AC 2010-1016: THE CONSTRUCTIVIST-BASED WORKSHOP: AN EFFECTIVE MODEL FOR PROFESSIONAL DEVELOPMENT TRAINING ACTIVITIES

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The Constructivist-Based Workshop: An Effective Model for Professional Development Training Activities

Abstract

Workshops have proven to be an efficient and popular mode of providing opportunities for professional development. However, the effectiveness of our workshop model in accomplishing the goal of providing an environment supportive of statistically significant learning has only recently been assessed. Given that the workshop is consciously modeled on the theoretical framework of our Engineering Teaching Kits (ETKs), the assessment is also a proxy for the assessment of the kits' model, both of which are based on the pedagogic philosophy of constructivism. Participants at three recent ETK workshops completed pre- and post-workshop self-assessments of their knowledge and level of experience with the engineering, science, and pedagogical concepts upon which the covered ETKs are based. The differences between pre- and post-workshop assessments of knowledge and experience are statistically significant ($p <= .007$) for a great majority of the concepts tested. This result indicates that active learning strategies can be as powerful a learning experience for adult learners as they are for younger students: a result that can inform the design of effective professional development training activities. This consideration may be especially important when designing workshops for participants with no prior exposure to covered topics.

Introduction

The workshop is a popular instructional model for professional development training activities. We have presented workshops on our particular instructional product, Engineering Teaching Kits (ETKs), to audiences of P-12 teachers and university faculty and students at various venues. However, the effectiveness of our model, based on the pedagogic philosophy of constructivism, has not been formally assessed until recently. We present a statistical analysis of the assessment results and discuss implications for future workshops in this paper.

Our research thesis is that an instructional model structured as described above is an effective method of delivering content and supporting learning. The research question investigated and reported upon here is therefore:

> A professional development workshop model based on constructivist principles provides an environment supportive of a statistically significant increase in learning.

The paper begins with a review of the motivation for developing ETKs. We also provide a brief history of ETK usage and outline its basic design. Next, we discuss the theoretical basis in which ETKs are grounded: constructivism. The specific constructivist-based instructional strategies used in ETKs, guided inquiry and inductive learning, are then described. The basic structure of our workshop model is outlined, and results from three recent workshops are presented and discussed. We end with conclusions and directions for future work.

Engineering Teaching Kits: Motivation, History, and Design

Extensive outreach has long been employed to attract middle and high school students to post-secondary study in STEM subjects. This outreach is in response to several trends that pose a threat to the United States' ability to remain globally competitive, such as stagnant or declining college enrollments in these fields while the need for trained professionals increases; and the under-representation of females, African Americans, Hispanic Americans, and Native Americans in STEM fields. The primary goals of these outreach programs are to educate, engage, and empower students with respect to STEM.

Initially, STEM outreach programs primarily focused on high school students because they seemed to be the most logical candidates for recruitment. However, many students were not academically prepared to enroll in college STEM courses without remediation, often because previous curriculum choices resulted in limited exposure to math and science in these students' programs of study. Other obstacles include students' lack of awareness of engineering as a possible career because of unfamiliarity with the profession.[1] One natural extension, then, was to focus projects at the middle school level, where timely interventions would ideally lead to enrollment in classes that would better prepare students for the rigors of college STEM studies. Research, however, is increasingly indicating that that intervention efforts must begin as early as possible for the best outcomes; therefore, several STEM initiatives are targeting elementary students.[1 - 3]

A signature outreach program at the University of Virginia's School of Engineering and Applied Science (UVa SEAS), the Virginia Middle School Engineering Education Initiative (VSMEEI), was created to address the need to engage students as early as possible in effective, empowering instructional activities introducing them to the engineering design process in order to motivate them to study science, technology, engineering, and math (STEM).[4 – 6] VMSEEI's primary intervention instrument is the Engineering Teaching Kit (ETK). An ETK is a set of standards-based lesson plans designed to teach math and science concepts within the context of the engineering design process. ETK activities are structured as challenges that students solve through application of selected concepts to design, prototype, and test a device, structure, or system that addresses a problem or meets a need. ETKs are primarily developed by teams of undergraduate students enrolled in the fourth-year capstone course MAE 467, Creativity and New Product Development I. The teams may be interdisciplinary in nature, but tend to be composed of mechanical engineering undergraduates. An ETK's validation process starts with its presentation to and subsequent review by the course instructor and the team's student peers. Upon acceptance, the ETK is reviewed by middle school teachers in the greater Charlottesville, Virginia area and graduate students from UVa's Curry School of Education for content accuracy and pedagogic effectiveness. The ETK is then piloted in local schools. Once tested and validated, it is available for distribution.[5 – 7]

