AC 2007-3069: ADAPTING A POST-SECONDARY STEM INSTRUCTIONAL MODEL TO K-5 MATHEMATICS INSTRUCTION

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Adapting a Post-Secondary STEM Instructional Model to K-5 Mathematics Instruction

Abstract

If Science, Technology, Engineering, and Mathematics (STEM) education is to be improved, knowledge about teaching and learning for STEM disciplines should be a fundamental consideration in curriculum design, beginning at the earliest grades. This study examines the efficacy of a mathematics project that adapts a post-secondary instructional model developed by Richard M. Felder and Elizabeth Brent to the lesson design of an elementary mathematics curriculum that includes materials for K-5 classrooms and for K-5 teacher development. The purpose of this paper is to describe how the Felder/Brent instructional model for post-secondary engineering students adapts to an elementary environment and to share preliminary findings in student mathematical achievement and program implementation.

Introduction

Enabling students from the earliest grades to develop confidence and competence in mathematics prepares them for a competitive job market and makes higher education more accessible. Failure to advance in Science, Technology, Engineering, and Mathematics (STEM) "gate keeper" courses is by far the leading cause of low numbers of Americans who are prepared to enter technical jobs out of high school or to enter engineer/technical degree programs at universities in this country. Preparing students to enter the job market or degree programs with mathematical confidence and competence not only increases their own personal opportunities, but it also contributes to the advancement of a well-prepared and competent American citizenry. Consequently, STEM preparation at the earliest grades is not only a matter of personal equity, but also a matter of social responsibility.

Because the foundation for STEM careers is laid in elementary classrooms, a pre-engineering mathematics curriculum program is a long overdue consideration. A team of K-16 educators and elementary classroom teachers, under the guidance of faculty from the College of Engineering and Science at Clemson University are developing a K-5 mathematics curriculum program designed to prepare students for STEM disciplines and to prepare teachers to effectively implement the program. This curriculum is designed to provide elementary students with the kinds of learning experiences that will not only prepare them for higher level STEM courses, but will also provide them with an interactive learning environment where communication and collaboration skills are developed. Such collaborative working environments are essential to production in many of today's STEM careers. Thus if students expect to succeed in engineering and technical fields, preparation must begin in the early grades to ensure that students have the kinds of learning experiences that enable them to advance through gate keeper courses and beyond.

Features of the Curriculum

The K-5 pre-engineering mathematics curriculum program, Math Out of the Box™, described in this paper has been designed based on the premise that access to innovative learning tools and well prepared teachers is a matter of equity and social responsibility. In school districts across the nation, shortages of qualified teachers and diminished resources for professional development and instructional materials prevail, and nowhere more acutely than in the high poverty communities, where math achievement for students is at the lowest.[17] In response to this disparity, the developers of this program have partnered with districts in culturally isolated, high poverty communities to provide the material and professional development resources needed to meet the challenge of preparing *all students* for STEM educational opportunities.

Instructional Materials—Research has shown that if children are to develop abstract concepts they must use their senses to investigate concrete representations of those concepts. Pictures in a book or concrete examples demonstrated by the teacher are not sufficient for students to develop meaningful understanding of complex ideas. They need to manipulate the materials and investigate the ideas in ways that help them to personally develop the concepts. All children, from every socio-economic class, are entitled to these kinds of experiences. The Math out of the Box curriculum program described in this paper meets this challenge by including inquiry-based lessons and all the instructional materials needed to teach those lessons, so that in a class of 30 children, every single child has the opportunity to explore how things fit together and come apart, how things are similar and different, and which ideas make sense and which do not. By including these instructional resources, this curriculum program incorporates "learning-by-doing" theories of cognition. Providing teachers with resources that support such theories ensures that "abstract instruction and concrete illustrations" are combined so that students are engaged in cognitive processes that support both retention and transference of knowledge.[1]

In addition to the materials designed for K-5 classrooms, this curriculum program also includes instructional resources that focus on teacher development. Research suggests that the single most significant factor in laying a solid mathematical foundation in the formative K-5 years is the elementary teacher. By focusing on the learning needs of both students and their teachers, this synergetic pre-engineering curriculum program enables teachers and students to develop confidence and competence in math. The teacher materials are designed based on the premise that teachers need to experience inquiry as a learner before they can support it as a teacher. Using the student materials as a basis for teacher development is a groundbreaking approach to teacher education that is documented in the literature and supported by research.[2,8,9,10,16,18,21,22,23,24,29] The student materials and tasks are adapted so that teachers can explore the mathematical ideas in ways that will help strengthen their understanding of the concepts and improve their ability to help children develop those concepts. In short this curriculum program is developed so that teachers are provided the resources and training they need to create and support mathematical environments where diverse learners work together to develop mathematical confidence and competence.

