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Studying the Effects of Korean Mathematics on American Teachers in Mid-America[1,2]

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Asian mathematics curricula and textbooks are being recognized in the United States as at least partial explanation for the higher mathematics achievement of students in Asian countries compared to students in the United States. As a result there is considerable interest among many educators in the United States in curricula from Singapore and curricula from Japan. In addition, researchers and educators at one university in the American heartland have been using the English translations of a Korean primary mathematics curriculum for professional development and assessment with groups of Missouri teachers for the purpose of enhancing teachers' understanding of the fundamentals of mathematics, and in hopes of raising student achievement scores. A professional development initiative begun seven years ago and revived this year will entail a rigorous assessment which will be reported in 2009. Results of assessment of the earlier initiatives are reported here.

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ZDM Classification: C70, D10, U20
MSC2000 Classification: 97C70, 97D10, 97U20

1. INTEREST IN ASIAN MATHEMATICS CURRICULA IN THE WEST

Mathematics achievement scores for 8th and 12th graders in the United States have remained alarmingly low as indicated on the Third/Trends International Mathematics and

[1] This paper will be presented at the 40th Korean National Meeting of Mathematics Education at Seoul National University, Seoul, Korea; May 16–17, 2008.

[2] This study is partially funded by federal No Child Left Behind funds granted to the author at Truman State University through the Missouri Department of Higher Education, in collaboration with several elementary and secondary Missouri School Districts and the Northeast Regional Professional Development Center located in the Department of Education at Truman State University.

Science Study (TIMSS) published in 1995, 1999, and 2003. Asian student scores in Singapore, Korea, and Japan, on the other hand, indicate high performance on primary and middle school mathematics in those countries.

While explanations for the differences in mathematics achievement in Asian countries and in America often cite cultural differences on the two continents, the TIMSS and other data have allowed some researchers to highlight classroom explanations for superior Asian mathematics achievement in Asian classrooms. Those explanations include a focused, more narrow and rigorous curriculum and textbooks, coherent lessons, and rigorous teacher content knowledge (Mayer, Sims & Tajika, 1995; Schmidt, McKnight & Raizen, 1996; Stevenson & Lee, 1995; Stigler & Hiebert, 1999; Stigler, Gonzales, Kawanaka, Knoll, & Serrano, 1999; Ma, 1999; Grow-Maienza, Hahn & Joo, 2001; Cai & Wang, 2006; Wang & Cai, 2007a; 2007b).

A widely read book in the United States is Liping Ma's *Knowing and Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States* (1999). Ma reports in detail the results of her in-depth interview study of the mathematical understanding of Chinese elementary teachers and American teachers. Ma demonstrates in her study the superior "knowledge packages" that Chinese teachers reveal when they discuss their pedagogy for teaching primary mathematics concepts. Chinese teachers focus on developing the conceptual underpinnings of mathematics. American teachers, by contrast, generally focus on procedures. Others have reported the concentration on developing conceptual understanding that is observed in Asian classrooms (Stevenson & Lee, 1995; Stigler & Hiebert, 1998; Hahn & Grow-Maienza, 1998; Grow-Maienza, Hahn & Joo, 2001; Cai, 2005; Wang & Cai, 2007a; 2007b).

Ma (1999) suggests that American teachers focus on procedures because they themselves lack deep conceptual understanding of the underpinnings of fundamental mathematics. In his forward to Ma's book, Lee Shulman suggests that Ma's findings should be very relevant to university professors and teacher educators in the United States. Future teachers are coming to teacher preparation programs without the fundamental mathematics knowledge needed to teach primary mathematics. Those teachers must get that fundamental knowledge in their university teacher preparation programs. In China, says Ma, teachers have received the fundamentals of mathematics from their own elementary and middle school teachers.

