Making the Case: Evaluating the Impact of a Design, Engineering, and Technology Course on K-12 Teachers' Practice

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Abstract

The purpose of this study was to document the effect of a course designed to help teachers integrate Design, Engineering, and Technology (DET) into their curriculum. Since research supports the importance of understanding teachers' perceptions of a new curriculum before implementation, we felt that we needed to know more about how the course was changing teachers perceptions as well as actions and knowledge about their current practice. Consequently, we used four analytical themes (Reflections on Practice, Changes in Practice, Intentions to Change Practice, and Change in Knowledge) to examine the likelihood that what teachers encountered in the course would transfer to their classrooms. Three graduate students allowed us to gather data over a semester to develop in-depth cases. The teachers were Alice, an elementary teacher; Denise, who taught at a Science Center; and Dana, a high school chemistry teacher. Alice intended to change, or changed things, such as teaching the design process explicitly, learning the science behind engineering concepts, developing activities for young children, using everyday contexts, and planning a model building unit. Denise changed her practice by attending to gender, integrating the design process and tinkering into lessons, and adding technology discussions. She helped the museum staff examine their program activities. Her unit indicated greater awareness of the time needed for hands-on exploration and discussion. Dana exhibited the most changes. She had students write about science and technology to determine prior knowledge. They designed labs as well as the lab instruments e.g. calorimeter. As department chair, she helped other science teachers incorporate DET into instruction. In creating her unit, she used the design process and her evaluation (including a delayed post test) which indicated that the students had learned everything intended.

Introduction

In 1996, "Science and Technology," was added to the NSF content Standards[1] to emphasize the process of design and to link science and technology. Standard E (Science and Technology) addresses "abilities to distinguish between natural objects and objects made by humans," "abilities of technological design," and "understanding about science and technology." Standard F (Science in Personal and Social Perspectives) addresses the challenges of science and technology locally to globally; invention; and the socioeconomic, political and ethical impacts of science and technology. Standard G (History & Nature of Science) addresses the human

component. Nevertheless, of the eight National Science Education Standards, those addressing DET are frequently ignored. While scholars[2,3,4] have argued that DET is a rich context for learning science, teachers often do not include DET concepts in their curriculum[5,6, 7].

Teachers' Familiarity with Design, Engineering and Technology Concepts

Australia[8], New Zealand[9,] and Northern Ireland[10] have made DET concepts a priority in K-12 classes. However, researchers in these countries found that many teachers have limited knowledge about the aim, meaning, and content of technology education[11]. A case study of Australian teachers found that they had difficulty scaffolding students' learning when they taught DET for the first time[8]. In the U.S., teachers felt that DET was important to teach but lacked knowledge, time, training and equipment, and felt that they could not teach DET because it was not part of the curriculum[12, 13].

A common misconception held by many, including teachers and administrators, is that technology education is limited to computers[14]. For example, primary and intermediate teachers stated that they used technology across the curriculum; e.g. computers and calculators in math, word processors in language arts. These teachers were generally positive about introducing DET in primary schools but wanted it integrated into other subject matter[15].

Research on teachers trained to use DET concepts, however, has shown that DET has a positive impact on students. For example, The Materials Technology Institute project provided teachers in Singapore with the background and curriculum needed to create a high school course in Materials Science and DET[16]. Students reported the courses: a) made them more interested in a science career; b) increased enjoyment of laboratory activities; and c) helped develop skills for working with equipment and in the lab, and 96% said they would recommend the class to their peers.

Purpose

This study documented the effect of a course designed to help teachers integrate Design, Engineering, and Technology (DET) into their curriculum. Three case studies were developed to describe the effect of the course on four categories that emerged from the data -Reflections on Practice, Changes in Practice, Intentions to Change Practice, and Change in Knowledge.

Design

The study was a component of a graduate course in science education supported by a NSF Bridging Engineering and Education grant. Created and taught by a team of faculty from education and engineering, the course was a follow up to a previous "bridging" course and was designed to address students' expressed need for a greater emphasis on integrating DET into the K-12 curriculum. The class met weekly in an industrial engineering lab with access to a wide range of materials, tools, and technical assistance. The course consisted of discussions of readings and written reflections on the readings, hands-on activities that exemplified aspects of DET (e.g. examining properties of materials, redesigning nutcrackers for ease of use, structure and function of skeletons as related to bioengineering), peer critiquing of a prospectus for a

science unit that integrated DET into their current curriculum; and weekly presentations, discussions, and revisions of the unit lessons. This work on the unit lessons included reports of successes and failures of lessons that they had field tested. This was an iterative process with characteristics of the Japanese lesson study. The unit included a statement of need, literature review, standards, a week or more of lessons, assessments and a report of the impact of the unit on students.

