Work in Progress—Improving K-12 Mathematics Understanding with Engineering Design Projects

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Abstract - **Engineering design projects can provide a rich opportunity to enhance student knowledge in core disciplinary subject areas, such as mathematics and science. 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 food dehydrator. four middle and high school teachers, from four different and diverse schools, participated in this research study. They had all used informed design and had taught the five-week unit on dehydration before. They were familiar with the pedagogical strategies inherent in the informed design process. The teachers implemented the unit in winter and spring of 2006. The paper will present preliminary results of the research which indicate a dramatic improvement in mathematical reasoning.**

Index Terms - Engineering design, mathematics, middle-school.

INTRODUCTION

Engineering faculty and middle and high school teachers expanded an action research project [1] examining the effect of using informed design to improve student knowledge in mathematics and science. The concept of refining the engineering design process to informed design was conceived and developed in the National Science Foundation NYSCATE [2] project. Anecdotal research from the NYSCATE project and a subsequent project, NYSPDC [3], indicated that students were developing better mathematical reasoning skills. This work in progress describes the goals and objectives of a multi-teacher action research project that sought to examine the effect of informed design on student mathematical understanding.

Informed design enables students to enhance their own related knowledge and skill base before attempting to suggest design solutions. In this way, students reach design solutions informed by prior knowledge and research, as opposed to trial-and-error problem solving where conceptual closure is often not attained. A key factor that differentiates informed design from other design processes is how the research and investigation phase is approached. To provide the foundation for informed design, activity learners are engaged in a progression of *knowledge and skill builders* (KSBs). KSBs prepare students to approach a design challenge from a more knowledgeable base. The KSBs are short, focused activities designed to help students identify the variables that affect the performance of the design. They provide structured research in key technology, science, mathematics processes, skills, and concepts that underpin the design solution. They also provide evidence upon which teachers can assess student understanding of important ideas and skills. The final design is "informed" by the knowledge and skills that students acquired enroute to designing and constructing their solutions.

DESCRIPTION

The Center for Technological Literacy at Hofstra University and Dutchess Community College were two collaborating institutions in the NYSPDC project. There are three middle school and one high school teachers participating in the work. At a two-day meeting the team refined the Drying by Design (DbD) activity. All of the teachers had taught the DbD at least once before, so they were familiar with the pedagogical approach and content.

The informed design process is exceedingly congruent with Wiggin and McTigue's *Understanding by Design* [4]. A challenging middle school technology education activity that had significant math, science and technology knowledge requirements was to be created. The activity was to illuminate several key ideas; one, the design process including trade-offs, the design elements, testing and evaluation; two, mathematics concepts of area, perimeter, percentage, and linear and non-linear functions; three, science concepts of humidity and evaporation. Importantly, there are learning outcomes in all three areas that are part of state standards in math, science, and technology curricula at the middle school level. Dehydration was selected as the technological area investigated because it appealed to many STEM teachers.

This multi-teacher action research project is framed by the question, "Does using informed design with Drying by Design demonstrably increase student understanding of math and science concepts?" The concepts that were assessed are humidity, surface area, percents and proportions. A variety of

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assessment strategies were used.

The authors collaboratively revised the original Drying by Design KSBs to incorporate better math pedagogy and focus more on the mathematics, science and technology topics that were the key ideas. Then, in a two-day workshop setting, the research team of teachers performed the new and modified KSBs. Final discussions on the first day centered on a uniform schedule and assessment protocols for the unit that the teachers agreed to follow. For meaningful results, everyone needed to commit to the same materials and schedule. The second workshop day focused on developing the assessments and reporting processes.

The pre/post assessment instrument was developed using New York State eighth grade annual assessments in mathematics and science. We used questions from these examinations that related to the content areas DbD covered. So while we could not use a validated assessment instrument, the one we created used many questions from validated examinations. The following data was collected:

Pre and post test data for every student in the class. The grading of the questions was agreed upon, what were satisfactory responses, what type of response would receive partial credit, and the valuation for each. Furthermore, the students were divided into quartiles based on their pretest score and one student was selected from each quartile on a random basis for additional assessment.