Instructional Model—Math Out of the Box is an inquiry-based curriculum program designed to promote the development of STEM faculties and to provide learning opportunities for diverse groups of students. Recent studies in cognitive psychology have led to many of the currently held views of intelligence and cognition. Such studies highlight ways to increase educational effectiveness in STEM disciplines by improving instructional methods.[1,4,7,12,15,19,30] Two of the foremost leaders in the study of the intellectual development of science and engineering students at the post-secondary level are Richard M. Felder and Rebecca Brent. Felder and Brent propose an instructional model that is designed to advance students in a "developmental progression" in which they take "increasing responsibility for their own learning" (p. 279).[14] Five components comprise this instructional model: 1) variety and choice of learning tasks; 2) explicit communication and explanation of expectations; 3) modeling, practice, and constructive feed-back on high level tasks; 4) a student-centered instructional environment; and 5) respect for students at all levels of development.

The instructional model recommended by Felder and Brent is based on the STAR Legacy learning cycle that was first conceived and developed through the NSF-funded VaNTH initiative for engineering education at Vanderbilt University.[5,6,26,27] The instructional approach supported by learning cycles like the STAR Legacy module is consistent with the principles of cognitive science and based on the *How People Learn* Framework[5] which consists of the following four elements:

i) Learner-centeredness: The class environment and instructional tasks take into account the knowledge, skills, preconceptions, and learning styles of learners.
ii) Knowledge-centeredness: Instructional tasks that help students learn with understanding by thinking qualitatively and by organizing their knowledge around key concepts.
iii) Assessment-centeredness: Frequent opportunities are provided for students to make their thinking visible in order to help them refine their understanding.
iv) Community-centeredness: Classroom norms are fostered that encourage students to learn from one another and that recognize the teacher as a co-learner.

Each lesson in the Math Out of the Box program is designed based on a four phase learning cycle *Engage-Investigate-Reflect-Apply* (Diagram A) that is similar to the five phase STAR Legacy learning cycle, *Challenge-Initial Thoughts-Perspectives/Resources-Assessment-Publish*, which is the basis of the Felder/Brent Instructional Model. Diagram B provides a detailed comparison of the STAR Legacy learning cycle and the Math Out of the Box learning cycle.

