AC 2011-2506: GIZMO FESTIVAL: K-8 OUTREACH AS A DESIGN/BUILD FOR ENGINEERING STUDENTS

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Gizmo Festival: K-8 Outreach as a Design/ Build for Engineering Students

Abstract

The Gizmo Project is completed by first-year engineering students as the final exercise in their introductory course: ENGR 100 – Exploring Engineering. The project also serves as a component for an inquiry-based unit designed by Elementary Education students in EDUC 344 –Science as Inquiry. The engineering students, in teams of 3-4, must design and build a "gizmo" that can demonstrate a given concept from science, mathematics, or engineering. Concepts are submitted by local teachers, scout leaders, or teachers-in-training. Students generate their own constraints and goals in addition to any imposed by the teachers/volunteers and the faculty imposed constraint that any Gizmo must be both safe and composed of $20 or less in materials. Concepts as diverse as "half-life" and "surface tension" have been foci of past Gizmos. The education students are required to create a detailed science inquiry unit. Inquiry must be used as the main method for teaching and a "gizmo" must also be infused into at least one of the lessons. The duration of the unit must be between 3 and 5 consecutive lessons and is aligned with the state and national science education standards.

This project acts as K-8 outreach in two important ways. First, the Gizmos and corresponding units are demonstrated in an interactive Expo, open to teachers, volunteers, children and parents. Typical attendance is over 200 people, over half of whom are K-8 students. Second, the Gizmos and units are given away by the end of the Expo event to any teacher or other adult who requests them, for continued use in educational settings. Survey data indicate that the Expo and Gizmos are very positively received by K-8 students as well as their parents and teachers, while achieving its educational objectives for the first year engineering students as well as the education students.

Introduction

<u>ENGR 100: Exploring Engineering</u>

ENGR 100: Exploring Engineering is a first-semester course taken by all engineering students as well as interested students from the college of Arts and Sciences, with a typical enrollment of 200 students. The course follows a modular structure, wherein all students attend overview lectures on engineering, teamwork, ethics, and the disciplines, but break into much smaller sections for an in-depth exploration of a given discipline (called a "seminar") [1, 2]. Each student takes three of nine possible seminars, so students arrive at the end of the semester through very different paths.

The faculty of ENGR 100 felt that the course would benefit from a "capstone" design experience that was not specific to any particular discipline. This type of project has been successfully implemented at a number of institutions in the past, to great educational benefit [3-6]. While each of the "seminars" was expected to have a systematic engineering design experience, the extent to which these were internalized by the students as teaching of design and teamwork as opposed to teaching only the major-related technical content, was limited. Therefore, the faculty sought to incorporate a project where use of both teamwork and design processes were an explicit outcome. Further, faculty wanted to give students the chance to integrate what they had learned throughout their various seminars earlier in the course. The target educational goals of the project are shown in Table 1.

Table 1: ENGR 100 project goals

Educational Goal	Rationale
Apply teamwork process	Ability to function on a multidisciplinary team is explicit course goal
Apply engineering design process	Application specified process is explicit course goal
Work with a real customer	Practice communication with a non-technical audience; work with customer provided constraints and requirements.
Practice oral and written communication	Communication is an explicit course goal. While all students will have written during the course, this is the only place to guarantee all students participate in an oral report.
Build / implement a design	Practice troubleshooting; practice tool use; practice time-management;

The previous course-wide project on ADA-compliance [7] achieved the first four goals. However, faculty observed students would propose designs that met requirements but would have been impractical in ways the students did not recognize due to their limited experience. Also, after three years of the course project, none of the proposals for wheelchair accessibility on campus made by student teams had been implemented, creating some level of disillusionment. Therefore, the fifth requirement was added to insure students would see their design in action. While it was not a formal goal, it was also felt by the faculty that having to deliver a real working prototype to a customer with whom the students had a personal relationship would be highly motivational.

The assignment conceived to meet the requirements of Table 1 is the "Gizmo" project. Student teams of four students of diverse engineering major are asked to create a working "gizmo" for $20 or less in materials that a teacher or Scout leader could use to educate children about a given topic in math, engineering, or science. Gizmos were described as team-created, interactive, functional creations. Use of pre-made parts was allowed, but any such parts had to be used in a creative or innovative way. For example, Lego bricks could be used to make a Gizmo, but not if used to exactly replicate the design on the package. Further, some element of student construction had to be included for a Gizmo to "count" – mixing baking soda and vinegar might be interesting and even educational, but without a built component, it could not be a Gizmo. The particular topic is assigned and is typically a state educational objective (for teachers) or a particular badge requirement (for Scouts). At the end of the project, student teams present their work in an Expo that is open to the public, where their creation is given away to any adult who asks for it. Details on the timeline, assignment, and customer interaction are included in the implementation section below.

EDUC 344: Science as Inquiry

EDUC 344: Science as Inquiry is a course required for all elementary and early childhood education students during their junior or senior year, with a typical enrollment of 20 students. The course is designed to provide students with instructional methods and curricular materials appropriate for teaching science concepts, processes and skills in the elementary grades. The course reflects best practices for the teaching of science as outlined in the *National Science Education Standards* and the *Pennsylvania State Standards*. Each of these reform documents emphasizes an approach to the teaching and learning of science, which highlights scientific inquiry as a prominent feature. As such, teaching science as inquiry serves as the foundation of the course.

The major goals for the course include assisting students in developing positive dispositions toward science teaching and learning, becoming familiar with the goals of contemporary science education reform at the national, state and local levels, developing an understanding of how children learn science, identifying, researching and discussing current trends and issues of curriculum and methodology in science education, planning and implementing inquiry-based science lessons/units, developing an understanding about the development of children's scientific literacy, and learning and utilizing various types of assessment strategies in the science classroom.

