Work in Progress - Math Infusion in a Middle School Engineering/Technology Class

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Abstract--**Engineering design projects can provide a rich opportunity to enhance middle school student knowledge in core disciplinary subject areas, such as mathematics and science and forms an important aspect of the NSF-supported Mathematics, Science, Technology Education Partnership (MSTP) project [1]. A key goal of the project has been to develop a model for infusing mathematics into science and technology at the middle school level. The informed design process was created as part of a NSF materials development program and formed the engineering design framework for this study. Structured mathematics activities (knowledge and skill builders - KSBs) were developed that linked to the design challenge. As a result of these hands-on activities, students apply the mathematical reasoning developed in order to solve an engineering problem; the design of a bedroom. A pilot research study, involved implementation of a math-infused bedroom design lesson. A paired t-test indicated the difference was statistically significant t (128) = 2.828, p<.005, providing evidence that students were showing gains on their math content knowledge.**

Index Terms—Engineering design, mathematics, middle school.

INTRODUCTION

In recent years, there has been a growing recognition of the educational value of design activities in which students create external artifacts that they share and discuss with others [2,3,4]. A synthesis of the literature reveals that pedagogically solid design projects involve authentic, hands-on tasks; use familiar and easy-to-work materials; possess clearly defined outcomes that allow for multiple solutions; promote student-centered, collaborative work and higher order thinking; allow for multiple design iterations to improve the product; and have clear links to a limited number of science and engineering concepts [5]. The design process begins with broad ideas and concepts and continues in the direction of ever-increasing detail, resulting in an acceptable solution [6]. Research shows that hands-on activities supported by meaningful discussion and theory building helps students construct meaning [7]. When children are encouraged to create artifacts, such as in design [8], they reflect; and student understanding is enhanced.

The design strategy used in this study was to infuse mathematics into engineering technology education based on the informed design cycle [9]. This design process is congruent with Wiggins and McTigue's Understanding by Design [10]. A critical element of the informed design process occurs during the research and investigation phase. The use of Knowledge and Skill Builders (KSBs) provides students with opportunities to engage in structured research and practice related to key ideas that underpin the design solution. In a pilot study by Akins and Burghardt [11] using informed design, significant improvement was found in students' mathematical competencies related to mathematics topics linked to the design challenge. In their study, the mathematics related to area, perimeter, percentage and linear and non-linear functions.

IMPLEMENTATION

Three technology teachers worked for one week in July 2007 with engineering and mathematics specialists to refine a five-week design challenge called *Bedroom Design*. In this challenge students need to design a scale model of a bedroom with a budget of $15,000. Specifications and constraints were provided: the window area must be at least 20% of the floor area, the minimum room size is 120 square feet, the minimum closet size is 8 square feet and the minimum height of all walls is 8 feet. The room must have two outside and two inside walls and the basic cost of construction is estimated at $75 per square foot of floor area.

The KSBs related to mathematics had been developed by the authors to reflect NCTM pedagogical guidelines with consultation from mathematics consultants. In addition, the teachers decided to use *Google Sketch-Up* so students could first create a virtual design, as well as a physical model (a 3-dimensional scaled version). Students also created scaled versions of the furniture and furnishings in the bedroom.

The mathematics in this unit related to ratio and proportion, percent, area and perimeter. A consultant was hired with expertise in middle school STEM to develop the pre/post mathematics assessment using questions from the New York State eighth grade mathematics assessments. These included multiple choice and extended response questions, consistent with the state's assessment practice. The pre/post assessment was developed after the summer workshop so the consultant could align the questions with the lessons.

RESULTS

The pre/post instrument had 12 math assessment items. Seven were multiple choice questions (scored as correct or incorrect) and five were extended response questions that were scored using a four point rubric (scored from 0, no knowledge of the concept to 3, full knowledge of the concept). The assessment was administered before and after students participated in the math-infused technology lesson. Although the same questions were asked during both administrations, the order of the items was randomly changed. An alpha reliability coefficient was calculated as a general indicator of the degree to which students consistently responded to the questions. The .692 alpha reliability coefficient provided some confidence that the test items were measuring the same constructs.

A paired t-test was performed to determine if students demonstrated greater mastery of the material following the math infused lessons. 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 was 9.652 (standard deviation of 3.14). Although these means are very similar, a paired t-test indicated the difference was statistically significant $t(128) = 2.828$, $p<.005$, providing evidence that students were showing gains on their math content knowledge.

CONCLUSIONS

Despite the small mean differences, the results were encouraging for several reasons. Based on teacher feedback and examination of the data, it appears that the assessment items were not optimal and that bridges were not explicitly made connecting the math students were doing as part of the design experience to math in their math class.

After careful review of material, we are refining the design challenge and the KSBs that support it. In particular, we are encouraging the use of non-rectangular shapes in the design, and making more explicit links to math, especially connecting vocabulary, e.g. slope (engineering) and rate-of-change (math). The use of *Sketch-Up* is being strengthened and a virtual design portfolio is being created so students can type, rather than write, their thoughts and observations. We are exploring the use of electronic pre/post assessments with the assessments being revised to enable us to explore deeper student understandings of math concepts.

A pilot implementation of the revised materials will be implemented in May 2008 and field test training of seven engineering/technology teachers will commence in July 2008. The revised *Bedroom Design* unit will be implemented again in fall 2008 with these teachers and data will be gathered about student performance in mathematics.

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