AC 2009-1747: THE EFFECT OF A TEACHER PROFESSIONAL DEVELOPMENT INTEGRATED CURRICULUM WORKSHOP ON PERCEPTIONS OF DESIGN, ENGINEERING, AND TECHNOLOGY EXPERIENCES

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The Effect of a Teacher Professional Development Integrated Curriculum Workshop on Perceptions of Design, Engineering, and Technology Experiences

Abstract

The goal of a professional development workshop on the use of DET activities in the classroom was to provide middle- and high-school level teachers (n=80) with the content knowledge and pedagogical skills to engage students in solving authentic, multi-disciplinary problems in a relevant context of sustainability engineering. Multi-disciplinary teams of teachers representing mathematics, science, language arts, social studies, and technology participated in a two-week summer workshop, follow-up sessions and an online professional learning community. Teacher teams experienced and developed cross-disciplinary, problem-based learning modules that correlated with state standards (e.g., design of a windmill). The teachers produced interdisciplinary engineering units that contained language art, social studies, technology, science and math content (this is a novel approach to professional development). Through various assessments, participants were encouraged to reflect on their own practice and use of DET activities to make effective choices regarding students' learning. The purpose of this study was to understand teachers' perceptions of the value and use of design, engineering, and technology (DET) activities in integrating science, mathematics, language arts, social studies, and technology in K-12 education.

Background

The integrative and inquiry-oriented nature of design and engineering creates the perfect vehicle for application of math and science at the middle- and high-school level. Inquiry learning in science and mathematics requires students to do more than sit and watch the teacher. It requires them to combine both scientific processes with content knowledge—they must use scientific reasoning and critical thinking to develop their understanding.¹ Students must apply multiple content areas such as mathematics, reading, writing, and speaking as they work through the many layers of an engineering activity. Students must be able to ask questions, make observations, design and conduct investigations, use appropriate technologies in order to gather and analyze data, utilize critical thinking skills, use evidence to develop explanations and predictions, and communicate this information to others.²

Engineering inquiries are designed to allow students to manipulate their environment in search of answers to questions they have. Students involved in real-life problem solving, inquiry-based activities develop strong and lasting conceptual understandings of fundamental scientific concepts.^{3,4} Using inquiry-oriented activities in the science classroom improves students' attitudes toward science and scientists.⁵ To this end, teachers must be able to structure the kinds of powerful problems that will engage students in productive inquiry. They must, themselves, understand the content necessary and reasoning goals appropriate to the inquiry, and to be successful, they must be able to mediate student's thinking and reasoning.

Many teachers, and consequently their students, lack such a comprehensive level of scientific and technological literacy. Nationally, recent calls to action⁶ strongly urge policymakers to

strengthen and build the United States' research infrastructure. The reports paint grim pictures of the country's technological and economic future if steps are not taken to improve and diversify STEM education. At the local level, it is becoming a high priority to increase teacher knowledge and pedagogical skill to, in turn, increase student performance as measured by such assessments as EPAS, API, and OSTP.

Workshop Structure and Teacher Outcomes

Figures 1 and 2 show the structure of the two week summer program. During the introduction module, the pre assessments were given, teachers were provided with materials that introduced engineering, the two week program was outlined and the expectations of the teachers were reviewed. The photo elicitation activity was an opportunity for the teachers select pictures and discuss in groups those that showed what engineering was. The rest of the first week was to model four interdisciplinary units for the teachers. The teachers were placed in their interdisciplinary school teams and first of all completed an engineering design activity (airplane module, windmill, penguins, and water purification). The teachers then reflected about the days engineering activity in a journal followed by a few minutes of debriefing. The next morning, school team personnel were split up into the 5 content area groups (math, science, social studies, language arts, and technology). Each group was provided with state standard sheets for grades 5-9 and was tasked with thinking about how to extend the previous days' engineering activity to have more content and to consider how to make the particular activity appropriate at each grade level. The school teams then reconvened and considered the content group input as the teachers considered how to implement the engineering module in their own classroom. After lunch, each school team presented the results of their engineering activity as well as described methods for extending and implementing the engineering modules across grade levels and in all content areas. Details of the engineering modules can be found at ([website http://osuitq.wikispaces.com/](http://osuitq.wikispaces.com/))