The Gizmo project is one way in which students demonstrate their competencies in relation to the above goals. Specifically, the goal of the project is to connect the world of science to the world of science teaching. As a result, this project is completed in collaboration with students enrolled in ENGR 100. Two meetings with the ENGR 100 students outside of class are scheduled to assist in the preparation of this assignment

Implementation

ENGR 100: Exploring Engineering

Students were placed in teams of four, selected on the basis of course section and diversity of intended major. The time-line for the project is shown in Table 2, and the overall assignment is attached as Appendix 1. In recognition of the struggle first-year students often have in organizing their time on their first open-ended design project, a number of intermediate due-dates for either drafts or completed sections of the assignment were required (available from the corresponding author on request).

Table 2: Example Gizmo Project Timeline

Date	Activity
10/27	Project kick-off and Customer Meeting #1
10/28	Project design lab (goal: preliminary design by the end of 2 hours)
10/29	Project work time in-class; draft of initial design turned-in
11/14 – 11/21	Initial draft returned with extensive faculty comments; revised draft created for customer review.
(10/31 – 11/14)	(Students taking their third seminar during this time)
11/22	Customer Meeting #2 for Design Review
11/29-12/5	Class and "Extra" work time (at least four hours daily). Drafts of documents due, working prototype must be demonstrated by 12/3.
12/6, 6-9pm	Gizmo Expo (held in large room, open to public, all students required to attend)
12/15, 3:45pm	Final memos and peer evaluations due (final exam slot)

Each team was assigned a customer, with whom they met three times. Customers were drawn from two main sources: students in EDUC 344: Science as Inquiry and local Cub or Girl Scout troops. Teachers in local school districts were invited and served as occasional customers occasionally during this project, however the overlap between ENGR 100 class times and school hours created a significant obstacle to customer-student interactions.

Student teams were assigned topics in addition to being assigned customers. Customers were interested in the given topic, but typically topics came from a "higher" source than the customers themselves, such as State Education Requirements or Scout Badge Requirements. Examples are shown in Table 3. Note that while these topics give students a direction, they are still open ended because a large number of possible designs could fulfill the request.

Table 3: Sample Gizmo Objectives

Topic	Source	Sample Gizmo
Know basic energy types, sources and conversions.	Pennsylvania State Educational Standards [8]	A Rube-Goldberg-type device, demonstrating the interchange between potential and kinetic energy
Demonstrate / build / observe how different materials react to load Demonstrate / build / observe how different shapes react to load	Junior Girl Scout Badgebook "Making it Matter" badge requirements [9]	A swing-impact tester in which a hammer could be swung a fixed amount to impact a given sample.
Create / build / complete an electrical circuit. What are the necessary components for this to work?	Webelos Cub Scout "Engineer" badge requirement [10]	An electrical "puzzle" with various circuit components that could be connected by alligator clips

Resources available to students included their faculty and near-peer TAs for questions as well as a "lab" space allotted for supervised project work. As can be seen in the Table 2 schedule, class and out-of-class hours were available for work-time in the lab. Ten toolboxes (drill, screwdriver set, wrench, pliers, hammer, saw, etc) were available for teams to use within the lab space, along with four workbenches and two hot glue guns. Students also had access to the university Project Development Lab, where there is large scale metal- and wood-working equipment, but only when approved by faculty to avoid overwhelming this limited resource. Students were expected to obtain their own materials including fasteners. However, at the start of the project a "scrap" pile, collected from the design shop over the course of the semester, was shared for free. This included scrap wood, metal, plastic, and conduit left over from other projects within the college of engineering. Finally, each team was given $20 in cash for their purchases. At the end of the project, they returned receipts plus remaining cash to total $20; from an outlay of $1020, $300 was returned. All resources were provided through donation or departmental budget, there were no student fees associated with the course.

The first customer meeting occurred on the very first day of the project, and was intended to give students context for their project. Specifically, the customers were asked to talk about what was appropriate in general, what the children (the ultimate users) could be expected to do and know, and other constraints. We found that first-year engineering students in general have a over estimation of what 8 year old children typically know and are able to do, as well as only a shaky understanding of what is considered "safe" in an elementary classroom or Scout context. This meeting helped ameliorate some of these issues.

The second customer meeting, nearly a month after the first (Table 2) served as a design review. Student teams would "pitch" their design to their customer, and the customers were allowed to give any feedback that occurred to them. This significantly helped the relevance of the student designs. As a side-benefit, since most of the Scout customers were drawn directly from college faculty and staff, they also provided a technical critique of the design.

The final customer meeting was at the Gizmo Expo, held in the evening and open not only to customers, but the general public as well. By this point, all Gizmos must be functional and student teams must be ready with an informative poster as well as a 5-minute "show" for both children and adults. Typical attendance exceeded 200 parents, children and teachers. Many of the attendees came as Scout troops, with the goal of visiting a sufficient number of Gizmo displays to satisfy badge criteria within one evening. At the end of the event, the Gizmos and supporting documentation were given away to the customers or another requesting adult.

All grading of the actual Gizmo artifact occurs during the Expo. To complete the requirements of a service-learning project [5], each team was required to submit a reflective memo discussing the Expo and their team processes as well as including copies of all Gizmo documentation and photographs of the Gizmo itself. Each individual student submitted a personal reflection memo on what they had learned, what they might have done differently, and a peer-evaluation. Each team also provides a poster on their Gizmo, instructions for its use, an explanation of the scientific/technical principle illustrated by the Gizmo, and a bill of materials. Taken collectively, this project was responsible for 20% of the students' grade in the course.

Some sample Gizmos from this project are shown in Figures 1 and 2. You can also get a sense of the expo from these images, which is held in a large dining hall on campus.