Diagram A: The K-5 Pre-Engineering Learning Cycle from Math Out of the Box™

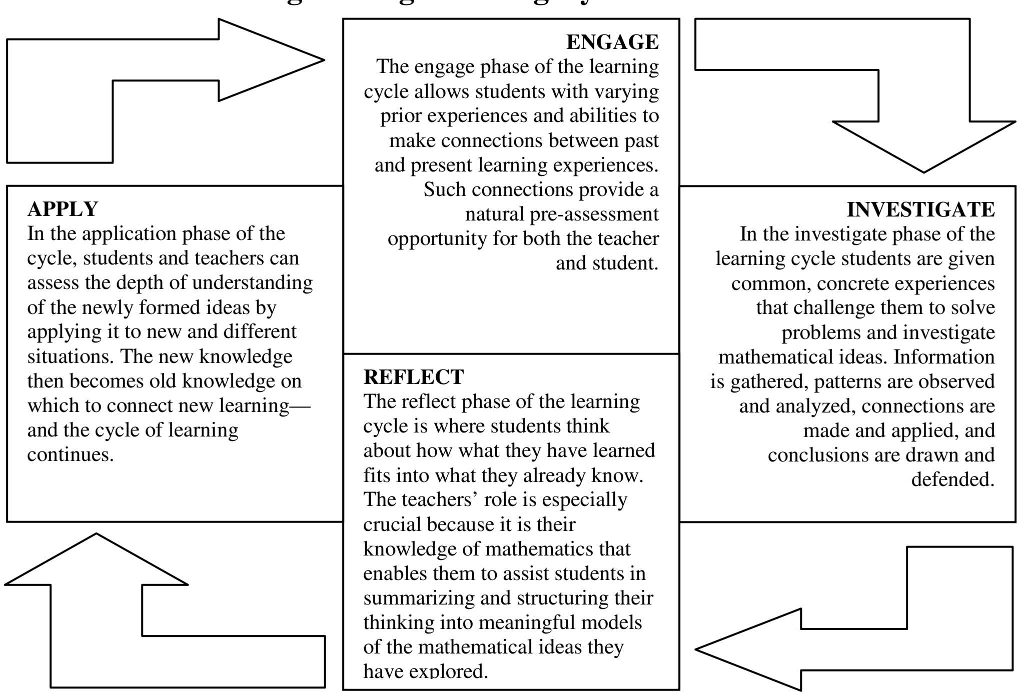


Diagram B: Comparison of the Legacy™ Cycle and the Math Out of the Box™ Cycle

STAR Legacy Learning Cycle™	Supportive Research	Math Out of the Box Learning Cycle™
Challenge Each cycle begins with a *Challenge*, a realistic scenario that educational professionals may encounter. **Initial Thoughts** The *Initial Thoughts* component gives students the opportunity to explore what they currently know about the opening scenario, even if their initial responses to the Challenge are naïve.	Experts in cognitive science and brain research[1,30] emphasize the retentive importance of connecting new knowledge to prior knowledge. The *Challenge* is an effective instructional method, based on cognitive research, that anchors specific content around challenges that serve as entry points into a series of learning activities.[6]	**Engage** The *Engage* phase of the pre-engineering learning cycle encompasses the first two phases of the Legacy Learning Cycle. In this phase, teachers present a scenario (*Challenge*) to students to solicit their original thoughts (*Initial Thoughts*) concerning the topic. This phase is designed to allow students with varying prior experiences and abilities to connect between past and present learning experiences. Such connections provide natural pre-assessment opportunities for both teachers and students. By soliciting prior knowledge during the *Engage* phase of the learning cycle, the lesson design embeds instructional strategies that support the research of what is known about how people learn.
Perspectives and Resources The *Perspectives and Resources* phase of the cycle is presented within the context of a "real-life" situation. Consequently, most students immediately see the relevance of the content provided here. Through a series of activities and materials students use the content of the module to investigate resources that are pertinent to the topic and to learn different perspectives, both of experts and peers.	This phase of the cycle is based on "the cognitive principle of assimilation which implies that understanding cannot be imposed" upon learners but instead must "progress developmentally" from concrete to abstract opportunities (pp.56-57).[3]	**Investigate** The *Investigate* phase of the pre-engineering learning cycle provides students with common, concrete experiences that challenge them to solve problems and investigate mathematical ideas. Information is gathered, patterns are observed and analyzed, connections are made and applied, and conclusions are drawn and defended. As patterns are observed and connections made, students engage in mathematical reasoning and problem solving that support conceptual understanding and procedural development.
Assessment The *Assessment* phase provides students the opportunity to apply what they know and to identify those topics requiring additional study. They are encouraged to return to the module's resources to re-study content until they are able to solve the opening challenge.	Schon[25] described two types of reflection—reflection-in-action, which is known as "thinking on our feet," and reflection-on-action, which involves exploring why we think the way we do. This linked process of reflection, in-action and on-action, compels students to take responsibility for their learning.	**Reflect (in-action)** The learning cycle structure provides for continuous reflection-in-action as students represent, verbally communicate, and compare their findings throughout each lesson. **Reflect (on-action)** The *Reflect* phase of the learning cycle provides an opportunity for focused reflection-on-action as students are asked to examine and explain their thinking by writing about what and how they have learned.
Publish The *Publish* phase concludes the module lesson. Students make public what they have learned through presentations, written papers, or online postings. Students are expected to use this opportunity to reflect upon their initial thoughts and assess the learning that has occurred throughout the Legacy Cycle.	Singley and Anderson[28] argued that application, or transfer between tasks, is a function of the number of different representations and opportunities to engage available to students over a course of study. Providing students with opportunities to investigate a variety of representations and to engage in numerous tasks with a similar focus secures the transfer of learning.	**Apply** As the information gathering process comes together, students make connections to past learning, new knowledge, and real world experiences. Students are far more likely to retain their ideas and concepts as they begin to see patterns and make connections to their knowledge of the world. Students are challenged to apply their knowledge to new or different situations and to explore broader or deeper applications of their discoveries. In the *Apply* phase of the cycle, both students and teachers can assess the depth of understanding of the newly formed ideas, as the knowledge gained is connected to new learning—and the cycle of learning begins again.

