshops, on-line and collaborative colleague support systems, and by providing first-hand experiences related to the learning and teaching of mathematics. As it was found in the Apple Classrooms of Tomorrow research project (Sandholtz, Ringstaff, & Dwyer, 1997), only after teachers had learned the fundamentals of using the technology and had become more comfortable would they drop their negative beliefs, attitudes, and concerns about using technology in the classroom. Without establishing this level of comfort, we cannot expect teachers to adopt or begin to think about how they could use the technology as part of their instruction.

T-Math Resources

The major components of T-Math include open-ended problems and investigations, materials and plans for workshops, and a mathematics dictionary. Technologies such as spreadsheet applications, dynamic geometry software, graphing tools, and graphing calculators are suitable to investigate the open-ended problems in T-Math. In the initial phase, the problems in T-Math were translated and adapted from InterMath, making problems more culturally relevant when necessary.

The T-Math project aims to organize its knowledge base within a user-friendly web-based system so that teachers and other users can easily access organized information without any frustration. To help teachers better organize and select problems, T-Math organizes and presents problems based on their mathematical content. For this purpose, the new mathematics curriculum in Turkish schools serves as a foundation. The curriculum is divided into five domains of mathematics: numbers, geometry, algebra, probability and statistics, and measurement. T-Math problems were categorized according to these five categories and also identified based on (a) the technological tools that may be used to investigate them, (b) the grade level(s) in which these problems could be used, and (c) the objectives of the new mathematics curricula that they correspond to. Investigations in the T-Math project consist mainly of the following four types:

1. Direct translations of the InterMath's investigations into Turkish. In doing these translations, we have considered Turkish educational and cultural contexts so that problem contents match Turkish school mathematics curricula, and problem statements and wording are appropriate for culture and curricula. The following case illustrates how we translated and adopted an InterMath investigation to a T-Math investigation:

> *InterMath version*: The U.S. Postal Service will only mail packages that meet certain size requirements. For cylinder-shaped packages (or "rolls"), the minimum length is 4 inches and the maximum length is 36 inches. There is also a restriction that the length plus two diameters can be no more than 42 inches. (Why do you think they have this restriction?)
>
> a. What are the dimensions of an acceptable box-shaped package that will have the greatest volume?
>
> b. When there must be only two opposite faces that are square, what are the dimensions of an acceptable box-shaped package that will have the greatest volume? The smallest volume?
>
> c. What are the dimensions of an acceptable box-shaped package that will have the greatest volume if each dimension is different?
>
> *T-Math version*: The Turkish Postal Service will only mail packages as letter post that meets certain size requirements. For box-shaped packages, it should have a side width at least 14 cm by 9 cm dimensions. Also, the longest side of the package cannot be longer than 60 cm. There is also a restriction that the sum of the width, length, and depth of the package cannot exceed 90 cm. What are the dimensions of an acceptable box-shaped package that will have the greatest volume?
>
> *Extension*: For cylinder-shaped packages (or "rolls"), the minimum length is 10 cm and the maximum length is 90 cm. There is also a restriction that the length plus two diameters can be no more than 104 cm and no less than 17 cm (why do you think they have this restriction?). What are the dimensions of an acceptable cylinder-shaped package that will have the greatest volume?

In translating the InterMath version to T-Math, the Turkish Postal Service restriction values were obtained to provide a cultural context for students. Also, unlike the InterMath version, the T-Math version extends the problem by adding a second case (i.e., box-shaped package) and by including an additional restriction (the minimum for the length plus two diameters) for the cylinder-shaped packages.

2. Adapted multiple-choice items used in previous Turkish standardized tests such as the Students Selection Exam (OSS), the Student Placement Exam and the High School Entrance Exam and converted to open-ended investigations. This adaptation was meant to eliminate students', teachers', and parents' concerns for learning, teaching, and preparation towards tests. As an example, the following item was used in OSS in 1999:

> If a is a positive real number, at most how many cm^2 can the area of the rectangle with dimensions a cm and $(8 – 2a)$ cm be?
>
> A) 64 B) 32 C) 24
>
> D) 16 E) 8

This problem was adapted into an open-ended problem as "You are making a rectangular flower garden. What is the largest area of the garden whose dimensions are *a* meters by *8 – 2a* meters? Extension: What is the largest area of a rectangular garden that you can enclosure by using 16 – 2a meters of fencing? If one side of the rectangle can use a barn wall, what are the dimensions of the enclosure with the largest area?" Students can use a spreadsheet, graphing calculator, and dynamic geometry software to investigate and solve the problem. This allows students to use multiple approaches or representations to conceptually investigate and understand such problems. Investigating the area of a rectangular region with a fixed perimeter can also extend the problem. Such problems dealing with optimization are covered in the InterMath project as well.

