
AC 2012-4365: ENGINEERING TEACHING KITS, EXPERIMENTS, AND DEMONSTRATIONS AS PART OF WORKSHOPS FOR TEACHERS TO FACILITATE LEARNING OF SCIENCE AND ENGINEERING

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Engineering Teaching Kits, Experiments, and Demonstrations as Part of Workshops for Teachers to Facilitate Learning of Science and Engineering

Abstract

Alimentos Divertidos is an inquiry-based science and engineering program for P-12 students¹⁻³. To promote our experiments, demonstrations, engineering teaching kits (ETKs), and to further encourage their implementation in P-12 schools, our faculty presented several workshops⁴ at the Yucatan peninsula, where P-12 teachers performed and learned how to teach more than ten experiments and demonstrations as part of two ETKs entitled *Racing Cars* and *Under Pressure*⁵. Most teachers agreed that the experiments/demonstrations and ETKs are interesting and useful. In general, attendees rated them as good or excellent and felt very or somewhat comfortable performing and teaching the experiments/demonstrations and ETKs after the workshops. More than 75% of the teachers plan to use experiments and/or demonstrations while more than 70% of the teachers plan to use ETKs. The written materials provided were rated as very helpful.

Introduction

Mexico is suffering from a national crisis in science and math education. At the elementary, middle, and high school level, Mexican students perform poorly on standardized tests in comparison to other developing countries. Additionally, most P-12 Mexican teachers never get the chance to learn about engineering¹⁻⁴.

Universidad de las Américas Puebla (UDLAP) is a Mexican private institution of higher learning committed to first-class teaching, public service, research and learning in a wide range of academic disciplines including economics, business administration, the physical and social sciences, engineering, humanities, and the arts. UDLAP places a high priority on reaching out to its local community. Such outreach fosters service opportunities so P-12 students can discover science, engineering, and technology careers. Service is a fundamental aspect of being a professional and thus fundamental to our students' education.

Alimentos Divertidos is an inquiry-based science and engineering program for P-12 students¹⁻⁴. We have developed, implemented and evaluated educational materials (simple and inexpensive experiments that utilize easy-to-obtain materials) and pedagogical practices designed jointly with P-12 teachers³⁻⁴. As part of this program, we have adapted (from the University of Virginia⁵⁻⁹) as well as developed several experiments, demonstrations, and engineering teaching kits (ETKs).

Alimentos Divertidos major goal is to transform how students view, think about, understand, apply and do science and engineering. Among program objectives are to develop, implement, and evaluate: a) educational materials, b) pedagogical practices designed jointly with elementary school teachers, c) workshops designed to help teachers incorporate the experiments and pedagogical practices, and d) teacher learning communities; as well as to apply and evaluate the use of foods as a tool to facilitate engineering and science learning¹⁻².

Alimentos Divertidos program can be incorporated to P-12 science classrooms without modifying the existing curriculum at the different types and modalities offered at these levels in Mexico¹⁰. Our program is fostering that kids learn science and engineering DOING science and engineering. In the majority of school classrooms learning is evaluated through answers to the question ¿What do you know about ...? Our program additionally emphasizes another question, ¿How do you know it? Demonstrations can illustrate us what we know, but experiments show us how we know it. *Alimentos Divertidos* is developing experiments and ETKs that include demonstrations¹⁻⁴.

Results to date indicate the importance of placing teachers in the role of “students” and allowing them to experience hands-on and minds-on inquiry-based activities as well as grapple with designing their own lesson plans in a peer group setting where they can brainstorm and receive feedback¹⁻⁴. Therefore annually we hold on-campus one-week summer workshops in order to help elementary school teachers incorporate the developed experiments, ETKs and pedagogical practices.

Workshops

To further promote the experiments and engineering teaching kits, and encourage implementation of *Alimentos Divertidos* program in schools in other states, our faculty presented workshops at the Yucatan peninsula. Around 250 teachers from the states of Campeche and Quintana Roo were engaged in 2-day seminars, during which they attended several distinguished lectures and two workshops where they performed and learned how to teach more than ten experiments and demonstrations as part of two ETKs, using recycled or inexpensive materials as tools to facilitate science and engineering learning. Workshops offer practical tools to the teachers in order to help them enhance their daily teaching activities, and different areas have been covered including math, history, Spanish, foreign languages, literature, science, engineering, among others³⁻⁴.

Experiments and demonstrations (planned to follow a guided-inquiry procedure) were included in the workshops such as first, second, and third Newton’s Laws, effect of friction, Archimedes’ principle, Pascal’s principle, among others. These were part of the ETKs entitled *Racing Cars* and *Under Pressure*⁵, which are centered on Newton’s motion laws and density and buoyancy

concepts, respectively. *Racing Cars* include a tow engineering design challenge that requires teams to use Newton's motion laws concept to design a car propelled by air that advances a maximum distance while *Under Pressure*⁴ includes a design challenge to build a submarine of minimum cost that achieves neutral buoyancy using a plastic bottle as a container as well as salt, sand, gravel, beans, and/or rice to achieve required buoyancy. Teacher teams competed against each other. Thus the ETKs approach involved hands-on and minds-on, inquiry-based, team-oriented projects.