Three students in the class who were in a science education masters program agreed to be studied in-depth. The first was Alice. She was an elementary teacher with more than five years of experience. She taught 3rd grade at an alternative school that gave teachers great freedom in deciding on the curriculum. The school's philosophy was constructivist and student centered. Textbooks were not used and students were not assessed by any mandated standardized tests. Alice had a good science background which she acquired on her own.

The second student was Denise. She taught at a Science Center and developed activities/workshops for children and their teachers related to a recent NSF grant awarded to the Center. The grant funded the writing of pre and post classroom experiences and assessments to accompany the museum visit activities. Although having considerable flexibility in terms of the content, Denise had to link the content to the museum exhibits and the grant. Denise had a weak background in science, and her content knowledge was acquired on her own. She had never taught in a public or private school.

The third student was Dana. She taught high school honors chemistry and was the science department chair. She was the most constrained by the existing curriculum and the need to teach so that students did well on the district and state standardized tests. Her classes were small and her students were motivated. She had a strong background in science, especially in chemistry, and had been a teacher for 15 years.

Data Sources and Analysis

Data were answers to pre/post course questions about the design process, definitions of tinkering and technical expertise, self-confidence in these areas, the relationship of science and technology, rationale to allocate time to DET in the K-12 science curriculum, and ways to modify curriculum to include DET. Additional data included weekly reflections on readings consisting of primary research on the impact of DET in the classroom, email correspondence, and two focus group reports. In addition, students created and tested a DET unit in their classroom. The unit and the report that evaluated the impact of the unit on students were also rich data sources.

All text referring to teaching was extracted from the data. This text was initially coded using a fine grained analysis (e.g. teaching with models, awareness of gender issues) by one of the researchers. This proved to be idiosyncratic to each student so a second pass was made through the data by a second researcher and the initial codes were replaced by Reflections on Practice, Changes in Practice, Intentions to Change Practice and Change in Knowledge. All text was then coded using these new categories.

Results

Alice

Having a good knowledge base initially, Alice's understanding of the design process became more precise and she acquired the vocabulary that promoted this precision. Since she already understood the pervasiveness of technology in our everyday lives, there was little change in this area. The biggest knowledge change was a move from describing science and technology as two parallel endeavors to seeing the reciprocal nature of science and technology. She realized that to foster children's understanding of DET, she would have to systematically plan it in each lesson.

Alice's reflections on her practice were very self-critical and she noted that she would have to redesign her lessons to allow for multiple solutions. She saw how she could use the iterative DET design process to help students understand why they had to write and rewrite in language arts. She realized that her project's time could be a more productive learning time if she changed from a crafts approach to a design approach and that the problems to be solved should be linked to the everyday lives of her students. She realized that if she had a model for the tinkering that students engaged in during project time, she would be better able to assess their work. Alice had a long list of things she intended to change: a) to teach the design process explicitly; b) to learn more of the science that supported various technologies and engineering concepts; c) to learn more about what kinds of DET activities were appropriate for young children; d) to use more everyday contexts for DET projects; and e) to plan a unit for summer school that included building models of the function of body systems.

Changes in her practice had a positive impact on her enrollment. Because Alice had replicated, with modification, activities explored in the graduate class, an increased number of parents enrolled their children in her class for the next year. Alice taught the design process as a way to solve everyday problems and focused on the iterative process rather than the end product. She helped her students explore requirements and constraints before jumping into designing solutions. She also included discussions of ethics and safety as important aspects of DET.

Her unit included everything she had learned and her intentions to change her practice. Her students were given two desert tortoises to keep as long as they had a proper living environment. Consequently, she focused her unit on guiding students to design and build a tortoise habitat on the school grounds. This was a real problem in which the functional requirements of keeping the animals alive and the constraints of budget were paramount.

