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Using TIMSS to Improve the Undergraduate Preparation of Mathematics Teachers

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Abstract

This paper looks at how the research from the Third International Mathematics and Science Study (TIMSS) can help prepare undergraduate preservice mathematics teachers for success in teaching mathematics. The findings from TIMSS provide implications for better practices which can improve the preparation of future teachers to teach mathematics in a more effective and researched based-manner. The authors feel that if preservice teachers are better prepared for teaching mathematics and have a strong mathematical foundation along with knowledge of the TIMSS, their future students will be better prepared, in terms of their mathematics achievement and attitudes, to experience success in our technological and mathematical world. This paper provides ten recommendations for teacher educators based on TIMSS findings which outline specific suggestions and ramifications for preservice teachers to aid in being effective educators for future students in the USA.

Introduction

The Third International Mathematics and Science Study (TIMSS) has received a great deal of attention over the past several years. TIMSS has provided great insight for educators into student performance and mathematics instruction at a global level. The TIMSS findings may also be used to provide a fresh look at how to better to improve the undergraduate preparation of future mathematics teachers. This paper will provide an overview of some of the findings from the TIMSS and give ten recommendations for teacher educators on how TIMSS may provide implications and ramifications to better prepare future teachers to teach mathematics in a more effective and researched based-manner.

Although many factors inside and outside of school influence students' level of achievement, the quality of classroom teaching is key to improving students' learning (National Commission on Mathematics ad Science Teaching for the 21st Century, 2000). Much of mathematics is taught through working on mathematics problems (TIMSS Video Mathematics Research Group, 2003). This similarity probably can be explained by a convergence of global institutional trends (LeTendre et al, 2001). The appropriate relationship of school mathematics to life outside the classroom has been discussed for some time (Stanic and Kilpatrick, 1988). As Furner (1996) has pointed out, making the relationship between mathematics and life is a way to reduce math anxiety. When anxiety is reduced, students can become more successful at math, and be better equipped to be successful in a world that is highly technologically which relies

heavily on mathematics and the sciences (Lesh & Lamon, 1992). According to Stigler and Hibert (1997), the U.S. had no large-scale mechanism for sustained teacher learning at the time. Although this is still the case, there is a growing sense that long-term, continued teacher learning is a key to improving practice (Darling-Hammond and Sykes, 1999). Improved practice leads to improved situations for students to show increased achievement in mathematics. Future teachers may glean a great deal from TIMSS to better understand how they can better serve their students when teaching mathematics. If preservice teachers are better prepared for teaching mathematics and have a strong mathematical foundation and knowledge of the TIMSS report, their students will be better prepared, in terms of their mathematics achievement and attitudes, to experience success in a technological and mathematical world.

A Brief Summary of Some of the TIMSS Research Findings

The Third International Math and Science Study (TIMSS) was administered by the International Association for the Evaluation of Educational Achievement to fourth, eighth and twelfth grade students. TIMSS, a large scale, cross national study of over 40 countries' educational systems and their outcomes, examined the science and math curricula, instructional practices, school and social factors, and student achievement through a collection of achievement tests, classroom observations, teacher interviews/surveys, videotapes of classroom instruction and ethnographic case studies (Schmidt, 1998; TIMSS Video Mathematics Research Group, 2003). Assessments and surveys were administered in more than 30 languages. In the U.S., more than 33,000 randomly selected students in about 500 schools were included in the study. Funds came from the National Science Foundation (NSF) and the National Center for Educational Statistics (NCES) of the U.S. Department of Education. By comparing what is "typical" in U.S. schools to what occurs in other countries and cultures, practitioners can examine areas related to curriculum and instruction. The TIMSS data does suggest ways to improve teaching practices that may lead to a more effective U.S. school math classroom (TIMSS Video Mathematics Research Group, 2003; Bracey, 1997).