3. Investigations added by the T-Math team. T-Math also extended the InterMath investigations by adding new investigations for middle and high school that are not drawn from standardized tests. A sample investigation of this type is given below.

> A Pythagorean triple is an ordered triple (a, b, c) of positive integers satisfying
>
> $a^2 + b^2 = c^2$. Find as many Pythagorean triples as you can. Can you come up with an easier way to find Pythagorean triples? Your friend claims that for any positive integer m, the triple ($2m$, $m^2 - 1$, $m^2 + 1$) is a Pythagorean triple. Does this work? Why?

The Pythagorean triples mentioned in the problem can be investigated through calculators, spreadsheet applications, and dynamic geometry applications (Figure 2 and Figure 3). Learners may use a spreadsheet application to investigate Pythagorean triples mentioned in the problem (Figure 2). They may assign positive integer values to the first two variables and calculate the third one using the first two values and observe if it is integer or not. In this way they can determine whether a triple (a, b, c) is a Pythagorean triple or not.

Similarly, learners may use a dynamic geometry application, such as Geometer's Sketchpad (GSP) (Jackiw, 2001), to investigate the same problem. A right triangle may be constructed whose vertices are snapped to grid points so that the side lengths of the triangle are integer values (Figure 3). Learners may play with the vertices to obtain right triangles with side lengths that satisfy the Pythagorean triples rule. In this way, a connection between the algebraic and geometric representation of the same problem can be made. This investigation can also be extended by allowing more advanced learners to use a graphing application that has 3-D graphing capabilities to explore the graph of $x^2 + y^2 = z^2$ to determine the integer values that satisfy this equation by intersecting the graph with various x and y values such that $x = n$ and/or $y = m$ where $m, n \in Z^+$.

4. Investigations added by the T-Math team that make use of local cultural elements. Anatolian land has been a crossroad for many cultures and civilizations such as Greek, Roman, Islamic, and many others. For this reason, Turkish history and culture offer culturally rich contexts to explore many mathematical topics. T-Math utilizes this opportunity to provide an ethnomathematical perspective in investigations while integrating technology. For example, traditional Turkish handicrafts – carpets and rugs, marbling

	A	B	C
1	a	b	c
2	2	7	=SQRT(A2^2+B2^2)
3	2	8	8,246
4	2	9	9,220
5	2	10	10,198
6	3	1	3,162
7	3	2	3,606
8	3	3	4,243
9	3	4	5,000
10	3	5	5,831
11	3	6	6,708
12	3	7	7,616
13	3	8	8,544
14	3	9	9,487
15	3	10	10,440
16	3	11	11,402
17	3	12	12,369

Figure 2. Investigating Pythagorean triples in a spreadsheet application

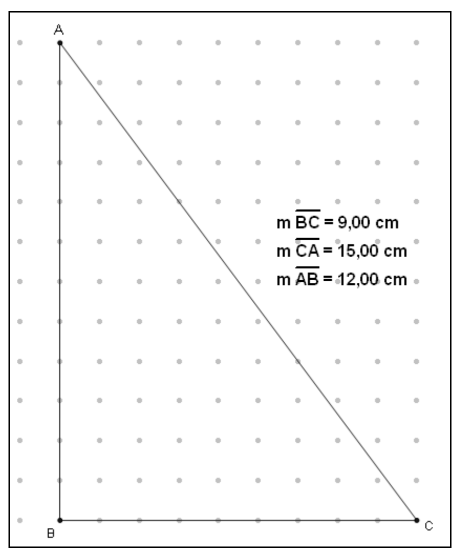

Figure 3. Investigating Pythagorean triples in a dynamic geometry application

(ebru), stone carvings, wood carvings, ivory carvings, tiles, calligraphy, embroidery, quilts, knitted socks, felts, fabrics and textiles, yazma (hand printed textiles), etc. – and historical structures offer superb opportunities to investigate symmetry, asymmetry, grids and tessellations, and other geometrical content. For this purpose, students were asked to visit websites (e.g., http://www.turkishculture.org) containing digital examples of traditional Turkish art styles mentioned above or to take their own digital pictures of the traditional art styles and historical structures around them. Students were asked to copy and paste the images into GSP to explore and reproduce reflection and rotation symmetry, asymmetry and tessellations such as the ones shown in Figures 4, 5, 6 and 7.