	Monday, July 14	Tuesday, July 15	Wednesday, July 16	Thursday, July 17	Friday, July 18
8:30 - 8:45		Sign-in and Brkfst	Sign-in and Brkfst	Sign-in and Brkfst	Sign-in and Brkfst
8:45 - 9:45		Content Breakout	Content Breakout	Content Breakout	Content Breakout
9:45 - 10:00	Registration	Break	Break	Break	Break
10:00 - 11:30	Introduction Module	Team Breakout	Team Breakout	Team Breakout	Team Breakout
11:30 - 12:30	Lunch	Lunch	Lunch	Lunch	Lunch on your own
12:30 - 1:00	Photo Elicitation Activity	Team Presentation	Team Presentation	Team Presentation	Team Presentation
1:00-2:00	PBL Scenario & Airplane Module				
2:00-2:15	Break	Break	Break	Break	Break
2:15-4:15	Airplane Module	Windmill Module	Penguins Module	Water Purification Module	Wrap up
4:15-5:00	Debrief/ Journal	Debrief/ Journal	Debrief/ Journal	Debrief/ Journal	

Figure 1 – Week One Workshop Structure

The teachers were then tasked with developing a new module that they would implement in their own school during the 2008/2009 academic year. For the first two days, school teams met to plan a module. During the mornings of the next two modules, the teachers were given an opportunity to present their modules to a group of middle school children to see how implementation would work. They then spent the afternoons assessing their work. Half of the schools presented on one day and half presented on the other day. The day that the teachers were not presenting, they observed the other school teams and provided feedback to the schools that presented their module that day. On Friday, the teachers were given information about their academic year expectation and what was required in their teacher work samples. This was the final product that the teachers provided the research team.

	Monday, July 21	Tuesday, July 22	Wednesday, July 23	Thursday, July 24	Friday, July 25
8:30 - 9:00	Sign-in	Sign-in	Sign-in	Sign-in	Sign-in
9:00 - 9:45	Recap of Week 1	Planning and Preparation for Student Academy	Student Academy	Student Academy	Teacher Work Sample
9:45 - 10:00	Break	Break	Break	Break	Break
10:00 - 12:00	Refine Module	Planning Team Module and Preparation for Student Academy	Student Academy	Student Academy	Teacher Work Sample
12:00 - 1:00	Lunch	Lunch	Lunch	Lunch	Lunch
1:00 - 2:00	Planning Team Module and Preparation for Student Academy	Planning Team Module and Preparation for Student Academy	Teaching Team assessment of instruction	Teaching Team assessment of instruction	Post-Test
2:00 - 2:15	Break	Break	Break	Break	Break
2:15 - 3:45 pm	Planning Team Module and Preparation for Student Academy	Planning Team Module and Preparation for Student Academy	Changes and Preparation for Day 2 of Student Academy	Wrap Up of Student Academy	Planning for Implementation

Figure 2 – Week Two Workshop Structure

Four follow up days occurred during the academic year to provide content area enhancement, guidance on completing teacher work sample, and discussions of engineering module implementation.

The integrated units that the teachers developed and delivered over the 2008/2009 academic year include:

- Earthquake!
- Sink or Float – Titanic
- Rocketry
- Oil Derrick
- Design a Shoe

- Survival!
- Catapult
- Rainforest
- Toy Vehicle
- Bridges
- Greenhouses

Research Study Methodology

The participants were 80 teachers that agreed to participate in the study. The majority of participants were female (n = 64). 57 teachers reported teaching primarily at the middle school level, and 23 were high school teachers. The teachers represented five content areas: mathematics (n = 20), science (n = 16), language arts (n = 17), social studies (n = 13), and technology or library media (n = 14). 67 participants were White, 11 – American Indian, and two – Asian. Most of the participants were in their early 40's ($\bar{X} = 39$, M = 41).

Participants were asked to complete a web-based version of the Survey to Assess K-12 Teachers' Perceptions of Engineers and Familiarity with Teaching Design, Engineering, and Technology.⁷ This 41-item instrument was developed and validated by a multidisciplinary team of scholars at Arizona State University with a sample of 98 Arizona teachers. This survey was administered at the beginning and end of the two week workshop.

The researchers also wanted to get at the teachers perceptions of what engineers do and what is technology. An instrument developed at the Boston Museum of Science⁸ was used for this purpose. The instrument has 16 items for each of what engineers do and what is technology that the students circle. These assessments were administered pre and post intervention.

Research Results

Arizona State University Survey⁷

In accordance with the purpose of this study, results are presented and discussed in the following sections: a) perceptions of the value and use of DET in K-12 education, b) factors that predict teachers' perceptions of DET, c) perceptions of the skills of a typical engineer, and d) perceptions of what the students need to understand about DET.