On the eighth-grade TIMSS math achievement test, the following top six countries were as follows: Singapore (643), Korea (607), Japan (605), Hong Kong (588), Belgium-Flemish (565), and the Czech Republic (564). The U.S. ranked 28th out of the 41 countries who participated in the eighth grade achievement test (Schmidt, 1998). American 8th grade math scores (500) fell slightly below the international average (513). However, American 4th-graders ranked 11th out of 26 countries, resulting in math scores that were significantly above the international average on the mathematics achievement test. In fact, 4th graders fared better in both math and science this time than on a previous international assessment test performed in 1991 (Schmidt, 1998). Some questions that arise - What is happening between grades 4 and 8 to create a decline in the national average mathematics score? What about what happens between grades 4 and 12? What can teachers glean from this study to better improve mathematics instruction in the U.S.? For more information about TIMSS one may want to look at the following websites: http://www.col-ed.org/smcnws/timss/splintrd.html and http://timss.bc.edu.

Implications and Recommendations from TIMSS for Undergraduate Mathematics Preparation of Teachers

Curriculum

Overall, William Schmidt (1998) of Michigan State University, U.S. TIMSS Project Director, contends that "curriculum matters." The math curriculum and pedagogy in the U.S.

appear to be quite different from some of the top scoring countries and more is not always better. The TIMSS study suggests that the American curriculum contains too many topics - more topics than any other country. Schmidt (1998) contends the U.S. tries to teach so much content at each grade-level that it really has no time to teach anything in depth. It has been said that the U.S. curriculum is too diffuse and has been described as being "a mile wide and inch deep" (Schmidt, 1998). There are just too many math concepts taught during grades K-8 with none of the concepts being covered in much depth. In fact, the U.S. covered 75% more topics than any other country in the TIMSS study. However, by the end of grade 12, most countries have covered about the same number of topics, and some in much more depth than the U.S. has done (Schmidt, 1998). The textbook publishers have contributed to the curriculum problems. Based on an analysis of about 1000 textbooks and teacher guides that were used in 45 countries, the TIMSS data indicated that the U.S. textbooks cover many ideas, but do so superficially leaving students with techniques but a lack of mastery of the underlying concepts.

Recommendation 1: The American curriculum needs more focus and depth on a smaller number of non-repetitive topics at each grade level. Preservice teachers need to be better trained for this teaching approach. Preservice teachers should be trained to teach for understanding by exploring and doing problem-solving in a meaningful/practical application manner. If there were a clear coherent vision this would result in a shared vision for school districts, textbook publishers, and standardized testing agencies. This approach may better help guide a new teacher in what he/she is teaching. This may also better prepare teachers who are competent to teach from state to state, all with a clear coherent set of standards and best practices. By reducing the number of topics covered in a given year, more time will exist for the mathematics teacher to concentrate on the depth of the topics. This in itself would make transition easier for preservice teachers coming into the classroom for the first time.

Content Issues

One notable issue raised from the TIMSS study is that all the countries involved have basically the same type of students, but what is being taught is quite different. Many other countries have a different emphasis on content and years when certain material is taught. Many of the TIMSS countries offer a form of algebra and geometry in 5th and 6th grades which is comparable to what we teach in 9th and 10th grades in the U.S. The entire middle school mathematics and science curricula are similar to other country's fourth grade. Schmidt (1998) feels that the American middle school curriculum provides an intellectual wasteland at the middle school level, lacking depth and challenge. Schmidt (1998) contends that most other countries begin a combination of algebra and geometry at the middle grade levels where the U.S. curriculum traditionally saves these courses for 9th and 10th grades. Also, most other countries teach algebra and geometry together not as separate subjects as the U.S. does. Japan spends half a year on Algebra and half a year on Geometry topics, such as congruence and similarity, with only 10-15 topics all together. This was identified as a primary reason for Japan's significant gains on the TIMSS test from previous tests.

Recommendation 2: Teacher preparation institutions need to focus more in the areas of teaching algebra and geometry and be sure preservice teachers are well trained in content to teach these branches with meaning and in a challenging in-depth manner while showing practical applications to the material. Preservice teachers need to be trained to provide more challenging,

less repetitive topics in more depth, especially in the areas of algebra and geometry, where many geometric patterns lead to interesting algebraic equations.