Information to report workshop outcomes was obtained from observational and interview field notes from the formal sessions, participant workshop evaluations³⁻⁴ and a 13-item workshop survey (adapted from the *Evaluation Survey* designed by Schnittka⁸⁻⁹), which has ten closed-ended questions for participants to rate (in a scale from 1 to 10) workshop aspects such as excitement, teamwork, learning, success, and challenge; and three opened-ended questions to discover participants' likes and dislikes regarding the workshop. Furthermore an exit survey was performed by the organizers of the seminars.

Results and discussion

Responses to the organizers' exit survey indicated that the instructors as well as the reported workshops were successful and highly satisfactory for the attendees (Table 1). Teachers rated the workshops (as well as the seminar) as a great opportunity to expand their knowledge and mention that they can apply what they learned, in their classrooms. In particular, instructors of the workshops related to ETKs were very well evaluated.

Table 1. Seminar organizers' exit surveys results

		Mean	Standard deviation
<i>Regarding the ETKs workshop and instructors</i>			
1	Do you consider that the instructors know the subject?	9.9	0.2
2	The ability of instructors to convey ideas	9.7	0.5
3	Teaching methods and instructional techniques used by the instructors	9.7	0.5
4	Degree of utilization of practical exercises	9.7	0.5
5	Instructors encourage participation by the group?	9.8	0.4
6	Did the instructors maintained participants' interest throughout the sessions?	9.7	0.6
7	Degree of integration of the instructors with the group	9.7	0.6
8	Overall rating of the instructors	9.9	0.4
<i>Regarding the seminar</i>			
1	Do you think that contributions were innovative?	9.7	0.5
2	Does the thematic content of the seminar has met your expectations?	9.7	0.5
3	Do you think it is helpful for your work what you learned in the seminar?	9.9	0.3
4	Overall rating of the seminar	9.8	0.4

Table 2 presents the school grade in which workshop participants teach, being predominantly elementary and middle school teachers. Female teachers accounted for around 79% of workshop participants. More than 20% of the participants are principals in their schools. Involvement of principals in the workshops (and seminar) is two-fold: first, to raise awareness among them of the possibility of implementing the ETKs and demonstrations at their schools, and secondly, several of them also have classroom responsibilities. Attendee's years of teaching experience is as follows, 20% of them have taught for less than 5 years and 20% have over 20 years of teaching experience.

Table 2. Participants by grade in which they teach (in percentage)

Preschool	38
Elementary	17
Middle school	13
High school	7
University	2
Principal (or Director)	22

Responses to the ETKs' workshop survey (Table 3) indicated that workshops were successful in preparing teachers and encouraging adoption of the experiments, demonstrations, and ETKs in Yucatan peninsula P-12 classrooms. Most teachers agreed that the experiments/demonstrations and ETKs are interesting and useful. In general, attendees rated them as good or excellent and felt very or somewhat comfortable performing and teaching the experiments/demonstrations and ETKs after the workshops.

Interviews revealed some aspects about the ETKs workshops intentions, Figure 1 illustrates the frequency of each answer (more than one can be repeated) to the following questions: What do you think tried to teach you the instructors?, What was the best part of having participated in the workshop?, and What was the worst part of having participated in the workshop?

More than 75% of the teachers plan to use experiments and/or demonstrations while more than 70% of the teachers plan to use ETKs. More than 90% of Pre-school, Kindergarten, and Elementary teachers plan to use two or three experiments or demonstrations and ETKs in their classes, while 70% of Middle and High School teachers will use only one or two and the ETKs. From the interviews we were able to extract information about the teaching load and distribute it among teachers of different grades. In pre-school and elementary school in Mexico there is only one teacher for every classroom that teaches every curricular subject (physical education and sometimes art or music have a different instructor/teacher). These teachers work with classrooms of 35-40 students in public schools and 20-30 students in private schools, thus they felt more comfortable trying experiments and/or demos in their classrooms. On the other hand, Mexican middle and high school teachers generally instruct only one subject matter (i.e. biology, physics,

chemistry, or math, in the case of science teachers) so they felt more comfortable with trying demos, experiments, and ETKs that in our case (for this workshops) deal with math or physics. Also these group of teachers mentioned that they will try to incorporate the ETKs along two or more different subject matters.

Table 3. ETKs workshop exit survey results.

	Overall		Male		Female	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
How much did you learned during the workshop?	8.89	1.27	8.92	1.23	8.88	1.29
How much fun was to participate in the workshop?	9.52	0.81	9.36	1.11	9.56	0.71
How difficult was the workshop?	4.56	3.09	3.96	3.32	4.72	3.02
How successful was your team's final design?	7.52	2.63	8.12	2.17	7.36	2.73
Did you enjoyed working in a team?	7.35	2.67	7.44	2.79	7.32	2.65
How engaged were the members of your team?	9.80	0.52	9.64	0.76	9.84	0.42
How well do you understand the concepts related to ETK's <i>Racing Cars</i> ?	9.52	1.10	9.48	0.92	9.53	1.15
How well do you understand the concepts related to ETK's <i>Under Pressure</i> ?	7.95	1.66	8.12	2.52	7.90	1.35
How well do you understand the engineering design process?	7.14	2.21	7.44	2.40	7.06	2.17
Were the instructors of the workshop able to help you learn science through the engineering design process?	9.29	1.26	9.32	0.75	9.28	1.37