As a solution to the "math wars" over whether to teach procedural skills or in-depth understanding, educators in the United States are waking up to the notion that procedural skills and conceptual development should not, cannot (Geary, 1994; 1995) be separated. Further, American educators are turning attention to the problem of too broad a curriculum. Schmidt (1998) pointed out the differences in

focus in Asian curricula and American curricula when he termed Asian curricula focused and in-depth, American curricula "a mile wide and an inch deep." The National Research Council and the National Council of Teachers of Mathematics in the United States are today recommending narrowing the focus of mathematics education in the United States and developing focused and coherent curricula for improving teachers' content and pedagogical knowledge and student learning (Kilpatrick and Swafford, 2002; NCTM, 2006). And practitioners are beginning to look at Asian curricula and texts.

Indeed, interest in Asian curricula and texts is becoming very keen. English translations of Japanese primary mathematics texts are now being sold on line in the United States.[3] Sales of an American version of Singapore Mathematics are going strong in the United States and being credited with raising mathematics achievement scores in many school districts (*Wall Street Journal*, December 13, 2004, p. A1).[4] The *Los Angeles Times*[5] reported this year that Ramona School in Los Angeles, an urban school in which only 45% of the students were at grade level in mathematics in 2005, claimed 70% of their students were at grade level in 2007. School officials were attributing the positive change to use of Singapore Mathematics in the classrooms (*LA Times*, March 9, 2008).[6] In Wentzville, Missouri, near the large city of St. Louis, the entire school district is adopting Singapore Mathematics in fall 2008. Parents and teachers are being prepared for the new system and looking forward to a rise in mathematics achievement for their students (*St. Louis Post-Dispatch*, April 6, 2008).[7]

2. THE MISSOURI MID-AMERICA INITIATIVE

In northern Missouri, at Truman State University, 50 teachers in 10 to 20 different school districts will be introduced to another Asian curriculum in August, the English translations of the 6th national curriculum of Korea, now called *gecKo mathematics*[8].

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[3] Accessed at http://www.globaledresources.com/products/books/math_elementary/index.html

[4] Accessed at http://www.nychold.com/art-wsj-041213.html.

[5] Landsbert, R. (2008). *At L. A. school, Singapore math has added value.* Los Angeles Times, March 9, 2008. Accessed at http://www.latimes.com/news/local/la-me-math9mar09,0,1449785.story

[6] Accessed at http://www.latimes.com/news/printedition/front/la-me-math9mar09,1,5861820.story.

[7] Accessed at http://www.stltoday.com/stltoday/news/stories.nsf/stcharles/story/B4C692CF1C0B988F862574230003298D?OpenDocument.

[8] gecKo mathematics (2008). Korean Mathematics in American Classrooms Edited by J. Grow-Maienza. Adapted from Korean Mathematics (2001). Kirksville, MO: Truman State University. http://kmath.truman.edu/

Janice Grow-Maienza, Professor of Education at Truman will lead a two-week mathematics institute in which teachers will be introduced to a 20-chapter pre-algebra module comprised of all the chapters across grade levels 2 through 5 on multiplication, division, fractions and decimals. The module is adapted from the English translations of the Korean 6th National Mathematics Curriculum for Grades 1–6 (Korean Ministry, 1993).

In this initiative teachers' conceptual understanding of fundamental mathematics and pedagogy is expected to be enhanced by a focus on the underlying principles of the 20-chapter pre-algebra module adapted from the Korean curriculum[9] which will be made available to the teachers online after the institute. Ma's notion of "knowledge packages" Chinese teachers demonstrate in their primary mathematics pedagogy will be demonstrated in the materials adapted from the Korean national mathematics curriculum. Teachers will be facilitated in developing units of instruction implementing the module into their own curricula. Teacher participants will incorporate the module into their respective curricula during the academic year 2008.

Effects of the professional development initiative on teachers' conceptual understanding of the content will be measured externally and internally by a collaborative team at the University of Missouri and Truman State University. Teacher knowledge will be assessed before and after the Institute, as well as at the end of the academic year 2008–2009. In addition, effects on mathematics achievement of pupils in teacher participants' classrooms will be measured in the academic year 2008–2009.