Social Concerns, Attitudes and Expectations

Often, schools in the U.S. worry more about self-concept issues during middle school years. All of the TIMSS countries must also deal with these students' raging hormones as well, but do not allow that to get in the way of the content being taught, requiring students to be more disciplined in their work. The U.S. tends to make many excuses for why kids cannot handle a higher level of math at the middle school levels. Many other countries also deal with issues of homework, drugs, violence, etc. Educators feel that students must be challenged more at the middle school levels and that the lack of intellectual challenge and the repetitiveness of the curriculum have created an environment where students are too frequently turned-off to math. In fact, American students tend to have very high absentee rates as compared to other countries participating in the TIMSS study. Another important factor is that many other countries place different values on education and have more stringent discipline than the U.S. does. American teachers try to diagnose students in order to find out what they do and do not know and then decide what to teach from that information. Instead of bringing the students up to the required level of instruction, the teacher spirals backwards in an attempt to remediate the student. A bit too much autonomy has created a limitation as well. If American teachers dislike teaching a topic, they may take it upon themselves to eliminate topics altogether from the curriculum or be selective in what and how they teach.

Recommendation 3: Preservice teachers should be trained in the application/practice of the NCTM Standards (1989 and 2000) and be familiar with NCTM's *Standard* #10 on dispositions toward mathematics. Marzano 's (1992) Dimensions Of Learning Model is based on the premise that before real learning can occur, students must have good attitudes and perceptions toward learning. In the same respect, then, students must have good attitudes about learning math before they both truly understand and develop confidence in their ability to do math. Preservice teachers need to be trained to assess students at the beginning of each year to check for anxieties/attitudes toward math and correct such poor dispositions early on. Although student attitudes have been proven to be an important factor in achievement and that certain social concerns and student differences are difficult to address, it is possible that an improved curriculum and a focus on the value of math education may lead to less social and attitude problems frequently found in the middle grades. Future teacher must realize that all students really need to graduate from high school feeling good about their math performance, it hinges on their future, career, and all decisions they may make in life. It truly is a teachers obligation to develop positive attitudes toward math within in his/her students (Furner, 1998).

National Standards/Coherent Vision

The decentralized educational system of the U.S. does not always allow for the many components of local districts, state agencies, and national organizations to work toward a common goal. The U.S. lacks a coherent vision of what a child should know before moving on to the next grade. Therefore, issues on retention and expectations are vague at best. Schmidt (1998) contends that the TIMSS data suggests that many top scoring countries have a national curriculum where the government is in charge of the curriculum and the educational materials. Schmidt indicated the most important instructional consideration must be a shared, coherent,

focused vision of the curriculum nationwide.

The TIMSS may help us understand the successes of other countries that have a national curriculum and structure/governance. A set of national standards that articulates a focused, consistent vision of what students need at each grade level in order to become productive citizens appears to be significant. Although NCTM (1989 and 2000) have provided guidelines for a national curriculum in the U.S, the U.S., still is lacking a clear vision of what a typical student should know at any given grade level, retains students less often than other countries. Most countries hold their students back if the expectations set for the student by the national curriculum have not been obtained, unlike American schools that lack a consensus on what students should know at individual grade levels. In the U.S. with each state in control of its own math curriculum and standards has not shown effective nationwide. National standards may result in a more coherent vision of what students should know and will result in less control to textbook publishers and standardized testing companies. The adoption of a national curriculum that is consistent and equitable may prove to be the ultimate "best practice" approach (NCTM, 1989 and 2000; Zemelman, Daniels, & Hyde, 1998). In order for this to happen, the standards must be official, all schools districts nationwide must adopt this curriculum, and all professional education programs should develop their programs around these standards.