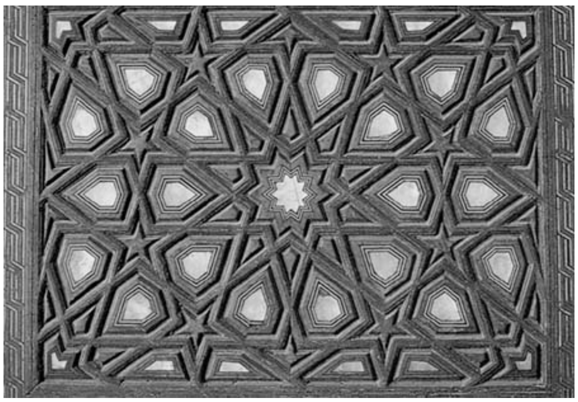

Figure 4. Wood Carving Shutter Panel in the Kilic Ali Pasa Mosque in Istanbul

Figure 5. Ivory Carving Belt Piece in Topkapi Museum in Istanbul, Dating from 1500s

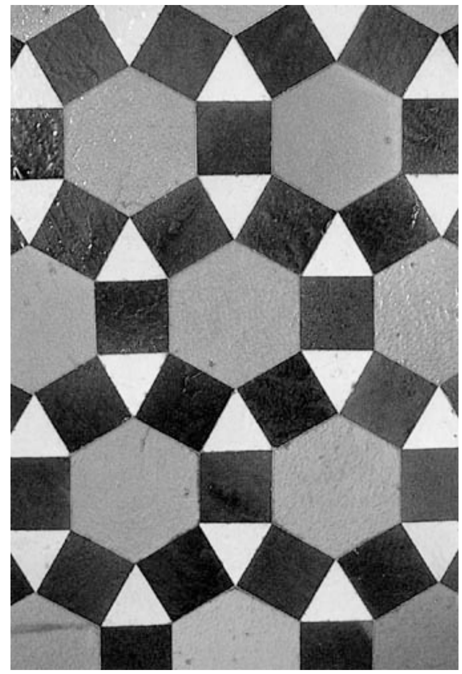

Figure 6. Panel from the Muradiye at Bursa, Dating from 1426

Figure 7. Tile from an Arched Panel in Iznik, Dating from Mid 16th Century

Role of T-Math Instructors

T-Math, like InterMath, is founded on the premise of providing teachers time during workshops to collaborate and work on problems. In workshops, instructors will act as a facilitator while teachers use technology to explore the investigations. Further, instructors attempt to help participants connect mathematical concepts to real-life and use a variety of activities to see how technology can be integrated in meaningful ways. The collaborative workshops are designed to assist in the establishment of a mathematical culture in which technology helps teachers develop their mathematics content knowledge. Mathematical understanding and communication is built on modeling and problem solving with interactive technological tools. These workshops are meant to help teachers reflect on their experiences and use them to develop content knowledge, as well as to help teachers become comfortable exploring mathematical problems.

Future Endeavors

The T-Math project staff is also adapting InterMath's mathematics dictionary and the Constructionary for the Turkish elementary and secondary school mathematics curriculum. The purpose of the T-Math dictionary will be to present explanations of mathematical terms for students, teachers, parents and other potential users so that they can study mathematical terminology, terms, and concepts in an interactive environment. The T-Math dictionary will help us meet a significant need for a mathematics dictionary in Turkish for elementary and secondary students. Existing printed mathematics dictionaries in Turkish only cover upper level mathematics, and the language used in defining and explaining terms is more suitable for advanced levels. The T-Math dictionary will use clear language that is both age and content level appropriate. It will be equipped with pedagogical elements such as links to related terms, real life examples and applications, and a forum where users can express and discuss their opinions about each component of the on-line mathematics dictionary. Considering that there are certain debates and disagreements about some of the mathematical terms in Turkish, this dictionary could be a platform for dialogue on Turkish mathematics terminology. We anticipate that the dictionary will be useful to teachers who are about to implement the new national curriculum for primary schools, since many teachers in elementary schools are not familiar with concepts such as patterns, tessellations, and transformations that are new in the curriculum and new to the Turkish school mathematics terminology.