ETKs are also designed to facilitate the integration of humanities and social sciences into the exploration of math, science, and engineering concepts. For example, an interdisciplinary team of eighth-grade teachers at a central Virginia middle school used the *Catapults in Action* ETK as the basis for a week-long series of integrated classes on medieval history. The potential for similar multidisciplinary activities can be found in all ETKs.

Each ETK contains a comprehensive teacher's guide; a unit overview and schedule; a review of relevant subjects, concepts, and standards; detailed plans for five 50 minute activity periods; and worksheets and other assessment instruments.

Although current ETKs are targeted to middle school students, we have used them with groups ranging in age from second grade to college professors. The kits require more direction and scaffolding for younger audiences, but the approach works well at all levels. Other programs in which ETKs have been used include UVa's Introduction to Engineering (ITE) program and ExxonMobil-Bernard Harris Summer Science Camp; and workshops at venues such as ASEE, FIE, and the National Science Teachers Association (NSTA).[8 – 11]

Recently developed ETKs include *Chain Reaction* (Rube Goldberg machines), *Crash Course* (properties of energy) *ElectroMagic* (properties of electricity), *Giggity-Goo* (properties of fluids), *HOOS E.Y.E* (optics), *Movers and Shakers* (effects of stress on structures), *Rock-It Power* (propulsion), and *Save the Penguins* (heat transfer).[12]

Theoretical Framework and Research Philosophy

The theoretical basis for ETKs is the pedagogical philosophy of constructivism, which emphasizes the use of active learning strategies.[13, 14]

In the constructivist model, learners actively and inductively (re)build their understanding of reality based on their experiences. The experiences are assessed according to the learner's mental schemata "that incorporate the student's prior knowledge, beliefs, preconceptions and misconceptions, prejudices, and fears (p. 124)."[15] Learning, therefore, is the process of adjusting the mental schemata to accommodate new experiences and hence is a search for meaning. Since meaning requires understanding both the "big picture" as well as details, learning must focus on primary concepts rather than random, unconnected factoids. Assessment is primarily formative in nature to support learner-based evaluation of progress.[16]

"Active learning" refers to a set of pedagogical strategies in which students accept responsibility for "co-creating" and directing learning. It is well documented that students retain more knowledge when actively engaged in the learning process, and active learning is often cited as an extremely effective instructional strategy.[17 – 22] The pedagogies have proven to be a good fit with the preferred learning and working styles of millennials in general and students from underrepresented populations in science, technology, engineering, and mathematics (STEM), including females, in particular.[23] Many active learning strategies involve some form of group work. Examples of active learning strategies are cooperative and collaborative learning, learning communities, inductive learning, and directed/guided inquiry.[24]

We concentrate on inquiry and inductive learning strategies in our workshop model. In directed/guided inquiry, learners are led to a solution through a set of carefully constructed questions. The question set can be constructed to assess alternate/misconceptions according to learner points of divergence from the expected conclusion. Inductive learning "encompasses a range of instructional methods…(that) are...*learner-centered*…(and)…*constructivist*" with elements of active learning, most notably cooperative learning (p. 123; emphasis ours).[15]

Project-based learning is the main inductive learning strategy that we use. Participants work in teams of up to 4 members to design, prototype, and test a solution to the challenge(s) identified by the facilitators.

Our research philosophy is influenced by two approaches to qualitative analysis. For Miles and Huberman,[25] the overall goal of research is the description and explanation of patterns of relationships among social phenomena; for Erickson,[26] the overall goals of research include the following which fit best with our research agenda: discovery of universals through concrete particulars, improvement in educational practice, and the identification of specific causal linkages. Our dominant positionality is post-positivism, which supports the quantitative survey methodology used in this study.