Excerpts from a Fifth Grade Lesson

The structure of the Math Out of the Box learning cycle is such that the five components recommended by Felder and Brent in their instructional model—1) variety and choice of learning tasks; 2) explicit communication and explanation of expectations; 3) modeling, practice, and constructive feed-back on high level tasks; 4) a student-centered instructional environment; and 5) respect for students at all levels of development—are embedded throughout each lesson. In each Math Out of the Box K-5 lesson, students are: 1) given variety and choice in learning tasks; 2) expected to communicate their thinking both verbally and in writing; 3) provided opportunities to model and practice with other students, with the expectation of constructive feed-back from peers and the teacher; 4) given tasks that are student-centered in nature; and 5) expected to work cooperatively in various group configurations to accomplish tasks. What follows are excerpts from each phase of the learning cycle from a fifth grade lesson, *Lesson 6: Creating a Growing Pattern*[11] with commentary explaining how the lesson components satisfy the Felder/Brent instructional model and support students in developing important mathematical ideas. The lesson is the sixth lesson in the Algebra unit. In the five previous lessons students have used a variety of concrete models to investigate number sequences. Using the concrete models, students have extended number sequences, found missing numbers in the sequences, made predictions about the sequences, and described recursive patterns in the sequences. They have also learned to organize their findings using the convention of input-output tables to aid in their investigations. In the sixth lesson, students are provided a simple recursive rule for creating a growing pattern. They are then instructed to create a concrete model of the growing pattern, to generate the number sequence associated with the growing pattern, and to determine an explicit rule, using words and variables, that will generate the elements of the number sequence.

In the **ENGAGE** phase of the learning cycle students demonstrate their prior knowledge and the teacher assesses how that prior knowledge fits into the lesson objectives. In Lesson 6 each pair of students is provided with a whiteboard, marker/eraser set, and a set of magnetic color tiles and is directed to create the first step of a growing pattern using four tiles. Then each pair of students is instructed to extend their growing pattern up to four additional steps, growing each successive step by four more tiles. All students are given the same parameters for creating a growing pattern, but each pair of students is at liberty to use the constraints of those parameters to create a unique growing pattern. Thus, the *student-centered* learning task provides students with *variety and choice* and a certain amount of autonomy, but within described parameters. The shared parameters ensure that all students will generate similar outcomes for discussion purposes, while the autonomy in creating the growing pattern allows students to investigate those outcomes using models that have meaning to them. Thus students use their prior knowledge to create meaningful models that will be used as they build new knowledge.

In the **INVESTIGATE** phase of the cycle, students gather and organize information, make connections among ideas, and draw conclusions toward some common goal. In Lesson 6, students name their pattern, complete the table, and eventually write an explicit function that generates the elements of the sequence, given a domain of counting "step" numbers. Students organize the information they gather from their model using the convention of an input/output table. In this task, students are provided a learning experience that allows them to make a foundational connection between simple number sequences, that are typically generated recursively, and function tables, for which explicit rules can more easily be discovered. This connection provides a natural transition from recursive relationships to explicit ones. A copy of Record Sheet 6, which students complete with their partners, is provided in the Appendix of this paper. As students work with their partner to complete the Record Sheet they are *provided opportunities to model and practice with other students*, with the *expectation of constructive feedback from peers and the teacher* to follow.

After completing the Record Sheet, students are brought together as a full group and asked to share what they have discovered. During the **REFLECT** phase of the cycle, students assimilate what they have learned with what they already know. The teacher's role during this phase is especially crucial because her selection of who-shares-what plays a pivotal role in how the learning is summarized. In Lesson 6, students are required to verbally communicate to the full class what they have communicated in written form with their partners. Thus students are expected to *work cooperatively in various group configurations to accomplish the task* and they are expected to *communicate their thinking both verbally and in writing*. Communicating first in the safety of a small group or pair provides students the opportunity to *model and practice* before receiving *constructive feedback from peers and the teacher*. The reflect phase of the cycle provides students with opportunities to communicate what *they know*, but it also provides them with opportunities to learn what *their peers know.* Thus, students have an opportunity to assimilate various aspects of what has been learned through the efforts of each pair of students. During this phase of the learning cycle, students learn about what they know, what their peers know, and how all this knowledge fits together.

The **APPLY** phase of the cycle has a number of tasks that can be used to enrich or remediate the lesson objectives. Students may explore a variety of number sequences by growing "letter patterns." A Home Connection task is also offered to provide additional opportunities to investigate a growing pattern using common concrete items found in a child's home. The apply phase of the cycle provides additional opportunities for those students who want to continue to investigate or explore the mathematical ideas of that lesson.

Lesson 6 provides opportunities for students to explore a mathematical concept through the use of concrete experiences and routinely encourages students to communicate their understanding using mathematical language and conventions that are both accurate and developmentally appropriate. By introducing standard mathematical language and conventions throughout the curriculum program, STEM development is fostered and advanced, so that students are not only better prepared to study STEM subjects at higher grade levels, but are better prepared to communicate complex ideas in standard mathematical language, starting at the earliest grades.

By attending to the curriculum design to include instructional materials that provide opportunities for students to explore concepts, and an instructional model that is based on post-secondary engineering education which supports the development of communication and collaborative skills, it is expected that the Math Out of the Box pre-engineering curriculum program will lay a solid foundation for STEM development in elementary students.
By developing the Felder/Brent model of instruction from the earliest grades, it is expected that a pipeline of educated, motivated students will complete the elementary grades better prepared to enter and succeed in STEM disciplines.