The professional development initiative will be assessed internally to investigate the effect of the two-week institute on teacher knowledge of fundamental mathematics. Gains in teacher knowledge will be measured with an instrument adapted from

1) Released items from the TIMSS 1995 and TIMSS 2003,
2) Interview questions referenced in Ma (1999), and
3) Problems from the English translations of the sixth national mathematics curriculum of Korea. The protocol for the external assessment is attached.

The institute and internal assessment of the effects of introduction to materials based on the Korean primary curriculum is being piloted in April, 2008, in a Master of Arts in Education course for pre-service teachers at Truman State University/ Subjects are 42 Master of Arts in Education candidates who will enter teaching internships in Fall, 2008. Results of the pilot will be reported at the May, 2008, Korean Research in Mathematics

[9] The English translations of the sixth national primary mathematics curriculum of Korea were partially funded by the National Science Foundation in 2000 and the Eisenhower Foundation in 2002 and 2003. Grow-Maienza's analysis of the translations can be accessed under *Report on Korean Mathematics to NSF* at the link at http://eisenhowermathematics.truman.edu

Education conference in Seoul, Korea. Effects of the Institute on practicing teachers will be reported in the fall of 2008, and in the spring of 2009.

3. RESULTS FROM PREVIOUS RESEARCH[10]

Grow-Maienza's present work began with the observation study she conducted with Hahn and Joo in 32 1st and 5th grade mathematics classes in Pusan in 1995–1996 (Grow-Maienza, Hahn and Joo, 2001). The authors reported the salience of coherent lessons focused on conceptualization of mathematical constructs in their findings. In analyzing the classroom data, the authors discovered that teachers were staying very close to the textbook. For this reason, Grow-Maienza took the series back to the States and had the entire series, grades 1 through 6 translated into English with funding from the National Science Foundation (NSF) (Grow-Maienza, 2002).

In her analytical report to the NSF, Grow-Maienza (2002) described the role of connections within and among constructs and strategies in the Korean mathematics series. She noted particularly:

1) the focus on the inverse relationships in the operations, between addition and subtraction, and between multiplication and division;
2) the focus on the base 10 decimal system in the presentation of operations;
3) the role of the use of multiple strategies and ways of modeling constructs and formatting problems to encourage flexibility; and
4) other connections and relationships such as the mutual and equivalent relationship of fractions, decimals, ratio, and proportion (Grow-Maienza, Beal, and Randolph, 2003).

Grow-Maienza pointed to this coherent focus on mathematical concepts and relationships as something lacking in many American curricula and in many schools in America. The United States, as is well known, does not have a national mathematics curriculum for elementary and middle school students.

The teacher institute described above is not the first time Missouri teachers have been

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[10] Results from previous research reported here were first reported in Grow-Maienza, J.; Minner, S.; Olsen, S. & Bethel, D. (2003). *Use of Conceptually Based Mathematics Curricula for Professional Development of Teachers.* Paper presented in session titled Teacher Learning in Mathematics for Division K, Section 1: Teaching Practices, Knowledge, and Education in Mathematics and Science, American Educational Research Association annual meeting, Chicago.

introduced to materials based on Korea's Sixth National Mathematics Curriculum. In the past 10 years, Grow-Maienza, with colleagues and students, has conducted several studies in numerous individual classrooms implementing modules developed from the Korean mathematics materials.

In a mathematics education initiative at Truman State University funded by the Eisenhower Professional Development program through the Missouri Coordinating Board of Higher Education in 2001 and 2002, 100 teachers and administrators from 37 school districts in Northeast and Central Missouri participated in 6-day workshops and follow-up meetings to build instructional modules focused on conceptualization of the constructs in the NCTM (2000) content standards (Grow-Maienza, Minner, Olsen, and Bethel, 2003). Participants received background input from 15 faculty and consultants from Truman State University, the Missouri State Department of Education, and the Northeast Missouri Regional Professional Development Center.