The U.S. is noted for having many textbook options, governing bodies, and standards from national, state, and local education organizations which have all added to an abundant supply of "best practice, best curriculum" offerings around the country. It is questionable whether the U.S. has a national and coherent vision for its mathematics curriculum or whether it is actually splintered and chaotic. Are the NCTM Standards (1989 and 2000), which are not officially accepted but rather voluntarily accepted, too broad in the content they suggest for each grade level? Is this contributing to the U.S. struggle to be number one in mathematics?

Recommendation 4: Preservice teachers must be trained to implement such national standards and know what the "best practices" are for teaching mathematics. By implementing the research and a possible national curriculum (perhaps using the NCTM Standards) as future teachers, they can better reach more students mathematically and perhaps improve mathematics achievement nationally. If the US is going toward a more coherent, more focused vision at a national level may be needed to provide school systems with the proper direction of math education, the appropriate curricular issues, and the appropriate level of expectations for each grade level in order for more consistency across the country. The National Council of Teacher's of Mathematics Curriculum Standards (1989 and 2000) offers a solid foundation on which to build upon. The National Council for the Accreditation of Teacher Education (NCATE) should expect professionally accredited universities to use these standards in the development of teacher education programs.

Academic Preparation and Instructional Planning

The TIMSS data show that most middle school teachers in other countries, such as Japan and Germany, have a stronger content background in mathematics and more practical training and academic support than do most American middle school teachers. Professional education programs should encourage a sound academic background in the content area and public schools should not accept under-prepared teachers in the areas of math and science. If needed, professional development should be provided to teachers who lack a sound background in the content area. Teachers must have more time to plan for instruction in order to make each math

lesson the best possible lesson for all students. Interestingly, many other countries have classrooms that contain more students than found in a typical American classroom yet score towards the top in the TIMSS study. However, teachers in these countries have more planning time to make the best possible lessons.

The typical American teacher teaches 30 hours a week while both Japanese and German teachers teach only 20 hours per week. Class preparation time in Japan is about 1 hour for every 2 hours of instruction, while the average American teacher is given about 1 hour for every 6-7 hours of instructional time. The Japanese teachers spend about 10 hours more per week planning for instruction and teach fewer hours per week than the average American teacher. Japanese teachers work very hard on crafting lessons that will reach all students. However, they do have larger class sizes, ranging from 40 to 45 students as compared to the 30 to 35 students in a typical American classroom. These findings indicate a sharp contrast to American teachers who have less time planning and more instructional demands but tend to have smaller class sizes. The key feature appears to be more planning time for teachers to create challenging, interesting lessons.

Recommendation 5: Teacher education programs should encourage a strong emphasis on the preservice and practicing educator's academic preparation in the content area and to encourage continued professional growth for all educators. Mathematics can much be compared to the playing of a musical instrument, in order to maintain proficiency in doing mathematics, one must continue to practice doing the mathematics. Preservice teachers need to have strong mathematics backgrounds. Teacher education institutions better serve their students when they give them a stronger curriculum which has a strong content base while providing many clinical teaching experiences prior to student teaching.

Recommendation 6: Preservice teachers need to study and work with teachers during a period of many years to master the procedures for an entire year of teaching mathematics to better see the entirety of the mathematics curriculum and how to do yearly and daily planning. An increase in the educator's instructional planning time to craft quality lessons must be viewed as a high priority. More time is needed to network with other educators to develop lessons and foster professional growth. However, this recommendation may result in an increase in class size, which has not been shown to be a significant factor in achievement. In this recommendation, it is the hope of the authors that teacher education institutions early on give preservice teachers many practicum experiences where preservice teachers work with the classroom teacher and students to better plan effective lessons, perhaps using the Japanese Lesson Study Model. Preservice teachers also need to be placed on teaching teams to plan and discuss best practices and constructivist lessons where teachers are teaching for understanding. Brewer & Daane (2002) have shown that when teams of teachers work together and discuss best practices and constructivist teaching approaches all teachers on the team are more likely to translate theory into practice into their classrooms.