Formerly, geometric constructions using Greek construction rules were covered only in the 10th grade geometry curricula in Turkey. However, with recent changes in the elementary school mathematics curriculum, geometric constructions are now covered in sixth, seventh, and eighth grades as well. Therefore, T-Math is adopting InterMath's Constructionary, which is an online tool designed to help users create geometric constructions using Geometer's Sketchpad, and include more constructions that will address the new curriculum covered in the 6-8 grades. This will be highly valuable for middle school mathematics teachers, as they may lack such content knowledge.

Challenges in the Adaptation Process

The issues around mathematics education in the USA and Turkey have many similarities and differences. School systems, classroom cultures, curriculum climates, and the teacher education systems in both countries should be carefully examined before adopting any educational innovation. Similarities between the two systems encouraged the T-Math team to benefit from the InterMath content and strategies in mathematics teachers' professional development. The differences, on the other hand, compelled us to come up with additional strategies for developing relevant professional development resources and for gaining acceptance of the teachers and the local mathematics education community.

Adopting InterMath principles and content into a different educational system is a challenge in many senses, especially considering the unique issues surrounding mathematics education in the USA and Turkey. A project aiming to place open-ended mathematical investigations into the heart of mathematics instruction will have to confront traditional attitudes towards mathematical tasks in both contexts. In the adaptation process of the InterMath principles, the T-Math project team has been developing and implementing the following strategies to deal with such unique challenges:

Making T-Math Content Culturally Relevant

As explained earlier, the investigations that were translated and adopted from InterMath have been revised and additional problems surrounding Turkish culture have been developed to make T-Math content more relevant for Turkish mathematics teachers' professional development.

Working with Private Schools.

There is a competitive environment among private schools in Turkey about the innovative educational initiatives. In its initial phases, T-Math aims to work with private schools that already have an agenda of integrating technology into instruction in order to create samples of exemplary T-Math implementation.

Emphasizing T-Math's Potential Contributions to the Implementation of the New Curriculum and to the Change Efforts.

On-going curriculum reform efforts in Turkey are hoped to trigger a culture of change in teachers' perceptions of school mathematics. Turkey's progress toward joining the European Union (EU) and the process of accession negotiations with the EU is an important motivation for Turkish institutions to change. In this sense, the MNE is open to innovative teacher education programs, which provides an important opportunity for T-Math to contribute to the change efforts. This possibility will be used to persuade teachers, private school administrators, and the MNE authorities to support mathematics teachers' participation in T-Math.

Convincing the Central Authority

Reaching the teachers of public schools in Turkey requires not only convincing them to participate but also getting the approval of the MNE. After the recent curriculum changes, the MNE has been searching for ways of collaborating with universities on the in-service training of teachers. By convincing the administrators in the MNE about the possible contributions of T-Math to teachers' professional development, we hope to establish an important channel for reaching a large number of schools and teachers throughout Turkey. Once the T-Math knowledge base (i.e., open-ended investigations, a mathematics dictionary, a dictionary of geometric constructions, etc.) is established, and pilot workshops are conducted, the T-Math team plans to submit a proposal to the MNE to take an integral part in their in-service teacher education agenda. We believe that data from the pilot implementations of T-Math is important in demonstrating its potential in teachers' professional development about integrating technology in mathematics education.

Learn from the InterMath Experience

Although there are considerable differences between Turkish and American education systems, there are many things that we can learn from the InterMath experience, especially on how to deal with challenges in changing mathematics teachers' conceptions of technology integration in mathematics education. In this sense, as explained earlier in this paper, T-Math team is making use of the feedback and the knowledge base shared by the InterMath project in planning workshops, selecting and developing open-ended mathematical investigations, and developing other components of T-Math project.

Conclusion

The revolution of technology in education, according to the curriculum reform in Turkey, requires mathematically sophisticated teachers that can integrate technology in meaningful ways. Regarding teachers' essential role in their classrooms, meaningful reform is more likely to succeed if teachers are adequately prepared to use mathematics-related technologies in ways that develop students' conceptual understanding and problem solving skills.