Input was given on TIMSS data, the NCTM (2000) content standards, the Missouri Assessment Program, Missouri Show-Me Standards and Missouri Frameworks for Curriculum Development, and on conceptually based curricula. The major resource, in addition to the NSF-funded reform curricula, *Everyday Mathematics* (UCSMP, 1999), *Investigations* (TERC, 1998), and *Trailblazers* (TIMS, 1997), was the newly translated Korean mathematics series for Grades 1–6 (*Korean Mathematics*, 2001). The purpose of the professional development initiative was to help teachers improve their conceptualization of constructs recommended in the NCTM content standards and the Missouri state standards, and ultimately to increase mathematics achievement of elementary and middle school students in Missouri.

Teams of teachers, armed with district assessment data and state and district curriculum guidelines, and selected content on which to develop modules at two pre-planning meetings. The same teams of teachers and administrators developed modules of instruction ranging in size from one to 32 lessons during the workshops. Resources used in development of the modules included National Science Foundation-funded reform curricula: *Everyday Mathematics, Investigations,* and *Trailblazers.* The major resources, however, were *Korean Mathematics*. Some modules developed in the initiative focused on one grade level. Others focused on one construct across grade levels. Choosing the former option, one middle school mathematics teacher developed the 4-lesson module for 8th grade summarized for its alignment with state and national standards in Table 1. Topics of the lessons were the characteristics of prisms, cylinders, and pyramids that included the concepts of volume and surface area for each, and the relationship between volume and surface area. Resources from both *Korean Mathematics, Grade 5-2,* and *Mathscape*, the text ordinarily used by the developer, were used in her unit on Geometric and Spatial Sense.

The modules produced in the initiative are generally of high quality, and in a format that can be used by other teachers immediately, given the necessary resources. All the modules can be accessed by teachers and other interested parties at the website created for the Eisenhower mathematics initiative at Truman in 2002.[11] Modules were implemented in the respective classrooms of participants, and results reported at follow-up meetings in November 2001, May 2002, October, 2002, and May, 2003.

Table 1. Summary of Module Alignment with State and National Standards

Modules based on Show-Me Standards, Missouri Frameworks for Curriculum Development	NCTM Content Strand	Grade Level	Concepts Addressed in Module
Geometric and Spatial Sense	Use of visualization, spatial reasoning, and geometric modeling to solve problems	8th	Rectangular prisms; triangular prisms; surface area of prisms, cylinders, and pyramids; volume, relationship of volume and surface area.

Assessment and Results of Early Initiatives

Three kinds of assessment were conducted to determine results of the initiative. First, teachers who participated in the workshop were assessed on their beliefs about mathematics and mathematics teaching prior to and after participation in the workshop. Second, formative evaluation data were collected after each phase of the initiative, that is, before and after each workshop, and at the end of the following academic year. Finally, student achievement was assessed. Participants' pupils instructed on a construct using a module developed from the Korean materials were compared with control groups on conceptual understanding of the construct. Significant results and gain scores from some of the pupil data are reported below.

Student Achievement Data

Pre- and post-assessment instruments are part of each module developed in the Eisenhower mathematics initiative at Truman, and can be viewed in the modules on the webpage.[12] Participants implemented the modules in their respective districts in the academic year 2001-02 and in the academic year 2002-03. Student assessment data were obtained in three districts the first year, in several more districts the second year. Results for the 2001 initiative show greater achievement on conceptualization of constructs in students exposed to modules developed from *Korean Mathematics*

[11] http://eisenhowermathematics.truman.edu
[12] http://eisenhowermathematics.truman.edu/

compared to control groups using only *Everyday Mathematics* (Dick, 2002), *Investigations* (Mues, 2002) or traditional materials (Sebastiao, 2002; Quinn, 2002). Dick, for instance, in her study of the effects of supplementing *Everyday Mathematics* with a module on multiplication of fractions from *Korean Mathematics*, obtained statistical significance on post-test scores at the .01 level between the control group and the experimental group of fifth graders in the direction of the experimental group. The experimental group had statistically higher scores on both calculation items, and on student constructed response items addressing conceptual questions (Dick, 2002).

