AC 2010-70: A STUDY OF MATH INFUSION IN MIDDLE SCHOOL ENGINEERING/TECHNOLOGY EDUCATION CLASSES

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A Study of Mathematics Infusion in Middle School Engineering Technology Education Classes

Introduction

This study is part of the *Mathematics, Science, and Technology Project* (MSTP), a Mathematics and Science Partnership project funded by the National Science Foundation (NSF) and conducted by the Hofstra University Center for Technological Literacy (CTL). As part of its goal to improve mathematics in the middle school, MSTP introduced *Bedroom Design*, an engineering technology education (ETE) curriculum for middle school, and examined its impact on student learning of mathematics. The curriculum uses an "informed design" approach[1, 2] to infuse grade-related disciplinary mathematical concepts into ETE instruction. Designed to be taught as a five-week unit, it features a hybrid instructional model that employs computer simulation as well as physical modeling. Fifteen teachers in New York State and 20 teachers nationally implemented the curriculum, and gains in student mathematical learning and attitudes were studied using pre and post curriculum assessments.

Background

The transition into the 21st century has seen a greater emphasis on student proficiencies in science, technology, engineering, and mathematics (STEM), with a focus on how these skills will help students thrive in the technological-based world and marketplace. Yet the mathematical achievement of students in the United States is below that attained by students in other countries, and American students are notably behind once they reach late middle school[3]. To address these weaknesses, educators have developed various strategies to increase students' STEM content knowledge. These include, but are not limited to, furthering teachers' professional development, changing curriculums, and increasing the amount of classroom time spent on teaching the STEM areas.

One way to improve student competencies in STEM is to make connections between these disciplinary areas; this will help students develop a broader understanding of similar concepts and ideas. But connected curriculum is not a new pedagogical approach; it has been recognized as an important teaching tool for many years[4]. A useful way to apply the connected curriculum concept to STEM education is to use mathematics as a thread to link science, technology, and engineering. The National Council of Teachers of Mathematics (NCTM) has in fact recommended the connected curriculum approach. It has suggested connecting mathematics to science, social science, and commerce as a way for students to increase their mathematical competence[5]. To address this recommendation, the MSTP project introduced the term "mathematics infusion" to describe an approach that makes connections between mathematics and ETE[6]. Through infusion, mathematics is brought into the ETE curriculum at critical points so that it fits with the material naturally and helps create connections between the disciplines. The *Bedroom Design* curriculum is the platform for the mathematics infusion in this study.

Unfortunately, there has been little research involving the effects of a connected mathematics and ETE curriculum. Two earlier pilot works, however, indicated the potential of math infusion in ETE. In one, a project developed by Akins and Burghardt[7], students applied mathematical

reasoning to solve an engineering problem: the design and construction of a food dehydrator. Four middle and high school teachers, from four diverse schools, participated in this research study. Project findings showed that the scores of students in the lowest quartile jumped from 24% correct in the math area to 54% correct, representing an improvement of 125%. Students in the second-lowest quartile improved their scores by 85%. Those in the two highest quartiles also improved their scores but by a lower percentage: 21% for the highest quartile and 51% for the second-highest. Findings indicated that all students benefited from the experience, with students in the bottom two quartiles showing the greatest improvement in mathematical reasoning and achievement.

The other pilot work was developed by Burghardt and Hacker[8]. In this project three ETE teachers worked for one week in July 2007 with engineering and mathematics specialists to refine a five-week design challenge called *Bedroom Design*. Notably these teachers decided to add a virtual design component to the physical modeling activity featured. Using Google SketchUp (GSU), a 3D modeling program available at no cost from Google, students created a virtual design on screen. Then they built a physical model, a three-dimensional scaled version that included furniture and furnishings. The mathematics in this unit related to ratio and proportion, percent, area, and perimeter. After this revised design challenge was implemented, a paired t-test was performed to determine if students demonstrated greater mastery of the material. Pre-post data were available for 129 of the 144 students. The summed mean test score on the pre-test was 9.108 (standard deviation of 3.30), and on the post-test it was 9.652 (standard deviation of 3.14). Although these means are very similar, a paired t-test indicated that the difference was statistically significant: $t\ (128) = 2.828$, $p < .005$. This evidence demonstrated that students were showing gains on their math content knowledge.