The studies and efforts by the MNE mentioned in this paper highlight the significance of technology for the future of education in Turkey. George Cantor (1845 - 1918) once said that, "The essence of mathematics is freedom" and we believe that technology can free teachers and students in their teaching and learning efforts. As White and Frederikson (1998) indicated, with the aid of technology teachers and students should and can question, "why it is they believe what they believe, and whether there is sufficient evidence for their beliefs" (p. 7). With the use of open-ended and interactive technologies, learners and instructors can model most mathematical situations as problems and investigate them interactively. One who is familiar with such technologies should recognize that what can be done with open-ended environments is usually limited by the computing knowledge of the user. With more and various technology usage, one can model mathematical problems in various ways with various technologies. In technology supported mathematics education, integrating technology into pre- and in-service teacher education in terms of not only how to teach with technology but also how to learn with it gains importance. Teachers will need to practice with relevant technology resources before they implement them in their classroom environments. Through the T-Math project site and its sophisticated publishing environment, teachers will be able to reach and use several technologies through a web interface. Additions and changes have been made to InterMath investigations, dictionary, Constructionary, and other tools to make them more culturally relevant and match curricular issues so that teachers feel more familiar with the overall content within the existing culture and educational systems. Thus, all the resources and applications that are developed for workshops or face-to-face implementations will also be available for teachers everywhere and all the time. Accessibility to resources anytime may motivate teachers who are not able to participate in workshops and other project activities because of the location, time, and cost problems.

In conclusion, we can and should utilize functionalities of computer technologies in learning and teaching for understanding in mathematics education. As Gottfried Wilhelm Leibniz (1646-1716) said long before the invention of computers, "It is unworthy of excellent men to lose hours like slaves in the labor of calculation which could safely be relegated to anyone else if machines were used." With this vision in mind, T-Math project, as an extension of InterMath, aims to contribute to the effective and meaningful use of technology in exploring and learning mathematics by providing professional development opportunities for teachers.

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References

Aloff, S. (1999). Two modes of mathematics instruction. *In Issues of Education at Community Colleges: Essays by Fellows in the Mid-Career Fellowship Program at Princeton University, 1998-1999*. (ERIC Reproduction Service No. ED437109). Retrieved August 8, 2005, from http://www.eric.ed.gov.

Ball, D. L. (1990). Prospective elementary and secondary teachers' understanding of division. *Journal of Research in Mathematics Education*, *21*, 132–44.

Cakiroglu, E., Cagiltay, K, Cakiroglu, J., & Cagiltay, N. (2001, April). *Elementary and secondary teachers' perspectives about the computer use in education*. Paper presented at the annual meeting of American Educational Research Association. Seattle, WA.

Cakiroglu, E., & Haser, C. (2002). Mathematics teachers' perceptions of computers use in mathematics instruction: A case study from Turkey. In D. Mewborn, P. Sztajn, D. White, H. Wiegel, R. Bryant, & K. Nooney (Eds.), *Proceedings of the Twenty Fourth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education,* (Vol. II, pp. 669–672). Columbus, OH: Eric Clearinghouse for Science, Mathematics, and Environmental Education.

Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. C. Wittrock (Ed.), *Handbook of Research on Teaching* (pp. 255–296). New York: Macmillan.

Clark, C. M., & Yinger, R. J. (1987). Teacher Planning. In J. Calderhead (Ed.), *Exploring teachers thinking* (pp. 84–103). London: Cassell.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher*, *23*(7), 13–20.

Coffland, D. A. (2000). Factors related to teacher use of technology in secondary geometry instruction. *Society for Information Technology and Teacher Education International Conference 2000*, 1, 1048–1054.

Cohen, D. K., & Ball, D. L. (1990). Policy and practice: An overview. *Educational Evaluation and Policy Analysis*, *12*, 347–353.

Ertmer, P., Addison, P., Lane, M., Ross, E., & Woods, D. (1999). Examining teachers' beliefs about the role of technology in the elementary classroom. *Journal of Research on Computing in Education, 32*(1), 54–73.

Ertmer, P., & Hruskocy, C. (1999). Impacts of a university-elementary school partnership designed to support technology integration. *Educational Technology Research and Development, 47*(1), 81–96.