Preliminary Results from South Carolina and New Jersey

Two separate evaluation efforts have informed development of this curriculum program. The curriculum developers have tracked student achievement at select field test sites in South Carolina since 2004. Educational Testing Service (ETS) in Princeton, New Jersey has also conducted an external evaluation of the implementation process in a district in New Jersey since 2005. A summary of those findings follow.

South Carolina: Internal Evaluation—In 2004 four South Carolina schools field-tested the third grade algebra unit *Plotting and Growing* during the second semester, prior to the administration of the statewide assessment PACT. The rationale for comparing the third grade students from the four schools in 2003 (prior to introducing this curriculum unit) with the third grade students in 2004 (after introducing the curriculum unit) is based on the similarities of educational expectations and opportunities within each of the four schools over the two year period. Though all four schools differed in terms of demographics, resources, instructional expectations, and educational opportunities, each of these areas remained somewhat constant for both groups of third grade students (2003 and 2004) *within each school*. While being distinct in terms of demographics, instructional expectations, and student populations, the demographics of the collective group of four schools were consistent with South Carolina demographics.

By grouping the tested students from the four schools into two sub-populations, Third Grade Students NOT USING the curriculum unit (2003) and Third Grade Students USING the curriculum unit (2004), reasonable comparisons were made between student subgroups. Using the statewide assessment scores as a basis for comparison (percentage of students meeting standard), PACT achievement levels for the 2003 and 2004 third graders in all four schools were compared to each other and also to third grade students statewide. See Table A for the comparisons among subgroups.

Table A: Third Grade Field Test Results on PACT*

Populations		**Percentage of Students Meeting Standard on PACT**	
		2003 students NOT USING curriculum unit	**2004 students USING curriculum unit**
Third Grade Students	Four Schools	81.3% N=344	**87.3% N=316**
	Statewide Various curricula used	*82.3% N=48,833*	*82.7% N=48,378*
African American Students	Four Schools	69.0% N=155	**82.8% N=128**
	Statewide Various curricula used	*71.6% N=20,021*	*72.8% N=19,351*
White Students	Four Schools	91.2% N=172	**92.4% N=172**
	Statewide Various curricula used	*90.9% N=26,369*	*90.4% 26,124*
Full Pay Meal Plan	Four Schools	89.8% N=147	**94.2% N=137**
	Statewide Various curricula used	*91.8% N=22,463*	*91.1% N=22,253*
Subsidized Meal Plan	Four Schools	74.9% N=195	**81.7% N=180**
	Statewide Various curricula used	*74.6% N=26,369*	*75.7% N=26,124*

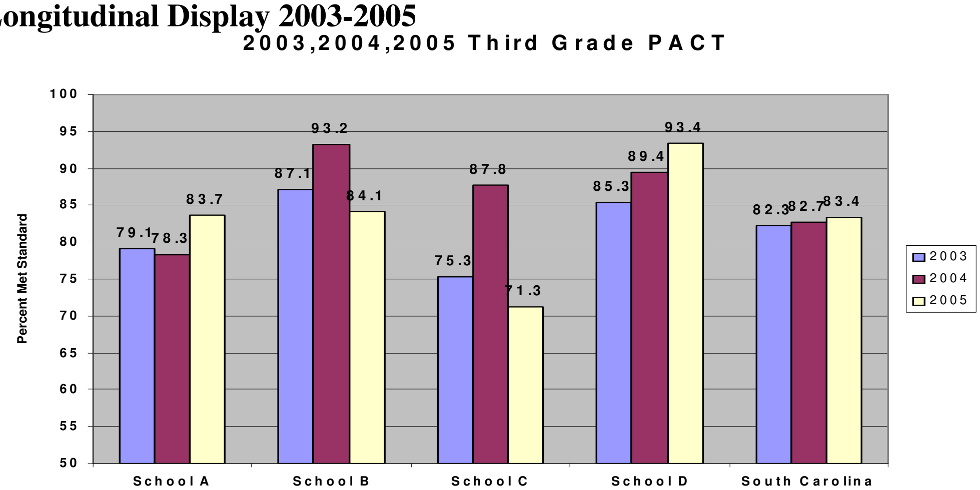
*PACT—Palmetto Achievement Challenge Test, South Carolina statewide assessment, aligned with NCTM mathematics standards, recognized as one of the best state accountability systems in the nation by the Princeton Review.[20]

When comparing the four-school population to the statewide 2003 population, prior to introducing *Plotting and Growing* in the four schools, the percentage of students meeting standard in the four schools was similar to the percentage of students meeting standard statewide. Collective demographics and mathematical achievement in the four schools matched South Carolina demographics and mathematical achievement. In 2004, after introducing *Plotting and Growing* in the four schools, the demographics of the four schools continued to match that of South Carolina, but the percentage of students meeting standard in the four schools *exceeded the statewide percentages for every subgroup*. Most strikingly, the math achievement of two student subgroups, African Americans and subsidized meal assistance recipients, was significantly improved. In meeting the challenge of closing achievement gaps for underrepresented subgroups of students, the significance in improvements in these two subgroups was especially noted.