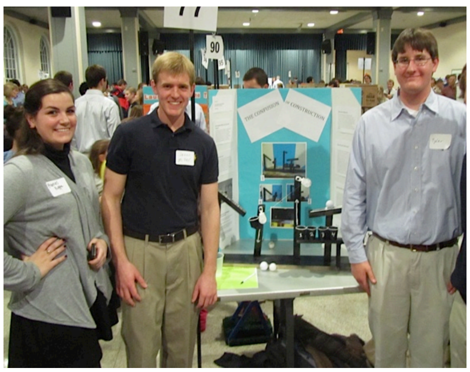
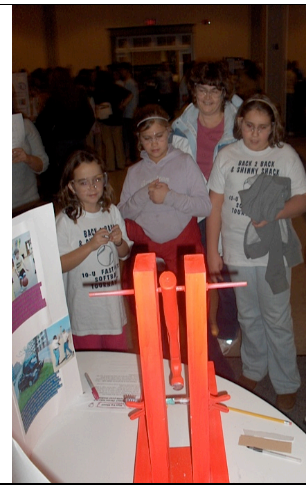
A) Rube-Goldberg Energy Conservation Demonstration, with Bucknell Engineers. A ball moves down an incline, into a cup that tips another incline, catapulting a second ball into one of four target cups. By imparting different potential energies to the original ball, children were encouraged to "shoot" for different target cups.	B) Impact Tester, as used by Girl Scout attendees. A sample, held with clothespins between wooden supports, was struck by a swinging hammer. A variety of materials were tested for impact resistance.	C) Electrical Circuit Puzzle, with ENGR 100 students. The Gizmo is a simple circuit with a battery and light bulb. To complete the circuit, children must attach conductive materials with alligator clips out of the selection of conductive (wire, pennies) and non-conductive (pencil, rubber band) materials provided.
		

Figure 1: Example Gizmos, corresponding to those listed in Table 2

While the faculty assess each Gizmo for its functionality and ability to demonstrate the core scientific / technical principles, its educational efficacy once given away is *not* directly assessed. Students complete a personal and team reflection after the Expo, including their post-implementation assessment. In these documents, the faculty are seeking seriousness of reflection and recognition of areas where the design was exceptionally good or where and how it could have done better. Over 90% of student reflections accurately capture these elements. Typical observations on successful Gizmos include the importance of: having a "hook" to capture children's interest, durability, and interactivity. Areas for improvement that often come up are in timing (first-year engineers are often surprised at the attention span of seven-year-olds) and in how challenging it can be to appropriately pitch the concept (students often express surprise at both how much *and* how little their customers know).

A) Center-of-Mass Demo with ENGR 100 student and Cub Scout (Cub Scout requirement on the concept of center of mass); each see-saw was attached to the bar at a different non-central point. Children were then to load marbles into the cups on the ends and observe how additional marbles were needed to counteract shorter lever-arms.	B) Trebuchet with ENGR 100 Students(PA State Objective on force and lever-arm); popular with Scouts and first-year engineers alike, this implementation of a hybrid trebuchet/catapult featured a repositionable pin that allowed both adjustment of spring-tension and throwing arm.
	

Figure 2: Additional Gizmo Examples

<u>EDUC 344: Science as Inquiry</u>

To gain practical experience developing curricula for the science classroom, students are required to create a detailed science mini-unit in teams of two. The topic of study for each unit is derived from the Pennsylvania State Education Standards. Inquiry must be utilized as the main method for teaching and an ENGR Gizmo must also be infused into at least one of the lessons. The duration of the unit must be between 3 and 5 consecutive lessons and each lesson is designed to be active, interesting, education, fun and meaningful. Students are encouraged to use current research in the field of science education to complete the assignment and all lessons must be aligned with the state and national science education standards.

In addition to planning the unit, students are also asked to justify the unit. Specifically, in a written format, students discuss how the mini-unit supports the Pennsylvania State Academic Standards, the National Science Education Standards, scientific inquiry and conceptual learning. In justifying their units, students must support their observations, claims, and recommendations with evidence and current educational research. Additionally, students are required to rationalize their choices of performance assessments and technology and teach one of the lessons from the unit to their peers in the EDUC 344 class as if they were the intended audience. As a final component of the project, students showcase their collaborative efforts at the Expo. Administrators, teachers, parents, scout leaders, and students from local school districts attend this Expo. EDUC 344 students are responsible for teaching their lessons to the children at the expo and also providing copies of their unit/lessons to these attendees. At the conclusion of the expo, some students from EDUC 344 were able to keep the gizmo and planned to use it as an educational tool in their future classrooms. Others who were not able to keep their gizmo often times go on to recreate the gizmo and later teach the unit that they designed during their student teaching experiences and/or in their future elementary classrooms.

To evaluate the EDUC students' performance on the unit, students were required to submit one outline, one draft and finally the completed unit product. The outline required students to describe the learning activities of the unit using the 5E learning cycle and instructional model [11]. The 5E model is an instructional model used to support learning through 5 specific phases: engagement, exploration, explanation, elaboration and evaluation. For each of these five phases students plan learning activities that reflect inquiry-based teaching and learning. After receiving professor feedback and suggestions on the outline, students then were required to complete a draft of their unit. This unit draft must adhere to the Understanding by Design approach for lesson and unit planning[12]. Overall, this draft is much more detailed in nature as compared to the outline. Specifically, the draft includes, state and national standards, performance standards, assessment strategies/techniques, adaptations for diverse learners, a list of necessary materials, and procedures. Again, professor feedback and suggestions were provided and then utilized by the students to complete the final version of the unit. This final version included the same components of the draft however also included a reflective component which required student to justify their instructional decisions using current research in the field of science education. Finally, to provide students with the opportunity to teach a portion of the unit, they were also required to teach one of the lessons from the unit to their peers in the EDUC 344 class as if they were the intended audience. The professor assessed this teaching experience, however in addition to professor feedback, students also received comments and suggestions from their peers. Overall, the design and implementation of this project provides students with a highly supportive experience through which they were able to gain an understanding of how to plan and teach an inquiry based science unit. (Grading rubrics can be found in Appendix 3)

An EDUC 344 student demonstrates her inquiry-based educational unit for a Cub Scout. The Gizmo concept is on natural resources management, specifically rainwater runoff. The scout can reposition the elements on the hill (farm, house, field, levee) in an attempt to redirect the water which will be poured from a trickling pipe (across the top of the red "field") once he has completed his design.