Instructional Issues

Once again, more is not better in regards to homework. American students are given more homework daily as compared to any other country. Research has shown that an increase in the amount of assigned homework does not appear to increase academic achievement. In addition, the U.S. spends more class time per week studying math and science than the

international average, in spite of the fact that the American school year is shorter than the international average. More instruction and more homework does not appear to be the solution. Overall, from the TIMSS data it appears that the use of cooperative learning, technology, smaller class sizes, more homework, and a longer school day may not be the solution to the American educational problems. In fact, no other country used collaborative groups and no other country beat the U.S. in the number of computers found in the schools. The problem was sighted that too many American schools do not effectively use the technology they have. Japanese teachers provide new instruction for 35 minutes in a 50-minute period daily as opposed to the American teacher who provides new instruction for only 10 minutes in a 50 minute period. American teachers spent time reviewing, going over homework, and offering in class time for practice. Fifty percent of American teachers use overheads on a regular basis as compared to Japanese and German teachers who virtually do not ever use the overhead.

Recommendation 7: Preservice teachers need to be better trained in teaching within a "block." Often times, teachers themselves had not taken classes in this format and do not know how to fill the "time." The use of technology and problem-solving are also options that can be incorporated into a longer lesson time. Preservice teachers need to be exposed by the use of clinical placements and practicums to more classroom mathematics experiences so that they can make the most of the instruction time, unfortunately, much time is wasted in math classrooms today where students are allowed to start homework or sit quietly, but not fill the time with meaningful mathematics learning. An increase in instructional time and a proper balance of practice and new instruction need to be obtained. A proper balance, with more time spent on instruction, appears to be a factor in improving academic achievement. Block scheduling has been positive in some respects for teaching mathematics where teachers are allowed to use an 80-minute class period to go into depth with lesson development and follow-up. Preservice teachers need to be taught as teachers to do more to make every minute of mathematics instruction count as suggested by Johnson (1997).

Conceptual vs. Procedural

According to TIMSS, when asked to describe the educational goal, the typical American teacher said it was to teach students how to do something, while Japanese teachers felt the goal was to help students understand the concepts. A typical American teacher stands up in front of the classroom, instructs students in a skill or concept, and then hands out a homework assignment with many problems to solve similar to the instructional model previously solved by the teacher. Students then practice on their own while the teacher assists individuals. Little critical thinking is required with this method. A typical Japanese teacher stands up in front of the class, offers a complex, thought-provoking problem, and allows students to struggle on a solution. Ideas are exchanged before the teacher intervenes, only when necessary, in order to summarize the lesson. Students then practice similar problems. Japanese teachers believe that the key to mathematical understanding must first be approached through the ability to communicate ideas and problems. Time is needed to first experience a problem and to struggle with the solution before the concept is mastered by the student. An American teacher is more inclined to instruct the students how to do something rather than to allow the students the opportunity to develop the concepts on their own.

Recommendation 8: Preserive math teacher preparation programs need to have a strong focus

on problem solving. Colleges of education can better prepare students be strengthening the problem solving within math methods courses. Teachers need to teach the problem-solving process and strategies for problem solving. This is a fundamental aspect to what all math teachers should start out with at the beginning of the year with their students. Teachers also need to be trained in teaching using math manipulatives and teaching in a concrete/constructivist method, teaching for understanding should be the focus while connecting learning to prior knowledge and also incorporate technologies (NCTM, 2000). Preservce teachers need to be trained educators who emphasize the role of quality, open-ended problems that address more complex mathematical issues, require multiple approaches and choices leading to multiple answers. A focus on conceptual understanding and multiple approaches rather than on procedural skills is vital to an improvement in critical thinking, problem solving, and mathematical achievement.

Instructional Approach

Interestingly enough, the TIMSS study may also imply that there is not necessarily one correct method(s) of teaching. About 1/3 of American teachers are content-oriented, 1/3 are process oriented and 1/3 appear to be a mix of both teaching styles. Showing American educators videos of master teachers may improve instructional techniques, but will not necessarily do the trick since no one method or pedagogy consistently appear to be significant in the TIMSS study. Constructivism, Behaviorism, the use of cooperative learning, technology, and hands-on approaches may not be the keys to mathematical success. It appears, however, that a mix of both content-oriented and process/real-world-oriented teaching methods is favored in the more successful countries in the TIMSS study. Other forms of instruction, multiple strategies, and open-ended approaches should be important factors to consider.