In the 2004 field test, the curriculum unit, *Plotting and Growing*, consisting of 20 lessons, was taught over a 7 week period, early in the second semester of each of the four schools. In the 2005 field test, a new Geometry unit, *Shapes and Paths*, was implemented in two of the four schools. In those two schools, *Plotting and Growing* was taught during the first semester and *Shapes and Paths* during the second semester. For a variety of reasons, two of the schools chose not to participate in the 2005 Geometry field tests. District pacing guides, new teachers at the grade level, and other factors influenced the extent to which the previous year's Algebra unit *Plotting and Growing* continued to be used in 2005 in the two schools that did not participate in field testing the Geometry unit. New teachers in the two non-participating schools did not use the materials at all, and returning teachers reported using the Algebra materials sporadically rather than consistently as they had been used the previous year.

Of the two schools that continued to participate in the 2005 Geometry field test, using both the Algebra and Geometry units, the percentage of students meeting standard in both schools improved. For the two schools that did not continue to participate in the 2005 field test, where inconsistent or no implementation of the Algebra unit was documented, the percentage of students meeting standard in 2005 fell below the 2003 levels. See Table B for the longitudinal display from 2003 to 2005 in each of the four schools and in the state of South Carolina.

Table B: Longitudinal Display 2003-2005

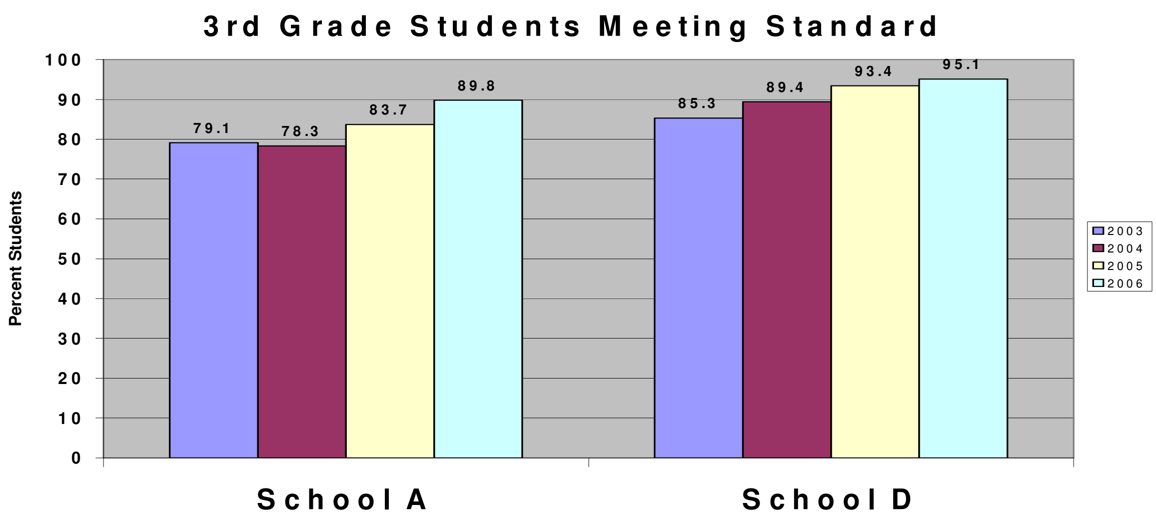


Schools A, B, C, and D all field tested the Algebra module in 2004.
Schools A and D continued to implement Algebra module and field tested Geometry in 2005.

These results, while preliminary and not conclusive, do show *immediate improvement* in three of the four schools during 2004 when all four schools participated in the field test. Conversely, student math scores *immediately declined* in the two schools that discontinued participation in the field test and implementation. Such immediate outcomes, however preliminary, suggests that this program can potentially impact mathematical achievement among students from diverse environments, with diverse groups of teachers.

Schools A and D continue to participate in the field test of new units and to implement the published units. They have continued to show improvement on the statewide PACT assessment. Both schools are designated as Title One schools because of the poverty index of the students who attend the schools. At both schools well over half the students receive subsidized meal assistance. The student population at School A is approximately 80% African American and the student population at School D is approximately 80% white. See Table C for the longitudinal display for each of the two schools 2003-2006.