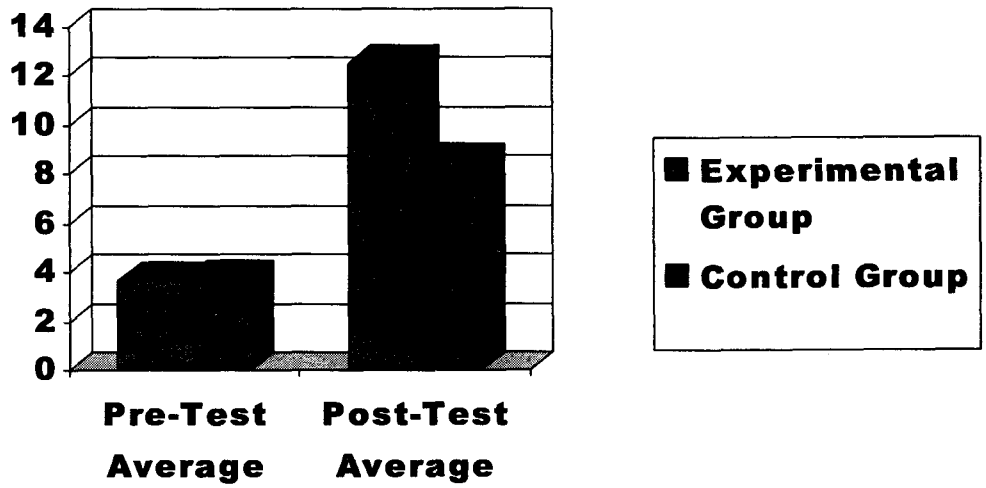

Figure 1. Results from (Dick, 2002)

In Sebastiao's study of 3rd grade division, learning of division did occur in both the experimental group (*Korean Mathematics)* and the control group (*Scott Foresman).* The differences between pre- and post-test scores were analyzed with t-tests to determine if significant differences were found. Statistical differences were found in favor of the experimental group, demonstrating that more learning took place with the integration of the Korean modification ($p = 0.0009$; $\alpha = 0.1$) (Sebastiao, 2002, 17).

A team of participating teachers from Northeast Randolph R-IV School District in Missouri presented results in the fall of 2002 which show significant gains for third grade students exposed to a conceptually-based module over a control group taught the same concept with traditional materials (Wyatt, Roth, & Thornton, 2002; Grow-Maienza, Roth, & Dick, 2002). Several objectives on "telling time" were taught to two third grade groups, the *Korean Mathematics* module taught to an experimental group, the control group taught with Houghton Mifflin's *Math Central* materials. No significant differences were

found between pre-tests for the experimental and control groups, nor for post-tests for the two groups. As seen in Table 1 below, significant differences were found between the gains of the two groups, favoring the experimental group at the .02 level.

Table 2. t-test scores for 2 groups of third graders taught "telling time" using a Korean Mathematics module (Experimental Group), or a Houghton Mifflin Central Math unit (Control Group) on pre-test, post-test, and gain scores.

	Pre Test		Post Test		Gain	
	Control	Experimental	Control	Experimental	Control	Experimental
	74	16	75	60	1	44
	37	21	50	60	13	39
	37	26	65	75	28	49
	42	47	75	90	33	43
	42	47	85	85	43	38
	68	47	55	75	-13	28
	53	53	70	90	17	37
	68	58	85	80	17	22
	37	63	40	80	3	17
	68	63	65	85	-3	22
	53	68	55	95	2	27
	63	95	90	85	27	-10
	53.50	50.33	67.50	80.00	14.00	29.67
	14.21	22.07	15.44	11.07	16.61	16.03
t-test		0.19		0.07		0.028

From: Wyatt, Roth & Thornton, 2002

4. CLOSING REMARKS

The earlier studies described above produced some interesting quantitative and qualitative data on effects of introducing various instructional modules based on Korean mathematics to various groups of elementary students.