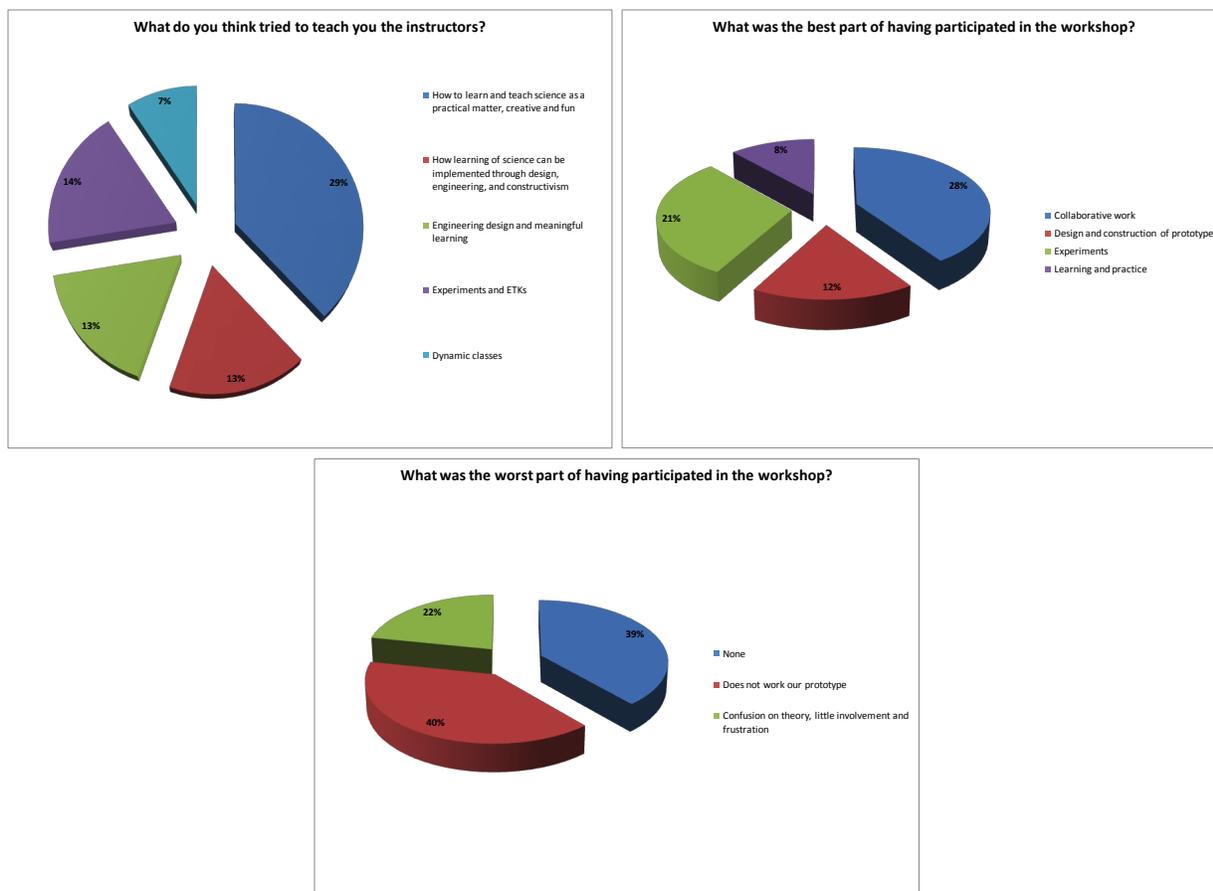


Figure 1. Frequency of answers to the following questions: What do you think tried to teach you the instructors?, What was the best part of having participated in the workshop?, and What was the worst part of having participated in the workshop?

The written materials provided were also rated as very helpful. Furthermore, workshops provided participants with opportunities to interact more closely and to develop strong interpersonal relationships, which are widely appreciated aspects of our *Alimentos Divertidos* program and valued highly by the P-12 teachers.

Final Remarks

The results of this study coincide with other studies in Mexico where it is stated that when teachers are faced with the task of innovation, come into play a variety of factors, on a personal level, their teaching concepts, attributes and goals, self-regulatory capabilities, previous experiences, as well as complex motivational processes¹¹. Although most teachers demonstrate willingness to experiment with new teaching strategies such as the use of experiments, demonstrations, and ETKs; to realize such innovations requires changes in their beliefs and attitudes, transformation of social and educational practices. It is not enough only with the

acquisition of skills or teaching techniques by the teachers. Although the workshops generated in the majority of teachers great interest and enthusiasm we can't forget a series of problems that teachers face in their workplaces that impact their teaching practices. Mexican teachers reported the existence of contexts with little support, lack of appropriate infrastructure and readily available for the transformation of classroom instruction, as well as social support from peers or qualified counselors and mentors¹¹.

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