Figure 3: EDUC 344 Educational Unit Presentation

Assessment and Discussion

A variation on this project has been implemented for five semesters in ENGR 100 and EDUC 344. Based on student, faculty, and customer feedback, the project was revised significantly three times. This paper here focuses on the two implementations of the project in its current form (2009 and 2010). Assessment centered on three areas: 1) Did students achieve objectives outlined in Table 1? 2) Did students value the experience? And 3) Did our customers / Expo audience value the Gizmos / Expo?

For the first question, we refer to the grading rubric used for the Gizmo assignment (Appendix 2). Table 4 summarizes rubric scores in the target areas. The high values for these goals reflect the fact that each element shown is subject to faculty feedback and student revision at least once before grading. In the case of Gizmo functionality, the paper designs go through at least three rounds of faculty comment followed by daily rounds of comment during construction, concluding with a required functionality demonstration two days before the expo. In a representative sample of teams, every team's performance fell in "met or surpassed" requirements for: Oral communication, Written communication, Design Process, and Design Implementation. Teamwork is assessed separately based upon teammate feedback. While the majority of students meet expectations in terms of Teamwork as well, four of the 43 students in the sample received less than 90% on their teamwork score, indicating they did not equitably carry their share of teamwork (100% for all team members indicates equitable sharing of responsibilities). Note that this data would be the basis of an ABET direct assessment, were this course targeted for assessment on any of the objectives in Table 1.

Table 4: Assessment of Educational Goals

Educational Goal	Mean Score (std. dev)*
Apply engineering design process	93% (4%)
Work with a real customer	100% (0%)
Practice oral and written communication	93% (7%)
Build / implement a design	95% (7%)

* Sample is randomly assigned subset of the class, graded by a single instructor. For consistency, only assessments from this instructor are shown.

Another window into Gizmo function is provided by the team- and individual- student reflections that were completed after the Gizmo was built, demonstrated at the expo, and given away. As mentioned above, over 90% of students reflections capture insights on possible improvements and design successes. This is a qualitative reflection, students will engage in quantitative assessment of projects later on in their curricula.

ENGR 100 student evaluation of the experience is assessed both through the course evaluation and through student comments. On a five-point Likert scale, the question "The Gizmo Project was a valuable component of the course" received a mean of 4.13, while "The interaction with customers from EDUC 344, Girl Scouts or Cub Scouts was beneficial for the gizmo project" received a 3.99. The project score is among the most highly-rated elements of the course. The lower score for customer interaction is understandable, as this is the first example of delivering a technical product to a non-technical audience for most of our students. Students can be frustrated by customers who add requirements, request design changes, or make vague statements, but these are all part of the customer relationship and valuable for the students to become accustomed to. Student comments on the course evaluation further highlight the project as a finale to the course, "The Gizmo project was a great way to put everything I learned to use and it was great to see the kids having fun with the gizmos." The most common criticism of the project was the need for more time. We note that over the course of implementation, the time devoted to the project has expended from two weeks to the present schedule, and at each step in the process more time has been requested.

To gain a better understanding of the ways in which this project impacted the education students, two data sources were administered to the EDUC 344 students. First, the self-efficacy scores for the education students were measured using the Teaching of Science as Inquiry (TSI) Instrument [13]. Overall, student's self-efficacy scores increased from the beginning of the semester to the end of the semester. Specifically, using a five-point Likert scale, students' mean self-efficacy scores prior to the collaborative project were 3.22, whereas after the project the self-efficacy scores were 4.23. Furthermore student outcome expectancy scores prior to the project were 3.51 and after the project they increased to 4.05. In addition to the TSI Instrument, students were also surveyed using an end of semester reflection. Qualitative data from these sources identify the gizmo project as being one of the most useful components of the course in relation to assisting students with the development of an understanding of the teaching of science as inquiry.

Attendees at the Expo were also surveyed on their reactions to the event. In the attendees in December 2010, there were teachers, at least three separate Cub Scout packs, at least three Girl Scout troops, two Odyssey of the Mind groups, and numerous interested people. The event was advertised through the university web-site and Facebook sites as well as in the local newspaper and word-of-mouth. Typical responses from adult attendees include “Awesome,” “Good Job,” and “Great event and explanations.” The most common suggestion for improvement was that the time devoted to the event be extended (it is currently two hours).

Faculty reflection on this project is also positive overall, but also reflects management challenges. A diverse set of customers is needed because no one source has sufficient people to work with the entire ENGR 100 class. As it is, each customer is assigned two or three teams with which to work. Initially, it was thought customers could be drawn exclusively from working teachers, however it proved too difficult in terms of timing and transportation to draw them to campus during class times to meet with students. While out-of-class meetings could have been required, the risks to the partnership of relying on first-year students to manage this in a professional manner were felt to be too great. Working with on-campus clients in EDUC 344 created educational benefits for both courses, but still provided some challenge to coordinate the schedules of the disparate courses. An unanticipated benefit of the interaction was that it improved the self-efficacy beliefs of the Education students in regard to the teaching of science as inquiry.

The “Gizmo” project is a service-oriented first-year design experience that is successful at achieving its academic and social goals. It is highly portable and flexible; it could easily be adapted by other institutions and the target objectives can come from a variety of sources and be changed yearly. On the down-side, it is reasonably resource intensive, requiring space and tool availability for 200 students, as well as communication with a large number of outside customers. On the whole, the faculty and students are satisfied with this project as a suitable capstone for the first-year course.