Table C: Longitudinal Display 2003-2006



The steady climb in student achievement documented at these two schools suggests that teacher proficiency at implementing the curriculum program may be a contributing factor to improved student achievement.

New Jersey: External Evaluation—Educational Testing Service in Princeton, New Jersey is currently conducting an external evaluation of the implementation of the Math Out of the Box curriculum program for the Lawrence Township Public School system. An executive summary report was presented to the school board in August 2006 detailing results from the first year of implementation. The focus of the first year's evaluation was on the fidelity of implementation and on developing assessment items to measure student learning outcomes. The following items summarize the ETS report[13] concerning the implementation of the program with a pilot group of approximately 25 teachers:

- The professional development sessions provided by the developers met the standards for high quality inquiry-based pedagogical training. Teachers, students, and parents were enthusiastic about the program.
- Classroom observations found teachers to be successful in implementing the curriculum program. Students had opportunities to communicate their understanding through discussion and writing. Students were often given the opportunity to work together in collaborative ways.
- Teachers used a variety of questions—both higher order and factual recall, which led to open discussions that provide opportunities for students to analyze and brainstorm about mathematical ideas.

Assessment measures were also developed and field tested during the first year of implementation. ETS reported that a total of 132 multiple-choice items and 36 open ended items were piloted with 245 students in the content areas of Algebra, Geometry, and Data Analysis. The constructed items were found to be similar in construct to the New Jersey assessment items on the statewide mathematics assessment ASK, thereby justifying their use.

Future Research Plans

During the field test phase of this project, two separate issues have influenced program development and revealed a need for further research. The first is the issue of implementation of the program. Fidelity of implementation logically should impact student achievement and thus a need to establish this relationship and to define effective implementation has emerged as a research consideration. The ETS study provides a foundation for establishing a protocol for determining the fidelity of implementation.

The second issue to emerge has been teacher mathematical knowledge. Implementation of the program has revealed misconceptions and deficiencies in teacher knowledge, not only to school leaders, but also to classroom teachers. Planning conversations consistently include clarification of mathematical ideas. Phone calls and emails to developers about mathematical topics in the lessons are common occurrences with teachers who are implementing the program. Thus a need to measure change in teacher mathematical knowledge has also become a research consideration worthy of exploration.

Future research plans include relating the fidelity of implementation of the program to student learning outcomes. In addition, teacher learning will be examined and a method of measuring teacher learning outcomes will be explored.

Bibliography

1. Anderson, J.R., Reder, L.M., and Simon, H.A. (1998). Applications and misapplications of cognitive psychology in mathematics education. Department of Psychology. Carnegie Mellon University. Pittsburgh, PA.
2. Ball, D.L., & Cohen, D.K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher*, 25(9), 6-8,14.