Workshop Structure

The ETK workshop's basic structure is designed to maximize the amount of time participants spend working on challenge projects. We begin with introductions of facilitators and participants, discussions regarding workshop logistics and expectations, an overview of ETK, and a pre-assessment of self-perceived competencies on the concepts addressed in the design challenges. Our goal is to keep the introductory part of the workshop under 20 minutes; we want participants working on challenges as soon as possible. The full version of the workshop has three challenges: building an insulated receptacle for penguin-shaped ice cubes (from *Save the Penguins* ETK[12]), building a receptacle from aluminum foil and assorted support materials such as popsicle sticks designed to support a maximum weight load (Archimedes' Principle /buoyancy challenge from the *HoverHoos* ETK), and building a solar car designed to pull a maximum weight load (*RaPower* ETK[8]). Interspersed among the challenges are discussions on the STEM principles addressed by the challenges and the various pedagogies used. We end the workshop with a post-assessment of self-perceived competencies on the concepts covered in the pre-assessment and a concluding discussion regarding ETK implementation.

The workshops from which the data are collected for the analysis presented here are:

- *Engineering in P-12 Education: Learning Science and Mathematics Through Guided Inquiry, Conceptual Restructuring, and Engineering Design*, June 13, 2009, 3 hours. This workshop was part of the 6th Annual ASEE Workshop on P-12 Engineering Education (ASEE) in Austin, Texas. The three challenges noted above were covered. The analyzed data is a subset of the collected data, cleaned to facilitate statistical analysis.
- *Introduction to StudioSTEM*, October 9, 2009, 3 hours at the Virginia Polytechnic Institute and State University (VT), Blacksburg, Virginia. The *Save the Penguins* ETK challenge was covered.
- *P-12 Engineering Education: Design Challenges for Pre-College Students*, October 26, 2009, 2 90 minute sessions (planned) at the College of New Jersey (TCNJ), Ewing, New Jersey. The Archimedes' Principle challenge was covered.

Figures 1 and 2 are from the third ETK workshop listed above. That workshop was a session in the Department of Technological Studies' 23rd Annual Professional Development Conference.

Figure 1. **Participants working on the Archimedes' Principle challenge at TCNJ's ETK workshop**

Figure2. **Participants working on the Archimedes' Principle challenge at TCNJ's ETK workshop**

Statistical Analysis of Workshop Model Effectiveness

Results from the pre- and post-assessments from three recent ETK workshops are presented in Tables 1 – 3, which are located after the list of references. Table 1 is an overview of the participant demographics. Numbers in the subcategories, when summed, may not be equal to the total number of participants since participants had the option to skip any question they did not feel comfortable answering. Tables 2 and 3 list the mean values of the pre- and post-assessment of self-perceived competencies and the results of the paired t-tests performed using that data, respectively. The hypotheses of the paired t-test are:

H_0 after ranking = before ranking (0 difference)
H_1 after ranking > before ranking (after – before > 0)

A review of the values in Table 3 indicates that a statistically significant amount of learning occurred at a level of $p <=.007$ with respect to all concepts with the exception of the concepts of constructivism ($p = .021$) and the engineering design process ($p = .02$), and of guided inquiry ($p = .08$) at the TCNJ workshop. This non-statistically significant result with respect to guided learning, based on an $\alpha <= .05$, is likely due to participant familiarity with the strategy and/or the small amount of time spent covering the strategy. TCNJ's workshop started late due to inclement weather and sessions were cut short as a result. Participant time and effort were therefore focused on the design challenge. While the results with respect to constructivism and the engineering design process are statistically significant at the identified α value, they are significantly higher than the results from the other workshops due to participant familiarity with the concepts and the homogeneous nature of the participant base. Almost all of the workshop's participants are students or alumni of the sponsoring department, which uses a constructivist-based curriculum and emphasizes the design process in every course.