As part of the general effort to discuss the development of student competencies in the STEM disciplines, the MSTP project hosted a national invitational symposium[9] in 2009 to develop recommendations and a research agenda for interconnected STEM teaching and learning. During the symposium, 45 participants—prominent STEM researchers, leaders from STEM education, assessment specialists, school administrators, and STEM teachers—met to discuss the importance of creating connections between the fields in schools. There was agreement across professionals that these connections would be powerful in helping students learn the concepts and achieve a higher level of proficiency.

The *Bedroom Design* Curriculum

The curriculum selected for the mathematics infusion study that is the subject of this paper is *Bedroom Design*, a middle school ETE unit that engages students in the planning, design, and physical modeling of a bedroom that must meet specific cost and building requirements (e.g., the window area must be at least 20% of the floor area, the minimum room size is 120 square feet, the budget is $27,500). Based on the revised design challenge of the same name, the curriculum was field tested in middle school classrooms and further revised and refined during the summer of 2008 by a team of middle school ETE teachers with the support of experts in mathematics education. The curriculum is considered a hybrid instructional model because it includes computer simulation as well as physical modeling: the students use Google SketchUp to create a virtual design and then construct a hands-on physical model (see figure 1).

Bedroom Design incorporates informed design, a validated design pedagogy developed through NSF projects conducted by the Hofstra CTL[10, 11]. Informed design allows students to increase their content knowledge before they suggest a design solution to a problem, so that they are informed by prior knowledge instead of trial and error[12]. Therefore, informed design fuses guided inquiry and open-ended design, helping students develop conceptual understandings prior to beginning the design phase of a project. In an informed design activity, students expand their science, technology, engineering, and mathematics (STEM) knowledge and skill base by completing a series of short, focused tasks called Knowledge and Skill Builders (KSBs). These KSBs are crucial to approaching a design challenge from a well-informed perspective. Detailed lesson plans are available at www.hofstra.edu/CTL.

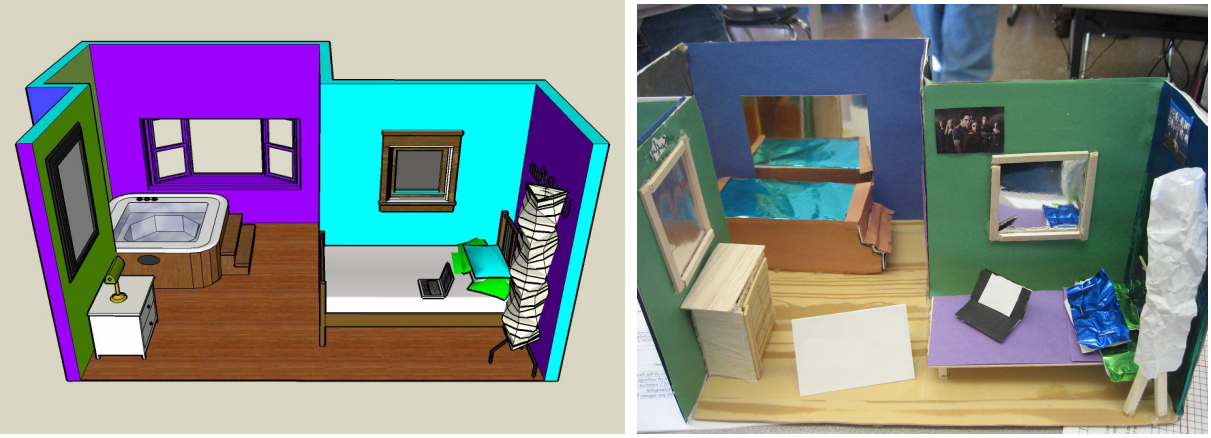

Figure 1. Students used Google SketchUp to design their bedroom plans on screen (left). They built physical models (right) based on their virtual designs at the end of the *Bedroom Design* unit.

Teacher Participants

Teacher participants in the mathematics infusion study comprised two cohorts, a New York State sample and a national sample. The New York State sample consisted of 15 Long Island middle school technology teachers from high-needs districts in Nassau and Suffolk counties. These teachers met for a week and a half of collaborative professional development during the summer of 2008. During this time, mathematical, technological, and engineering experts were present to help guide, mentor, and provide training in how to teach the *Bedroom Design* unit. Teachers were also given the opportunity to revise each day of lessons to include further mathematical content, all the while increasing their conceptual and pedagogical understanding of the mathematics involved. As part of a national dissemination effort, 20 teachers from various locations across the United States received training in spring 2009 on how to teach the unit at the International Technology Education Association (ITEA) conference in Kentucky.