3. Baroody, A.J. & Ginsburg, H.P. (1990). Children's mathematical learning: A cognitive view. In R.B. Davis, C.A. Maher, & N. Noddings (Eds.) *Constructivist Views of the Teaching and Learning of Mathematics (Journal for Research in Mathematics Education* Monograph No. 44, pp. 51-64). Reston, VA: NCTM.
4. Baumgartner, L.M., Lee, M., Birden, S., Flowers, D. (2003). *Adult learning theory: A primer.* Office of Educational Research and Improvement. Washington D.C.: Department of Education.
5. Bransford, J., Brown, A., & Cocking, R. (Eds.). (2000). How People Learn: Brain, Mind, Experience and School. Washington, D.C.: National Academy Press.
6. Brophy, S.P. (2000). Guidelines for Modular Design. Vanderbilt University.
7. Carver, S.M. and Klahr, D. (Eds.). (2001). *Cognition and instruction: Twenty five years of progress.* Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
8. Collopy, R. (2003). Curriculum materials as a professional development tool: How a mathematics textbook affected two teachers' learning. *The Elementary School Journal, 103* (3), 287-312.
9. Davis, E. A. & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational researcher, 34*(3), 3-14.
10. Diaz, D. P. (2004). The role of standards-based curricula in teacher learning and instructional reform. Unpublished doctoral dissertation. Clemson University.
11. Diaz, D.P; Moss, D.A.; Moss, W.F.; Lashley, E.L.; Sanders, S.P. (2005) *Math Out of the Box:Developing Algebraic Thinking*, Rhythm and Design, Grade K; Together and Apart, Grade 1; Collecting and Sorting, Grade 2; Plotting and Growing, Grade 3; Signs and Symbols, Grade 4; Steps and Distance, Grade 5. Carolina Biological Supply, Inc.: Burlington, NC.
12. Doyle, S.K., Edison, M.I., Pascarella, E.T. (2000). *The influence of instructional processes on student cognitive development.* National Center on Postsecondary Teaching, Learning, and Assessment. Washington D.C.: Department of Education.
13. Educational Testing Service. (2006). Executive Summary First Year Report, *Math out of the box curriculum in Lawrence Township Public Schools.* Prepared by P. Handwerk, R. Courtney, & L. Romeo. ETS: Princeton, NJ.
14. Felder, R.M. and Brent, R. (2004). The intellectual development of science and engineering students. II. Teaching to promote growth. *The Journal of Engineering Education 93*(4), 279-291.
15. Grouws, D. and Cebulla, K. (2000). *Improving Student Achievement in Mathematics*. Brussels: International Academy of Education. Retrieved February 14, 2005, from http://www.ibe.unesco.org/International/Publications/EducationalPractices/EducationalPracticesSeriesPdf/prac04e.pdf
16. Harris, C.J. (2006). *Investigating Instructional Practices and Student Learning during the Enactment of an Inquiry-Based Chemistry Unit.* Unpublished doctoral dissertation, University of Michigan, Ann Arbor.
17. Hirsch, E. (2002). *No child left behind's teacher quality provisions*. Retrieved November 19, 2006, from http://www.nga.org/common/issueBriefDetailPrint/1,1434,4194,00.html
18. Lloyd, G. (2002). Mathematics teachers' beliefs and experiences with innovative curriculum materials: The role of curriculum in teacher development. In G. Leder, E. Pehkonen, and G. Törner (Eds.), *Beliefs: A Hidden Variable in Mathematics Education?* (pp. 149-160). Netherlands: Kluwer Academic Publishers.
19. MacRae-Campbell, L. (1989). *The importance of neurological and cognitive research for reading instruction.* Office of Educational Research and Improvement: U.S. Department of Education.
20. Princeton Review (2003). Testing the Testers 2003: An Annual Ranking of State Accountability Systems Executive Summary. Available online: http://www.princetonreview.com/footer/testingTesters.asp
21. Remillard, J. (2000). Can curriculum materials support teachers' learning? Two fourth-grade teachers' use of a new mathematics text. *The Elementary School Journal, 100*(4), 331-350.
22. Reyes, R., Tarr, J., & Chavez, O. (2004). *Do textbooks matter? Findings from a study of NSF and non-NSF mathematics curricular materials.* Paper presented at the 36th Annual Conference of the National Council of Supervisors of Mathematics, Philadelphia.
23. Russell, S.J. (1997). The role of curriculum in teacher development. In S.N. Friel & G.W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in K-6 mathematics* (pp. 247-254). Lanham, MD: University Press of America.
24. Schneider, R.M. & Krajcik, J. (2002). Supporting science teacher learning: The role of educative curriculum materials. *Journal of Science Teacher Education, 13*(3), 221-245.
25. Schon, D. (1983). *The Reflective Practitioner: How Professionals Think in Action.* London: Temple Smith.
26. Schwartz, D.L., Brophy, S., Lin, X., & Bransford, J.D. (1999). Software for managing complex learning: Examples from an educational psychology course. *Educational Technology Research and Development. 47*(2). p. 39-60. [Online: http://peabody.vanderbilt.edu/ctrs/ltc/schwartzD/weblegacy]

27. Schwartz, D.L., Lin, X., Brophy, S., & Bransford, J.D. (1999). Toward the development of flexibly adaptive instructional designs. In Reigeluth (Ed.), *Instructional Design Theories and Models: Volume II.* Hillsdale, NJ: Lawrence Erlbaum Associates.
28. Singley, M.K. & Anderson, J.R. (1989). *Transfer of cognitive Skill.* Cambridge, MA: Harvard University Press.
29. Spencer, D., Chiappinelli, K., & Mark, J. (2004). *The textbook matters: Why instructional materials are a powerful lever for improvement.* Paper presented at the 36th Annual Conference of the National Council of Supervisors of Mathematics, Philadelphia.
30. Wolfe, P. (2001). *Brain matters: Translating research into classroom practice.* Alexandria, VA: Association for Supervision and Curriculum Development.

Appendix

Record Sheet 6

Name:____________________________________Date:____________________

1. Display the growing pattern in the table.

_________________________Pattern

Step Number	1	2	3	4	5	6	7	8	9	10
Number of Tiles										

2. Describe the growing pattern.

3. Write a rule in words and with variables using step numbers to find any number of tiles.

4. How many tiles will be in the 50^{th} step? How do you know?