Table 1 - Results of central tendency and dispersion measures on the pre- and post-test of teachers' perceptions of the value and use of DET in K-12 education

Measure	Familiarity	Importance of pre-service education	Importance of integrating in classroom	Confidence about integrating	Consequences for the society
Mean	1.71/3.00	3.24/3.38	3.31/3.55	2.04/3.26	3.69/3.89
Median	2/3	3/4	3.5/4	2/3	4/4
Mode	2/3	4/4	4/4	2/3	4/4
Standard Deviation	.71/.75	.87/.75	.82/.61	.89/.61	.54/.32
Variance	.51/.56	.77/.57	.67/.38	.79/.37	.29/.10

Range	3/3	3/3	3/2	3/2	2/1
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Note: On the scale of 1 to 4 (Strongly Disagree to Strongly Agree). PRE/POST.

The survey asked the participants to rate a) their familiarity with DET, b) importance of pre-service education for teaching DET, c) importance of integrating DET into K-12 curriculum, d) confidence about integrating DET, and e) consequences of DET for the society. Table 1 provides results of the measures of central tendency and dispersion on the pre-test and post-test of the teachers' responses to these questions.

Measures of central tendency as well as the results of paired samples T-tests indicate that the professional development workshop produced a positive effect on the teachers' perceptions of the value and use of DET activities in K-12 education: a) familiarity with DET ($t_{(79)} = -13.63$, $p < 0.001$), b) importance of integrating DET into K-12 curriculum ($t_{(79)} = -2.77$, $p < 0.05$), c) confidence about integrating DET in the classroom ($t_{(79)} = -11.99$, $p < 0.001$), d) and consequences of DET for the society ($t_{(79)} = -3.071$, $p < 0.005$). Measures of dispersion also demonstrate that there was less disagreement among the participants on these questions during the post-test.

Workshop participants tended to report their agreement with the importance of pre-service education for teaching DET both before ($\bar{X} = 3.24$) and after the workshop ($\bar{X} = 3.38$). The difference between these means did not reach significance however.

Stepwise multiple regression analyses were conducted to determine to what extent teachers' characteristics (gender, age, ethnicity, content area, grade level, and number of years teaching) predict their pre-test and post-test responses on each of the following dependent measures: familiarity with DET, importance of pre-service education for teaching DET, importance of integrating DET in the K-12 curriculum, confidence about integrating DET, and consequences of DET for the society (Table 2). Predictor variables were entered simultaneously into the equation in each test. Stepping method criteria were set to .05 as probability of F for entry and .10 for removal.

Table 2 - Results of stepwise regression on factors predicting teachers' views on DET

Criterion	Predictor	R ²	β	t	F
Familiarity with DET, Post-test	Age	.107	-.327	-3.061	$F_{(1,78)} = 9.370$
Importance of pre-service education for teaching DET, Pre-test	Gender	.060	-.244	-2.226	$F_{(1,78)} = 4.954$
Consequences for the society, Pre-test	Gender Grade	.168	-.388 .220	-3.674 2.083	$F_{(1,78)} = 7.783$

Age was found to be the only significant predictor of the teachers' familiarity with DET during the post-test. Teachers' age was negatively correlated with their self-reports of the familiarity with DET, which signifies that younger teachers tended to report better familiarity with DET after the workshop. The fact that age was not a significant predictor of this dependent measure during the pre-test may indicate that younger teachers were also more receptive of the treatment.

Gender was found to be the only significant predictor of the initial (pre-test) teachers' views on the importance of pre-service education for teaching DET. Gender was negatively correlated

with this dependent measure, and since the female participants were coded as 1s and male – as 2s, this indicates that before the workshop female teachers tended to emphasize the importance of pre-service education for teaching DET more than male teachers. This is consistent with the results of previous studies.⁷ This difference disappeared after the workshop, however, because no significant predictors of this dependent variable were found during the analysis of the post-test.

Both gender and grade level were found to be significant predictors of the teachers' perceptions of the consequences of DET on the society as evidenced by the pre-test. As in the case with the importance of pre-service teacher education for teaching DET, gender was negatively correlated with this dependent measure, which indicates that female teachers tended to believe in the positive consequences of DET for the society before the workshop more than male teachers. This predictor was not significant in the regression analysis of the post-test however. Grade level, on the other hand, was positively correlated with this dependent measure, which indicates that high school teachers held more esteem towards DET in terms of its consequences for the society (middle school teachers were coded as 1s, and high school teachers – as 2s).

No other tests reached significance.

The workshop improved K-12 teachers' perceptions of the skills of a typical engineer. Table 3 presents results of paired samples T-tests on the comparison of means between pre- and post-test responses that describe characteristics of an engineer ($p < 0.05$).