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Appendix 1: Gizmo Assignment Memo

Memo

Date: October 27, 2010
To: Engineering 100 Interdisciplinary Teams
From: ENGR 100 Faculty, on behalf of local teachers
Re: Final Project: Gizmo!

The United States is facing a possible shortage in future engineers as the needs of high-technology sectors grow and the fraction of first-year college students choosing engineering falls. A logical approach to this problem is to foster experience with and interest in engineering among younger students, who will then hopefully pursue engineering when they reach college. In order to teach the foundations of engineering to K-12 students, local teachers of science and math would benefit from being able to use hands-on, interactive "Gizmos" in their courses. This is particularly true for concepts that are difficult to understand without a demonstration. Therefore, there is a need for engineers to assist in developing appropriate educational tools that teachers and those who work with children can use to introduce their students to science, math, engineering and technology. The goal of your team project is to aid in this effort by creating a Gizmo (defined in Appendix A) - that could be used by:

Section #	Faculty Coach	Room	Customer	Projects
1&2		Dana 134 Class and Lab	Cub Scouts	Appendix C, Table 3
3&4		Breakiron 165 class and lab	Student Teachers (EDUC 344)	Appendix C, Table 2
5&6		Dana 221, Class and lab	Student Teachers (EDUC 344)	Appendix C, Table 2
7&8		Breakiron 263 class, Breakiron 166 lab	Student Teachers (EDUC 344)	Appendix C, Table 2
9&10** (for space purposes, two students have been reassigned to section 1, please check spreadsheet!)		Breakiron 065 class; Breakiron 064 lab	Cub Scouts	Appendix C, Table 3

You will be helped in this project through an interaction with actual customers: Teachers, Scout leaders / parents and students from EDUC 344(teaching of science). Your team will be partnered with one customer, who will give you guidance on what is appropriate for children and give you feedback on the appropriateness of your Gizmo. In return, you will explain the principles behind your Gizmo and make it available for them to use in classes / meetings.

Your team has been assigned a Concept, PA State Educational Standard or Scout Badge Requirement as the inspiration for your Gizmo. As you can see from the standards / badge requirements (Appendix C), there is a wide range of possibilities - the goal of your gizmo may be to introduce students to an engineering discipline, demonstrate how a common object or material works, or demonstrate an important physical principle or something else entirely. In the creation of your product, you are to follow the engineering design process, as set forth in the beginning of the semester. While you will not proceed to commercializing your product, you will get customer feedback on it and you will need to have a *working* model/version of your demonstration. This working demo will be shared with local teachers, educators, advisors, scout leaders, **and children (~100 Cub Scouts, teachers, and local residents)** during an Exposition from 6:00-9:00 pm on Monday, December 6. All ENGR 100 students are required to attend and present.

You are required to bring the following to this session:

- A poster, fixed to a 30"x40" foam board / tri-fold board explaining what your demo is (with a picture), how it works, what it's supposed to teach people about, a brief and clear statement of the Concept / Pennsylvania State Educational Standard or Badge Requirement addressed by your Gizmo/ program and an explanation of how it does so.
- The Gizmo that your customer would show to a group of students / scouts in the course of a learning unit on your Concept / PA State Standard / work on that badge. Materials to build this demo must cost $20 or less.
- Bill of materials with prices for final materials used, documented fully with recipts for reimbursement.
- Instructions for the teacher / scout leader on how to *use* this Gizmo.
- A brief description, for the use of the teacher, on the underlying technical principles for your Gizmo. In other words, *how and why it works*, including suggestions for further reading.

At the end of the exposition, all of the above materials will be *given away* to an interested teacher/ Scout leader! Your goal, during your presentations, is to convince your audience that they want/need your demo for their group.

By 6:30pm on Wednesday, December 15, a memo with the documentation of this work, including copies of all written material above, is due in the Engineering Dean's office. Specifications for memo contents will be forthcoming.

Further details on expectations for each segment of this project are included in the attachments as well as in intermediate in-class and homework assignments to be provided to help you stay on track. You will start brainstorming and doing design work on this project in lab on October 28, 2010 (1-3 or 3-5, as assigned).

We look forward to seeing your creations!
ENGR 100 Faculty Team / EDUC 344 Faculty

Attachments
Appendix A: What is a Gizmo / Gizmo Constraints and Requirements

Appendix B: Project Documentation Requirements
Appendix C: Project Topics

A Gizmo is a device or program the use of which allows students to discover the engineering / scientific / mathematic principle specified by your customer / professor. Characteristics of a Gizmo include:

- It is constructed or programmed by your team
- It is the result of the Engineering Design Process
- It may use pre-fabricated parts, but must use them in a creative or different way from their original source
- It is interactive (for teacher / leader or students)
- Its total materials cost does not exceed $20

Table 1: Examples of Gizmos and Not-Gizmos

NOT a Gizmo	**Gizmo**
A bridge made of popsicle sticks	A device for *testing* bridges made of popsicle sticks by students/Scouts (would want to provide an example bridge)
A bowl of Jello	A contraption to demonstrate the physical properties of Jello (for example, resilience), perhaps with temperature control
A Lego model constructed exactly following package instructions	Something using Lego pieces in a way designed by the team, as long as it accomplishes the educational goal and is interactive in some way.
Mixing baking soda and vinegar	Making something go, move or otherwise change as a result of mixing baking soda and vinegar. Can still be centered on reaction, but must include an element of construction to be a gizmo.
A movie made in Alice	An interactive movie or game made in Alice

Gizmo Requirements / Constraints (also add your own):

- The gizmo/ program must be something a teacher or scout leader can use to demonstrate a concept to the entire group within an approximate 15 minute period (exact times may differ, check with your customers). It may be a physical object, a set of physical objects, or a computer program. But it must fit the definition of "Gizmo" given above.
- The gizmo must be **safe** to use with and around children.
- The final materials out of which the demonstration gizmo is constructed must cost no **more than $20**. If you purchase something and do not use it in the final product, its cost does not count towards this total. If you purchase something and use only part of it in the final product (ex: ½ a can of paint), the cost shown in the bill of can only be for the fraction used. **For all project purchases, receipts are required**. Note that the *value* of any item obtained for free (say, from your house) must be accounted for in your bill of materials (but only collect receipts for items that are actually bought). Only truly free items (items recovered from trash or recycling such as cardboard tubes from paper towels) may be counted as no-cost. Note that items need not be purchased new; eBay and similar sources are a valid resource.