Fleener, M. (1995). A survey of mathematics teachers' attitudes about calculators: The impact of philosophical orientation. *Journal of Computers in Mathematics and Science Teaching, 14*, 481–498.

Frank, M. L. (1990). What myths about mathematics are held and conveyed by teachers? *Arithmetic Teacher, 37*(5), 10-12.

Hadley, M., & Sheingold, K. (1993). Commonalties and distinctive patterns in teachers' integration of computers. *American Journal of Education, 101*, 261–315.

Halpin, P., & Kossegi, J. D. (1996, June). *The WWW, preservice teachers and their mathematics courses*. Paper presented at the Association of Small Computer Users in Education Summer Conference, Myrtle Beach, SC. (ERIC Reproduction Service No. ED405819). Retrieved August 8, 2005, from http://www.eric.ed.gov.

Hanks, R. F. (2002, June). *Environmental and personal factors effecting K-12 teacher utilization of technology*. Paper presented at the National Educational Computing Conference, San Antonio, Texas, (ERIC Reproduction Service No. ED475934). Retrieved August 8, 2005, from http://www.eric.ed.gov.

Hazzan, O. (2002). Prospective high school mathematics teachers' attitudes toward integrating computers in their future teaching. *Journal of Research on Technology in Education, 35*, 213.

Hembree, R., & Dessart, D. (1992). Research on calculators in mathematics education. *Calculators in mathematics education: 1992 yearbook* (pp. 23–32). Reston, VA: National Council of Teachers of Mathematics.

Jackiw, N. (2001). Geometer's Sketchpad 4.01. [Computer software]. Berkeley, CA: Key Curriculum Press.

Kellecioglu, H. (2002). Ortaöğretim öğrencilerinin üniversiteye giriş sınavları ve sınavın öğrenimlerine etkisi hakkındaki görüşleri [The Point of High School Students on University Enterance Examination and Effect of This Examination on Their Learning]. Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 23, 135–144.

Liu, J. (2001, November). *Integrating educational technology into field experiences and teacher education curriculum: A systemic approach*. Paper presented at the National Convention of the Association for Educational Communications and Technology. Atlanta, GA. (ERIC Reproduction Service No. ED470192). Retrieved August 8, 2005, from http://www.eric.ed.gov.

Manouchehri, A. (1999). Computers and school mathematics reform: Implications for mathematics teacher education. *Journal of Computers in Mathematics and Science Teaching, 18*(1), 31–48.

Margerum-Leys J.,& Marx, R. W. (1999, April). *Teacher education students' beliefs about technology*. Paper presented at the Annual Meeting of the American Educational Research Association, Montreal. (ERIC Reproduction Service No. ED429589). Retrieved August 8, 2005, from http://www.eric.ed.gov

Mouza, C. (2003). Learning to teach with new technology: Implications for professional development. *Journal of Research on Technology in Education, 35*, 272–289.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

Norton, S., McRobbie, C. J., & Cooper, T. J. (2000). Exploring secondary mathematics teachers' reasons for not using computers in their teaching: Five case studies. *Journal of Research on Computing in Education, 33*(1), 87–109.

Organization for Economic *Co-operation and Development (2005). Education Policy Analysis 2004*. Paris: Author.

Orrill, C. H., Polly, D., Ledford, S., Bleich, L., & Erbas, A. K. (2005). *Technology and content in teacher professional development: An examination of the role of technology in changing teachers' understandings*. Manuscript in preparation, University of Georgia.

Parr, J. M. (1999). Extending educational computing: A case of extensive teacher development and support. *Journal of Research on Computing in Education, 31,* 280–292.

Quinn, R. J. (1998). Technology: Preservice teachers' beliefs and the influence of a mathematics methods course. *Clearing House, 71*, 375–378.

Rosen, L. D. & Weil, M. M. (1995). Computer availability, computer experience and technophobia among public school teachers. *Computers in Human Behavior, 11*(1), 9–31.

Sandholtz, J., Ringstaff, C., & Dwyer, D. C. (1997). Teaching with technology: Creating student-centered classrooms. New York: Teachers College Press.

Slough, S. W., & Chamblee, G. E. (2000). *Implementing technology in secondary science and mathematics classrooms: A perspective on change*. In Proceedings of the Society for Information Technology and Teacher Education International Conference, San Diego, 1-3, 1021–1026.