Recommendation 9: Preservice teachers need to be shown many master teachers in action, by watching videos of master teachers from the US and other countries and observing actual classrooms, preservice teachers can then form their own effective stules for teaching mathematics. Teacher preparation programs should encourage pre-service teachers to look for an approach that is both effective and comfortable for them. Preservice teachers must realize that being a teacher is a true challenge in our society in this day and age and it requires a great deal of hard work and dedication on their part. They must be up for the challenge and all the work involved in being an effective educator for obtaining the true math success of their students. No one instructional approach is best, but a safe environment where all students are encouraged to participate in active learning is optimal. Any method that has proven beneficial and effective for all students is ideal, particularly what is advocated by NCTM (2000) and Zemelman, Daniels, and Hyde (1998) in their "best practices."

Tracking

Tracking is a large part of the American educational framework, especially as regards to mathematics. Schmidt (1998) claims that no other country who took part in the TIMSS allowed tracking of any kind and many consider the American method of tracking illegal since it prevents all students from receiving the same content. The U.S. begins much of the tracking at the middle school level. If students are able to achieve at a particular level, they are tracked in a college prep type of class while students who struggle in math classrooms that are too frequently taught in traditional ways are left behind in general math classes or eventually placed in remedial

classes. Schmidt (1998) feels that any form of tracking is damaging to our country as a whole and raises the question of whether all students have equal access in the present American educational-caste system.

Recommendation 10: Preservice teachers should know the ramifications to tracking students. Tracking at the lower levels can be damaging to a students self-esteem and perhaps preservice math teachers need to be trained in working with diverse groups of students in an inclusion type setting where they are better trained to reach all types of learners. The method of tracking truly should be examined for its intent and purpose with the possibility of inclusion of more or all students into the algebra/geometry curriculum. Many schools around the country, like the Florida schools, are now advocating "Algebra for All" for all students in Florida in order to receive a high school diploma. NCTM (2000) places a strong emphasis on mathematical opportunities for all students and that as teachers we must do all we can within our realm to reach all types of learners where modifications, accommodations, and enrichments are made for each student. Preservice math teachers then must be properly trained to reach all types of learners and provide specific accommodations when necessary.

Summary

The results of the TIMSS study give a comprehensive look into math performance and math instruction on a global level. While the study provides much detail about student performance in mathematics while sharing how math is taught in many different countries, this paper has used the TIMSS findings to focus on what can be gleaned to better prepare preservice mathematics teachers in the USA. Using TIMSS, teacher education institutions can help to improve the undergraduate preparation of future mathematics teachers. We are no longer living in isolated lands where best practices are confined to our individual countries. There are many modifications educators in the U.S. can make to improve the educational system by better preparing mathematics teachers that are trained to reach all types of learners. TIMSS can have lasting effects on the undergraduate preparation of mathematics teachers. In general, curriculum really does matter and schools can make a difference. What the teacher does is important; however, teaching isn't fixable until the curriculum has a clear, universal vision. American schools need more academically prepared educators who are given more instructional preparation time to prepare quality lessons that encourage critical thinking and conceptual understanding and an alternative to the traditional methods of tracking. Issues related to the curriculum and instructional methods of other high achieving countries might be usable in the American classrooms. Teacher education program can better prepare future math teacher when they expose there students to global perspectives and lessons on what works in a math classroom from high performing countries in the area of mathematics. By incorporating the TIMSS results into teacher preparation programs, positive outcomes may result in that our undergraduate mathematics teachers will be better prepared for success in the classroom and for providing for future success of their students performance in the area of mathematics. TIMSS can be the driving force if used in the undergraduate preparation of mathematics teachers for real change and improvement in schools in the USA.

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