- The gizmo must be “portable” for a typical teacher / leader without assistance, and should generally have a footprint of 30”x30” or less (if your idea cannot fit within this area, talk to your ENGR 100 faculty member). It should also be sturdy enough that it could be carried from one room to another (or from the car into the classroom) without fear of damage.
- The gizmo must **work**.

Note that *if* you are producing a computer program, most customers will not have Alice or software products readily available. You will have to include instructions for obtaining, installing, and using this program in your instructions. Programs produced in any other language (C, Java, Flash, etc) must be in <u>executable</u> form.

Similar work has been done by ASME and ASEE – visit these websites to see what others have done. Note that merely replicating one of these activities is plagiarism, and therefore is <u>not</u> acceptable.

Things you may assume teachers / Scout leaders have available / know:

- <u>Knowledge</u>: The teacher will have an advanced science and math background, but is likely *not* to have any coursework in engineering itself. Scout leaders may be engineers, but that is not a given.

- <u>Materials you may assume are available</u>:
- - Common appliances and furniture: hot plate / stove; blow dryer; fan; refrigerator; table, chairs.
- - An internet-connected computer (PC or Mac, can’t assume one or the other). This computer *will not* have Alice or perhaps other software pre-installed on it. If you need Alice or another software package to make your demo work, you need to include how to download and install it in your instructions.
- - Common classroom and household materials such as paper, pencils, markers, glue, ice, water, and scissors.

Bill of Materials with Prices and Receipts (due: at expo):

A bill of materials is an itemized list of all of the raw materials that went into the production of an item, along with the price and source of each. It is a valuable starting point for anyone who wants to re-create your demo, as well as a good way to keep track of your budget. This information is best presented in a table or a nicely formatted Excel spreadsheet. Note we will only be able to reimburse purchases for which there is a receipt, and only for the portion of the purchase used in construction of the gizmo. Example and further guidelines will be provided at a later date.

Teacher Instructions (due: at expo):

Write step-by-step easy to follow instructions for using your demo. Include pictures and diagrams, dimensions, and be sure to label important parts of your gizmo/program. Test the effectiveness of the instructions by handing them and your demo to a friend who is new to your product. If they can't make the demo work without asking you for help, then you need to rewrite. Example and further guidelines will be provided at a later date.

Teacher / Leader Technical Background (due: at expo):

While your customers are educated people, they may not have done significant coursework in the particular area addressed by your Gizmo. Therefore, create a short (1 page or less) description of the technical background that a person needs to understand how your Gizmo/program works and what it does. Example and further guidelines will be provided at a later date.

Poster requirements (due: at expo):

The goal of the poster is to "sell" your Gizmo. At a minimum, the poster should give the educational objective of the gizmo, background on the engineering involved, an explanation of how the gizmo works, and how the students will learn from watching it. Complete details on the poster will be provided later in the semester.

The poster must be mounted on a single tri-fold board. Your poster should be printed as letter size (8.5"x11") sheets that are then mounted on the foam board; the large number of posters needed for 50 ENGR100 groups precludes use of the large-format printer (in other words, the use of the large-format printer is not permitted). Further details will be available as the Gizmo Expo approaches.

Memo requirements:

The memo serves two purposes: to summarize your work and give you an opportunity to reflect on the design and presentation experience. The memo will have both a team and individual component, and will be due in the ENGR 100 Final Exam Slot, Wednesday, December 15, no later than 6:30 pm. Further details on Memo requirements will be posted as the due date approaches.

TABLE 2: Objectives for EDUC 344 Customers (Orbison, Nepal, Meng)

Note: Exact Standard will be assigned to your team!

Pennsylvania State Standards for Elementary Education: Standards found both most relevant to engineering and most challenging for educators
3.4.4. A. Recognize basic concepts about the structure and properties of matter.
Describe properties of matter (e.g., hardness ,reactions to simple chemical tests).
Know that combining two or more substances can make new materials with different properties.
Know different material characteristics (e.g., texture, state of matter, solubility).
3.4.4. B. Know basic energy types, sources and conversions.
Identify energy forms and examples (e.g., sunlight, heat, stored, motion).
Know the concept of the flow of energy by measuring flow through an object or system.
Describe static electricity in terms of attraction, repulsion and sparks.
Apply knowledge of the basic electrical circuits to design and construction simple direct current circuits.
Classify materials as conductors and nonconductors.
Know and demonstrate the basic properties of heat by producing it in a variety of ways.
Know the characteristics of light (e.g., reflection, refraction, absorption) and use them to produce heat, color or a virtual image.
3.4.4. C. Observe and describe different types of force and motion.
Recognize forces that attract or repel other objects and demonstrate them.
Describe various types of motions.
Compare the relative movement of objects and describe types of motion that are evident.
Describe the position of an object by locating it relative to another object or the background (e.g., geographic direction, left, up).

3.6.4. C. Know physical technologies of structural design, analysis and engineering, finance, production, marketing, research and design.
Identify and group a variety of construction tasks.
Identify the major construction systems present in a specific local building.
Identify specific construction systems that depend on each other in order to complete a project.
Know skills used in construction.
Identify examples of manufactured goods present in the home and school.
Identify basic resources needed to produce a manufactured item.
Identify basic component operations in a specific manufacturing enterprise (e.g., cutting, shaping, attaching).
Identify waste and pollution resulting from a manufacturing enterprise.
Explain and demonstrate the concept of manufacturing (e.g., assemble a set of papers or ball point pens sequentially, mass produce an object).
Identify transportation technologies of propelling, structuring, suspending, guiding, controlling and supporting.
Identify and experiment with simple machines used in transportation systems.
Explain how improved transportation systems have changed society.