The KSBs (two math, one science and one engineering-technology) were graded according to an agreed upon rubric. Teachers found the average score for each quartile, as well as the individual student score from each quartile.

The Design Folio was assessed, again with agreed upon rubrics, and the grades provided for each quartile and the selected students.

Student Self-Assessment was gathered regarding individual perception of their own conceptual understanding in the math, science and engineering/technology topics of the DbD unit. This instrument was used pre and post. The post assessment included three additional questions seeking the student perception of how the unit helped them improve their math, science and design abilities.

PRELIMINARY FINDINGS

A large volume of data and information was collected from the teachers. Preliminary data analysis focused on quantitative data for work performed with the highest level of consistency among the four teachers that completed the unit as planned. These four teachers collected data on a total of 63 students in grades 7 through 9. Although the 7th and 8th graders were in a required technology course, their academic level was not significantly different from the students in the 9th grade elective technology course as attested by the teacher and reinforced by the data. The districts ranged from rural to suburban and high poverty level to upper middle class.

The results are unmistakable. For every quartile, a significant improvement is noted on the students' overall, math, and science scores. Furthermore, the improvements are markedly more pronounced for the bottom two quartiles. For example, the lowest quartile improved from only 24% correct in the math area to 54% correct, an improvement of 125%. The second lowest quartile improved their math score by 85%. The two highest quartiles also improved their math scores but not by as large a percentage: 21% for the highest quartile and 51% for the second highest. It is also noteworthy that the second lowest quartile performed better on the post test in every category than the second highest quartile thus significantly raising the competency of the lower performing average student.

CONCLUSIONS

The preliminary data analysis is very promising. The improvement observed in the mathematical competency of the students, especially those in the lower two quartiles, is nothing less than remarkable. All the math and science subject matter selected for this research study should have already been covered in 6th grade. Therefore, the pre-test scores are indicative of the students' competency based on the study of the subject matter in math and science classrooms. On the other hand, the post test scores are indicative of their improved understanding of the same math and science concepts within the framework of informed design implemented in technology classrooms.

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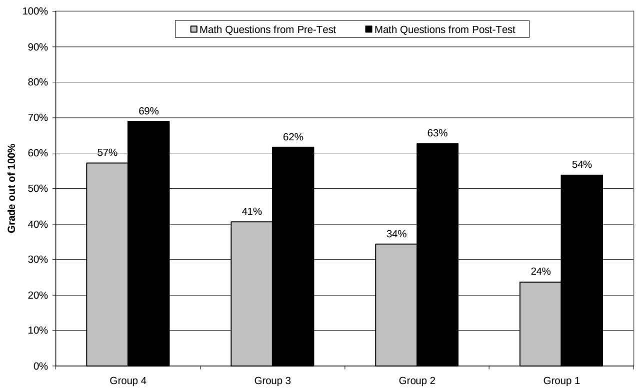

Figure 1(b) Average grade for each quartile based on scores for only the math portion of the pre- and post-tests.

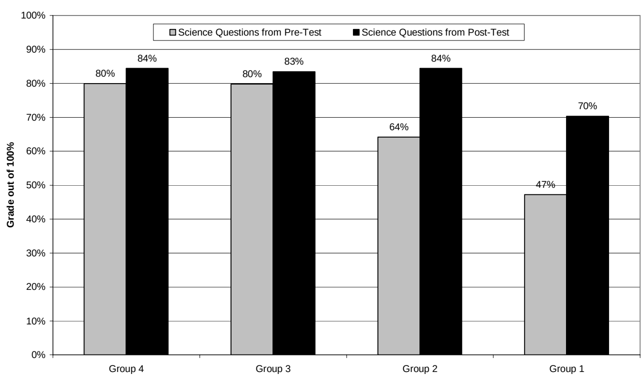

Figure 1(c) Average grade for each quartile based on scores for only the science portion of the pre- and post-tests.