Researchers' ability to generalize from these studies is necessarily limited. Each study was assessed with an idiosyncratic instrument designed by the teacher/researcher. Control groups in the studies were exposed to several different curricula to be compared to the Korean module. No cognitive data, only attitudinal data were gathered on teachers in these studies. And no external assessment was conducted in the studies.

In the current study which will be completed in the fall of 2009 it is expected that data gathered will be very useful for making generalizations about the impact of material

adapted from Korean mathematics on teacher knowledge in Missouri as well as on the mathematical achievement of students. All participants in the current study will be developing modules from *gecKo mathematics* materials adapted from Korean mathematics. The external and internal assessment teams will develop common assessment instruments for teachers, and similar assessment instruments with some common elements for each group of elementary and middle school pupils. The protocol for the external assessment of teacher participants in the Institute is attached in the Appendix. It is expected that data will be collected that will provide an opportunity for rigorous analysis that can be generalized to some very useful conclusions about the efficacy of employing mathematical modules adapted from Korean mathematics to Missouri children. The rigorous assessment of teacher participants in the current study is expected to provide insight into ways to enhance American teachers' own in-depth understanding of the underlying principles of elementary mathematics.

5. IMPLICATIONS FOR CLASSROOMS IN AMERICA AND OTHER ENGLISH-SPEAKING COUNTRIES: *a word from the author*

gecKo mathematics is a work in progress. Six chapters on fractions and decimals, both student texts and teacher manuals, are currently online at a Truman State University website.[13] As developer and editor of *gecKo mathematics,* Grow-Maienza hopes to see the entire series, now in manuscript form, online, available to teachers, parents, and students all over the English-speaking world. Why materials adapted from Korean mathematics? Why not Singapore mathematics, originally developed in English? Why not Japanese mathematics, sold today online?

The classroom observation study that began Grow-Maienza's work on the Korean textbook series was conducted out of Pusan National University. When graduate research assistants at PNU told Grow-Maienza "The teachers are staying very close to the text book," Grow-Maienza responded, "Let me see that textbook!" The first lesson translated told Grow-Maienza, "It's all here!" The concepts were laid out consistently, systematically, coherently. The teacher manuals were rich in mathematical background for teachers. The Singapore and Japanese text series in English have no teacher manuals. Korea has made a unique and important contribution to the western world in the development of consistent written materials for teachers to accompany the systematic coherent primary mathematics curriculum. The English-speaking world owes gratitude to Korean educators.

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[13] http://gecKomath.truman.edu/lessons

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APPENDIX

Cycle 6 Professional Development Evaluation Data Collection Schedule

	Summer Institute 2008			School Year									Notes
	Start	Middle	End	Start			Middle			End of Project			
Participating Teachers													
General													
Teacher Participant Data Questionnaire	X												On-line – 30 min
Interview (4-8 selected)			X									X	Selected – 45 min
Horizon Observation + field notes			X									X	
Content Knowledge													
Project-specific knowledge exam Pre-Post Design	X		X									X	Project develops & admins
Inquiry / Pedagogy													
Classroom Practice Instrument	X											X	On-line- 20 min (pre),
													30 min (post)
Project Evaluation													
Teachers' PD Evaluation Survey			X									X	On-line – 20 min
Other Project-specific Measures													
*Observations of Teachers/Classrooms													Project develops & admins
*Teacher attitudes													Project develops & admins

(Continued)

	Summer Institute 2008			School Year									Notes
	Start	Middle	End	Start			Middle			End of Project			
Teachers' Students													
Content Knowledge													
*Teacher / project developed tests Pre-Post Design				X			X					X	Teacher develops & admins
District administered standardized tests (MAP and/or others)				X							X	X	District administered - collect administrative data
PD Directors / Instructors													
Classroom Practice Instrument (pre)	X												On-line - 20 min
Interview			X										Director & staff - 1 hour
Higher Ed Impact Questionnaire												X	On-line - 20 min