3.7.7.C Explain and demonstrate basic computer operations and concepts.

TABLE 3: Objectives for Cub Scout Beltloops (Vigeant / Baish)
Note: Exact Standard will be assigned to your team!

Engineering Achievement
E5. How is electricity generated, how does it get to my home?
E6. Electrical Circuits Create / build / complete an electrical circuit. What are the necessary components for this to work?
E7. What are different types of bridges, why are they different, how do they work, how are they built?
E8 / 9. Lifting, Throwing, Mechanical Advantage and Conservation of Energy Create / Build / Demonstrate how forces may be transmitted through a system to make a given task easier / possible (for example: throwing things with a trebuchet; lifting things with pulleys, etc)
Science Achievement
S1. What is Bernoulli's principle, how does it work, what does it mean, how do we apply it?
S2. What is inertia, how does it work, what does it mean, how do we apply it?
S4/5. What is pressure, how does it work, how do we apply it? Particularly interested in atmospheric pressure and/or water pressure.
S6. What is Newton's 3rd Law, what does it mean, and how do we apply it?
S7. What is "center of gravity", what does it mean, how do we apply it?
S8. Identify, explain, and use "Simple Machines"

Appendix 2: Gizmo Grading Rubric

Team Number:

Team Members:

2-point scale = check; check-minus; zero
5 point scale: 1 = Lacking, poor, multiple elements missing or incorrect - fails to meet expectations
5 = Correct, complete, clear: meets/exceeds expectations

	Task	Grading Criteria	Graded out of 2 or 5	Points Earned	Scale Factor	Points Available	Points Awarded		
Written Materials	**Summary Memo**	Writing Description / Reflection Photos with labels	5		1.4	7	0		
	Bill of Materials	Complete, all items included, all prices, well organized	2		1	2	0		
	Connection to standard	Link to PA standards / Badge / requested topic Accuracy	2		1	2	0		
	Teacher Instructions	Completeness, accuracy Clarity	5		0.6	3	0		
	Technology background	Accuracy Clarity	5		0.6	3	0		
	Copy of Poster Materials	Is it present?	2		1	2	0		
	Homework #1 (design process)	Following process; rational decision making; good ideas; good criteria; completeness, meets constraints	5		0.6	3	0		
	Homework #2 (design revision, meeting, memo)	Revisions account for prof comments; memo indicates on-task meeting, feedback recorded and plans for addressing made	2		1	2	0		
	Homework #3 (design revision memo)	Comments address customer requests	2		1	2	0		
	Homework #4 (draft documents)	Draft instructions clear and easy to follow; draft science outline clear and accurate; draft bill of materials appropriate	2		1	2	0	**Total, written**	
	Homework #5 (demo)	Did it work?	2		1	2	0	0	
Presentation	**Poster (written / visual)**	Clarity of written parts Clarity of visuals Salesmanship of idea Completeness / accuracy	5		1.6	8	0		
	Presentation (oral)	Clarity of explanation "Sales" pitch (includes demo) Teamwork (everyone participates)	5		1.4	7	0	**Total, presentation**	

		Professionalism (dress, speech)						0
Gizmo	**Functionality of Gizmo (works)**	Works; works well; works repeatedly; **Note:** final design must meet constraints and reflect changes based upon prof / customer comments to merit full credit in this area	5		5	25	0	**Total, Gizmo**
	Effectiveness of Gizmo (teaches)	Teaches what it's meant to; age appropriate; useful	5		2	10	0	0
Individual	**Individual Memo**	Writing; Evidence of self-reflection: Reflection on teaming; Reflection on learning; Reflection on customer impact; Reflection on customer reception	5		2	10	0	
Creativity	**Creativity / Virtuosity**	Creativitiy, exceptional analysis, above and beyond; applies to gizmo, writing, or any part of the project process. Score between 0 and 10	5		2	10	0	
		TOTAL				100	0	
		Adjustments (Peer Evals or Absences)					0	
		Adjusted Score					0.0	

Appendix 3: Grading Rubric, EDUC 344

Analytic Scoring Rubric for Mini-Unit Draft
EDUC 344

	7	**5**	**3**	**0**
Points Earned				
EU's and EQ's	The enduring understandings and essential questions are **exceptionally** developed and **distinctively** reflect the content of the unit	The enduring understandings and essential questions are **generally** developed and **adequately** reflect the content of the unit	The enduring understandings and essential questions are **somewhat** developed and **inadequately** reflect the content of the unit	The enduring understandings and essential questions **are not** well developed and **do not** reflect the content of the unit
Points Earned				
5E Lesson Outline	The procedures for the lessons are **exceptionally** clear and **thoroughly** follow the 5E Model. The EFCI are identified **correctly**.	The procedures for the lessons are **generally** clear and **partially** follow the 5E Model. The EFCI are identified **partially correctly**.	The procedures for the lessons are **somewhat** clear and **inadequately** follow the 5E Model. The EFCI are identified **incorrectly**.	The procedures for the lessons are **not** clear and do not follow the 5E Model. The EFCI are **not** identified.
Total Points ___________ / 14				