We therefore have a positive response to our research question: a constructivist-based model **does** provide an environment supportive of a statistically significant increase in learning in professional development workshops. These results mirror the results from a landmark study on the effectiveness of the workshop model for professional development activities.[27] This study, one of the first national empirical surveys on the topic, found that three factors had the most impact on self-assessed increases in competencies and knowledge: a focus on content knowledge, active learning-based activities, and relevance to the participants' instructional responsibilities.

Conclusions and Future Work

We will continue to use and assess a constructivist-base model in future ETK workshops. Based on participant feedback from the ASEE workshop and the results from the Tech workshop, we will limit challenges to one or two activities. This limitation will allow us to cover a subject in greater depth and provide participants opportunities to identify and explore related topics and alternative activities, thus further emphasizing the iterative nature of the engineering design process. We will also follow up with participants to determine the impact of exposure to and use of ETKs on their teaching and/or outreach. Many participants indicated in the surveys' comment section that while they would like to use ETKs in their classroom, tight instructional schedules driven by testing considerations may preclude them for doing so. We will investigate targeting kit activities to test topics; if implemented, we will research the effectiveness of ETKs in supporting test preparation and performance. Finally, we will refine the assessment instrument to cover active learning concepts and strategies in detail.

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Table 1. Workshop Participant Demographics

	ASEE	VT	TCNJ
Gender			
Female	24	15	3
Male	16	3	10
Years Teaching			
0 - 5	5	5	2
6 - 10	2	3	4
11 - 15	6	2	1
16 - 20	5	1	--
21+	4	2	2
not applicable	5	5	4
Current Position			
P - 12 teacher	20	14	9
University faculty	10	3	--
University student	4	--	4
Other	5	2	--
Current Position Location			
Elementary	9	--	--
Middle School	4	9	2
High School	6	4	7
University (faculty)	9	3	--
Other	10	1	4
Main Subject(s) Taught			
Core	8	1	--
Engineering	8	--	--
Math	5	2	--
Math and Engineering	2	--	--
Science	4	6	--
Science and Math	--	2	--
Technology/Pre-Engineering	4	--	9
Other	--	1	--
N	29	18	13

Table 2. Pre- and Post-Assessment Mean Values of Self-Perceived Competencies

	ASEE	VT	TCNJ
Buoyancy			
before	2.88	--	3
after	3.85	--	3.62
Conduction			
before	2.67	2.72	--
after	3.66	3.56	--
Constructivism			
before	3.16	2.83	3.04
after	3.64	4	3.62
Convection			
before	2.6	2.72	--
after	3.62	3.5	--
Engineering Design Process			
before	2.95	2	4.23
after	3.64	3.5	4.54
Guided Inquiry			
before	3.33	3.06	3.46
after	3.88	4.11	3.62
Heat Transfer			
before	2.85	2.78	--
after	3.72	3.72	--
Misconception Remediation			
before	2.76	1.89	2.71
after	3.82	3.56	3.54
Radiation			
before	2.5	2.83	--
after	3.66	3.56	--

Table 3. Results of Paired T-Tests

	ASEE	VT	TCNJ
Buoyancy			
t-value	5.18	--	2.89
p-value / effect size *r*	0/.475	--	0.007/.326
Conduction			
t-value	4.72	4.12	--
p-value / effect size *r*	0/.513	0/.417	--
Constructivism			
t-value	3.15	4.51	2.29
p-value / effect size *r*	0.002/.23	0/.551	0.021/.245
Convection			
t-value	5.1	3.5	--
p-value / effect size *r*	0/.465	0.001/.406	--
Engineering Design Process			
t-value	3.55	6.46	2.31
p-value / effect size *r*	0.001/.277	0/.662	0.02/.216
Guided Inquiry			
t-value	3.63	4.49	1.48
p-value / effect size *r*	0.001/.311	0/.511	0.08/.073
Heat Transfer			
t-value	5.13	7.43	--
p-value / effect size *r*	0/.451	0/.493	--
Misconception Remediation			
t-value	5.17	7.79	3.08
p-value / effect size *r*	0/.461	0/.683	0.005/.4
Radiation			
t-value	5.86	4.12	--
p-value / effect size *r*	0/.485	0/.436	--