Table 3 - Results of paired samples T-tests on comparing perceptions of characteristics of a typical engineer

Variable	t	r
Works well with people	-6.050	.383
Has good verbal skills	-6.027	.355
Has good writing skills	-4.185	not significant
Likes to fix things	-2.350	not significant
Does well in science	-2.083	.513

While the above tests detected an improvement in teachers' perceptions of the characteristics of a typical engineer, the fact that there was no significant correlation between the pre- and post-test scores on items 3 and 4 may indicate a radical change in perceptions for those participants, - specifically, for those who tended not to believe that engineers have good writing skills and like to fix things before the workshop.

A portion of the survey asked the participants to rate their perceptions as to whether they agree that as a result of a DET activity, students need to understand: a) design process, b) use and impact of DET, c) science underlying DET, d) types of problems DET should be applied to, and e) process of communicating technical information. Table 4 provides results of the measures of central tendency and dispersion on the pre-test and post-test of the teachers' beliefs on this subject.

Measures of central tendency as well as the results of paired samples T-tests ($p < 0.001$) indicate that the professional development workshop produced a positive effect on the teachers'

perceptions of what their students need to understand in all of the categories: a) design process ($t_{(79)} = -4.63$), b) use and impact of DET ($t_{(79)} = -3.96$), c) science underlying DET ($t_{(79)} = -4.26$), d) types of problems DET should be applied to ($t_{(79)} = -3.90$), and e) process of communicating technical information ($t_{(79)} = -3.16$). Measures of dispersion also demonstrate that there was less disagreement among the participants on these questions during the post-test.

Table 4 - Results of central tendency and dispersion measures on the pre- and post-test of teachers' perceptions of what their students need to know

Measure	Design process	Use and impact of DET	Science underlying DET	Types of problems DET should be applied to	Process of communicating technical information
Mean	3.15/3.55	3.20/3.58	3.02/3.44	3.24/3.60	3.26/3.54
Median	3/4	3/4	3/4	3/4	3/4
Mode	4/4	4/4	4/4	4/4	4/4
Standard Deviation	.84/.61	.85/.57	.90/.69	.83/.57	.81/.55
Variance	.71/.38	.72/.32	.81/.48	.69/.32	.65/.30
Range	3/3	3/3	3/3	3/3	3/2

Note: On the scale of 1 to 4 (Strongly Disagree to Strongly Agree). PRE/POST.

Boston Museum of Science⁸ What do Engineers Do/What is Technology

Figure 3 and 4 show the results from the “What do Engineers Do/What is Technology?” assessment for the teachers pre and post workshop developed at the Boston Museum of Science.

Figure 3 – Pre and Post Scores for What Do Engineers Do?

As expected teachers knew that engineers did not arrange flowers, sell food, clean teeth or make pizza. There was less agreement for careers that are considered technical in nature, such as driving machines, repairing cars, constructing buildings etc. There then was more agreement on the setting up factories, designing ways to clean water, working as a team, designing things, and improving machines that are truly engineering functions. There was noticeable change between pre and post workshop in that more of the teachers realized that technical trades such as wiring are not engineering.

Figure 4 – Pre and Post Scores for What is Technology

For the “What is Technology” assessment data in Figure 4, teachers easily were able to identify that dandelions, parrots, oak trees and lightning were not technology. On the pretest, teachers were not in agreement on the items that don’t have a lot of sophistication (cup, shoes, etc). The teachers were more accurately able to understand that these items are also technology. The items at the right side of the figure tend to run on electricity and are much more intricate and more students were able to identify these as technology. On the post test, there was much more agreement about the items that were technology (anything manmade) and those that weren’t.

Discussion

The treatment of this study had teachers, participating as learners; solve engineering problems in a real-world application format using math, science, reading literacy, information literacy, social studies, and instructional technology content and skills. Results of the study support evidence⁹ that exposure and engagement of K-12 teachers to the implementation of the DET methodology

in the classroom can indeed increase teachers' awareness and understanding of the importance of such activities (and engineering in general) in the K-12 curriculum, and can potentially cause a shift in teachers' classroom pedagogy from a uni-disciplinary model to a multi-disciplinary model of inquiry-oriented problem-based learning in which student thinking is the key to student learning.

This project is novel in that it had teachers in the five content areas develop integrated units. This allows for strengthening the students exposure to engineering and helping them to realize that engineering is not "just a math and science" thing. This exposure for the teachers encourages them to talk about engineering in their entire classroom curriculum. Additionally, this project delved into current curriculum to help the teachers appreciate how everyday content has engineering components. It is not necessary to add new activities to classrooms to introduce engineering, but it is also possible to talk about engineering through current curriculum.

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