Unit Rubric – Draft
EDUC 344

Academic Standards	**0 1 2 3 4 5 6 7 8 9 10**
• Appropriate state and national academic standards are identified • State and national standards are appropriate for the content and grade level being taught	
UBD Format	**0 1 2 3 4 5 6 7 8 9 10**
• The EU and EQ's identify the theme and the "big ideas" of the unit • The specific understandings are clear and well developed • A clear relationship between EU and EQ's is evident • The performance standards are clearly articulated • Assessments are varied and thoroughly developed • Adaptations for special learners are exceptionally addressed	
Lesson Plans	**0 1 2 3 4 5 6 7 8 9 10**
• Lesson plans are exceptionally developed • 3-5 consecutive lessons are included • A comprehensive list of Materials necessary for implementing the lesson is identified • Procedures are clearly articulated • Technology is integrated into at least one lesson of the unit	
Gizmo Implementation	**0 1 2 3 4 5**
• The ENGR gizmo is effectively integrated to the overall unit • The gizmo supports the EU's and EQ's	
Inquiry	**0 1 2 3 4 5 6 7 8 9 10**
• The unit distinctly emphasizes inquiry methods for learning • The unit requires students to engage in the essential features of classroom inquiry • The essential features are clearly addressed in the procedures of the lessons	
Instructional Model	**0 1 2 3 4 5**
• Lessons clearly and correctly implement an instructional model to support inquiry teaching and learning	
Additional Materials	**0 1 2 3 4 5**
• Rubrics for evaluating performance tasks are included • Worksheets and/or handouts necessary for the unit are also included • These additional materials are well developed and relate to the rationale, goals, objectives and procedures	
Total __________/ 55	

Unit Rubric – Final
EDUC 344

Criteria	Score
Academic Standards	**0 1 2 3 4 5 6 7 8 9 10**
• Appropriate state and national academic standards are identified • State and national standards are appropriate for the content and grade level being taught	
UBD Format	**0 1 2 3 4 5 6 7 8 9 10**
• The EU and EQ's identify the theme and the "big ideas" of the unit • The specific understandings are clear and well developed • A clear relationship between EU and EQ's is evident • The performance standards are clearly articulated • Assessments are varied and thoroughly developed • Adaptations for special learners are exceptionally addressed	
Lesson Plans	**0 1 2 3 4 5 6 7 8 9 10**
• Lesson plans are exceptionally developed • 3-5 consecutive lessons are included • A comprehensive list of Materials necessary for implementing the lesson is identified • Procedures are clearly articulated • Technology is integrated into at least one lesson of the unit	
Gizmo Implementation	**0 1 2 3 4 5**
• The ENGR gizmo is effectively integrated to the overall unit • The gizmo supports the EU's and EQ's	
Inquiry	**0 1 2 3 4 5 6 7 8 9 10**
• The unit distinctly emphasizes inquiry methods for learning • The unit requires students to engage in the essential features of classroom inquiry • The essential features are clearly addressed in the procedures of the lessons	
Instructional Model	**0 1 2 3 4 5**
• Lessons clearly and correctly implement an instructional model to support inquiry teaching and learning	
Additional Materials	**0 1 2 3 4 5**
• Rubrics for evaluating performance tasks are included • Worksheets and/or handouts necessary for the unit are also included • These additional materials are well developed and relate to the rationale, goals, objectives and procedures	
Total __________/ 55	

<u>Justification Rubric</u>
EDUC 344

PA Standards	**0**	**1**	**2**	**3**	**4**	**5**
• A clear indication of how the PA standards are supported throughout the unit is articulated • Specific comments regarding lesson activities and academic content are discussed						
National Standards	**0**	**1**	**2**	**3**	**4**	**5**
• A clear indication of how the National Science Education Standards are supported throughout the unit is articulated • Specific comments regarding lesson activities and academic content are discussed						
Scientific Inquiry	**0**	**1**	**2**	**3**	**4**	**5**
• Articulates distinctively how the unit supports inquiry teaching and learning • Specific connections are made between lesson activities and the essential features of classroom inquiry • The value of inquiry teaching is addressed						
Performance Assessments	**0**	**1**	**2**	**3**	**4**	**5**
• Performance assessments are defended and justified in terms of their worth within the unit • Relationships among the assessments, EU, EQ's and performance standards are discussed						
Gizmo	**0**	**1**	**2**	**3**	**4**	**5**
• The inclusion of Gizmo into at least one of the lessons is justified in relation to how the gizmo is presumed to assist in the educational process						
Claims	**0**	**1**	**2**	**3**	**4**	**5**
• Claims are made to clarify position • Claims are reflective of individual beliefs • Claims are related to classroom teaching and learning						
Evidence	**0**	**1**	**2**	**3**	**4**	**5**
• Claims are supported with evidence • Evidence from personal experiences is utilized • Evidence is related to classroom teaching and learning • Evidence is reflective of EDUC 344 classroom discussions and/or course readings and assignments						
Justification	**0**	**1**	**2**	**3**	**4**	**5**
• Claims are justified with research and/or literature in the field of science education • Justification is related to classroom teaching and learning						
Total __________/ 40						

<u>Lesson Presentation Rubric—EDUC 344</u>
EDUC 344

Name(s): ____

Lesson: ______________________________ Grade Level: ______________________

Lesson	**0 1 2 3 4 5 6 7 8 9 10**
• The relationship to PA and National standards is evident • Developmentally appropriate • Active/meaningful learning • Students creatively convey important content and/or concepts	
Inquiry	**0 1 2 3 4 5 6 7 8 9 10**
• The lesson distinctly emphasizes inquiry methods • Learners are explicitly required to give priority to evidence when constructing explanations • Attention is given to the essential features of classroom inquiry	
Presentation	**0 1 2 3 4 5 6 7 8 9 10**
• Encourages active and meaningful learning • Demonstrates focus and is organized • Presenters are enthusiastic in their teaching • Presenters are professional in their implementation	
Reflection/Discussion	**0 1 2 3 4 5 6 7 8 9 10**
• A clear summary is provided • The goals for the lesson are clearly articulated and correlate to the lesson activities • Teaching practices and decisions are justified using course readings and discussions • Modifications of the lesson are discussed after the peer teaching experience • Modifications are justified based on experience and current research in science education	

Total ___________/40