Denise

Denise's understanding of DET and related issues changed significantly. She went from thinking of technology as computers or components of objects to realizing that technology was pervasive. Viewing the design process as less formulaic and more iterative, while also realizing that tinkering was not just playing but included experimentation, she no longer separated science and technology, but saw them as reciprocal. She also gained a greater understanding of the challenges faced by teachers trying to integrate DET into their classrooms and no longer expected as much from them in her work at the Science Center.

Denise reflected on her practice in several ways. She questioned the grade level appropriateness of topics and the kinds of curriculum and workshops she was developing. She wondered how students were perceiving the museum activities. Finally, she remembered past instances when she saw students engaging in inequitable gender interactions and had not intervened because she did not recognize them as inequities.

Denise changed her practice at the Science Center by paying more attention to gender equity, integrating the design process and tinkering in her lessons and including an examination of the properties of materials used in lessons whenever possible. She also added a discussion of technology to her lessons. In addition, she formally shared what she had learned with the other museum staff to begin an examination of their current activities in their school program. The progressive work on her unit indicated that she was more aware of the time students need to engage in hands-on exploration and discussion and that activities needed a real world context. The number of unit topics decreased as Denise focused on the key DET concepts she wished students to learn. The unit moved from a series of activities where students had fun building bridges without knowing why some bridges held up the toy cars and others did not to a series of activities that explored the science behind building bridges by systematically exploring concepts such as load, and the function of arches and spans.

Denise also intended to change practice. She intended to create a DET workshop focusing on properties of materials and include women inventors in lessons. All future workshops would also include decision making, project management, communication and collaboration to create a team experience. She wanted to do systematic observations of gender interactions in her teams and determine how students conducted investigations with the intent to make changes where needed.

Dana

Dana's change in understanding of the design process was from describing it as a short process without technical vocabulary to a more iterative process with appropriate vocabulary. She developed a more reciprocal understanding of science and technology. Her biggest change in understanding was from having no idea of how to incorporate DET into her curriculum to allowing students to design a lab procedure incorporating DET where students must consider the constraints, design a procedure (and sometimes even the artifact to test the procedure) and test it.

Dana's reflections on her practice indicated that she was struggling to incorporate design in her classroom. She saw parallels in the design process and the scientific method and thought this parallel approach might be a way to incorporate design. She thought that science teachers should teach problem solving; however, she was frustrated because the readings indicated that there was a debate about general problem solving skills. She wrote about how hard it was for her students to learn that an iterative process was good and that initial failure was not bad. She also took issue with the need for everything to be in an everyday context and again struggled to think about ways to do this with the abstractions of chemistry.

Dana exhibited the most dramatic changes in practice. She had her students write about science and technology to determine their prior knowledge and then had them design their own labs as well as the instruments needed to conduct the labs e.g. calorimeter. As department chair, she began to help the other science teachers incorporate DET into their instruction. In creating her

unit, she used the design process and her evaluation of the unit (including a delayed post test) which indicated that the students had learned everything she had intended. Furthermore, they had retained that knowledge on the delayed post test and were enthusiastic about taking it because they felt they had learned the most when doing the activities in the unit. Dana was a person of action and put her intentions to change practice into action. She did not write about what she was going to do but instead concentrated on the challenges and outcomes of what she was changing.

Discussion and Conclusions

Helping teachers infuse DET into their current practice is not a simple matter but it can be accomplished under the right conditions. The three cases presented are indicative of the kinds of changes that can be made under varying conditions of context and teacher background knowledge when there is the right kind of support. Alice, Denise, and Dana were able to change their practice because they were provided the opportunity to read and discuss the research on classrooms applications of DET, to discuss possible changes in their own practice, to develop lessons and try them, to then share their successes and failures with one another, and to continually refine their lessons throughout the 15 week period of the course. In short, the class became a community of learners who provided support for one another as they tried to infuse DET into their practice. We believe that we were successful in bringing about change because of the structure of the course. We recommend that others seeking to infuse DET into the K-12 curriculum take a similar approach. We also recommend that engineering educators who wish to infuse DET into the curriculum familiarize themselves with the curricular and testing constraints that teachers face. Alice was the most successful because she had fewer constraints than Denise and Dana.

Follow-up research with Alice, Denise and Dana is planned to determine whether they continue to infuse DET into their practice without the support that the course provided. All three teachers intended to make additional changes but whether intentions become actions will depend upon contextual factors such as administrator and parental responses, school rankings in statewide tests, and the resources (time and supplies) to develop activities that employ DET.

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