Research Design

Both impact studies used a pre-post design to examine student change in mathematical content knowledge, and attitudes toward mathematics, following participation in the math infusion lessons. As part of the New York study (2008–2009), each technology infusion teacher was paired with a comparison teacher (typically another technology teacher from the same middle school). The comparison teacher did not teach *Bedroom Design*, but instead taught the typical curriculum for that school. Data were collected from students in both the infusion and the comparison classes. The national sample included only infusion students.

Infusion and comparison students completed assessments before and after completing 20 days of the math-infused *Bedroom Design* lessons. The mathematical content assessment included seven multiple choice and ten open-ended questions (one question included both open-ended and multiple choice components) focusing on the mathematics concepts included in the technology *Bedroom Design* lesson. The multiple choice questions were scored as either 0 (incorrect) or 1 (correct). Questions were adapted from the New York State eighth-grade assessments and were developed by an expert math consultant. The open-ended questions were scored using a three-point rubric ranging from 0 (no evidence of understanding) to 2 (full understanding of the math concept). A total math content knowledge score was computed by summing the number of correct multiple choice responses and the rubric score on the open-ended questions.

New York Sample

Composite scores for each student were computed separately for the multiple choice questions and the open-ended questions. For each type of question, the number of correct responses was divided by the number of possible correct responses, and the resulting fraction was converted to a percentage by multiplying by 100. Thus each composite score represented a percentage correct. A paired-samples t-test revealed significant differences for the infusion students on their pre- and post-test scores. Infusion students' composite scores were higher and more statistically significant on the post-test than on the pre-test for both the multiple choice and open-ended questions. There were no significant differences between pre- and post-test composite scores for comparison group students. Further, an independent-samples t-test was used to test for statistically significant differences between infusion and comparison students on their post-test scores. Results showed that composite scores for infusion students were statistically significantly higher for the multiple choice questions ($M = 60.21$, $SD = 24.64$) when compared to control group students ($M = 49.15$, $SD = 24.44$). Infusion students also scored higher at post-test for open-ended questions ($M = 39.99$, $SD = 25.06$) than their comparison group counterparts ($M = 29.99$, $SD = 19.87$). Overall, there was a significant effect of group placement, $t\ (809) = 6.28$, $p < .01$, with infusion group students scoring higher than control group students.

National Sample

Data collected from the national sample of teachers who participated in the *Bedroom Design* study were examined in a similar manner to data collected from the New York classrooms. At the individual question level, increases in scores were seen for both the multiple choice and open-ended questions. In comparison to pre-test scores, infusion students scored higher at post-

test on all but one of the eight multiple choice questions, with statistically significant t-test differences on four of the questions. Additionally, students scored higher on all ten of the open-ended questions at post-test compared to pre-test, and seven were higher and more statistically significant at post-test. There were significant differences from pre-scores ($M = 41.83$, $SD = 21.02$) to post-scores ($M = 46.21$, $SD = 20.03$) where post-scores were a statistically significant amount higher than their pre-scores: $t\ (377) = 4.95$, $p < .001$.

In both the New York study and the national dissemination study, students in the infusion experimental group showed significant increases in content scores from pre- to post-test. In addition, in the New York study, this group of students had significantly higher post-test scores than comparison group students after controlling for pre-test differences. Moreover, comparison group students showed no significant increases in scores.

Conclusions

For the New York State and national groups of students, there were statistically significant increases in student understanding of mathematics. The average amount of mathematics instruction during the *Bedroom Design* unit was six hours in both the New York and the national samples. Concerns that an ETE class would become another math class were unfounded. Interestingly, teachers in the New York sample received ten days of professional development and ongoing technical assistance, much of which was targeted toward improving STEM connections for the lowest-performing students. In some cases, the unit extended over a period of several months, often being taught only twice a week. In contrast, the teachers in the national sample represented a diverse group of schools and received only a half day of professional development. Yet even this sample of students showed significant improvement. These results indicate that *Bedroom Design* is a robust curriculum that can be implemented with little professional development, and with its use, students can make significant gains in mathematics.

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