Sudzina, M. R. (1993). *Technology, teachers, educational reform: Implications for teacher preparation*. Paper presented at the Annual Meeting of the Association of Teacher Educators, Los Angeles, CA.

Tozoglu, D., & Varank, I. (2001, November). *Technology explosion and its impact on education*. Paper presented at the National Convention of the Association for Educational Communications and Technology, Atlanta, GA. (ERIC Reproduction Service No. ED470179). Retrieved August 8, 2005, from http://www.eric.ed.gov.

Trueblood, C. R. (1986). Hands on: Help for teachers. *Arithmetic Teacher, 33(*6), 48–51.

Trumbull, D. J. (1987). On changing perspective: An examination of teachers' dilemmas. *Journal of Curriculum and Supervision, 3*(1), 45–60.

Turkish Ministry of National Education. (2005a). İlköğretim Matematik Dersi 6-8. Sınıflar Öğretim Programı [Elementary Mathematics Curriculum: Grades 6–8]. Ankara: Devlet Kitapları Müdürlüğü Basımevi.

Turkish Ministry of National Education. (2005b). Ortaöğretim Matematik (9, 10, 11 ve 12. Sınıflar) Dersi Öğretim Programı [Secondary Mathematics Curriculum: Grades 9–12]. Ankara: Devlet Kitapları Müdürlüğü Basımevi.

Turkish Ministry of National Education. (2005c). Öğretmen Yeterlikleri [Teacher Competencies]. (Draft ed.). Retrieved July 12, 2005, from http://oyegm.meb.gov.tr/yet/OGRETMEN_YETERLİKLERİ.doc

Vannatta, R. A., & Fordham, N. (2004). Teacher dispositions as predictors of classroom technology use. *Journal of Research on Technology in Education, 36,* 253–272.

Wetzel, K., Zambo, R. & Buss, R. (1996). Innovations in integrating technology into student teaching experiences. *Journal of Research on Computing in Education, 29*, 196–214.

White, B., & Frederikson, J. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction, 16*(1), 3–118.

Willis, J. W. & Mehlinger, H. D. (1996). Information technology and teacher education. In J. Sikula (Ed.). *Handbook of Research on Teacher Education* (pp. 978-1029). New York: Macmillan Library Reference.

Yoder, A. J. (2000, October). *The relationship between graphing calculator use and teachers' beliefs about learning algebra*. Paper presented at the annual meeting of the Mid-Western Educational Research Association, Chicago.

Yükseköğretim Kurumu. (1998) Eğitim Fakültesi Öğretmen Yetiştirme Lisans Programları [Undergraduate Programs for Teacher Education in Education Faculties]. Ankara: Y.Ö.K. Ankara.

Appendix

Technology-Related Teacher Competencies as Defined by the Turkish Ministry of National Education

In supporting the Basic Education Project, the Turkish Ministry of National Education initiated a study to redefine the qualifications for teachers (Turkish Ministry of National Education, 2005c). Six main competency areas, together with 39 sub-competencies and 244 performance indicators, are determined for in-service teachers teaching in Turkey. The six main competencies are (a) personal and professional values – professional development, (b) acknowledging students, (c) the teaching and learning process, (d) tracking and evaluating learning and development, (e) school-parent and school-society relations, (f) curriculum and content knowledge. Knowledge of technology and integrating that into the teaching and learning process is highly emphasized in this vision of a competent teacher. Some of the sub-competencies related to technology knowledge and its utilization emphasized for a professionally competent teacher are given below:

A5.12. Technologically literate (has knowledge and skills of concepts and applications related to technology).

A5.13. Follows developments in information and communication technologies.

A6.2. Uses information and communication technologies in order to support his/her professional development and increase his/her productivity.

A6.8. Utilizes information and communication technologies (on-line journals, software, e-mail, etc.) to share knowledge.

B2.3. Utilizes information and communication technologies to prepare suitable learning environments for students with different experiences, characteristics, and talents.

C1.8. Gives place to ways of using information and communication technologies in lesson plans.

C3.8. Sets an example for effective usage of technological resources and teaches them.

C5.8. Takes various needs of students into consideration and utilize technologies to promote and support student-centered strategies.

C7.8. Develops and uses strategies for behavior management in technology-rich learning environments.

D3.2. Analyzes data by using information and communication technologies.