International Journal of Engineering Education Vol. 27, No. 6, pp. 1174–1185, 2011
Printed in Great Britain
0949-149X/91 $3.00+0.00

Nifty Ideas and Surprising Flops in Capstone Design Education*

SUSANNAH HOWE
Picker Engineering Program, Smith College, 151 Ford Hall, Northampton, MA 01063, USA. E-mail: showe@smith.edu

KEVIN CAVES
Pratt School of Engineering, Department of Surgery, Duke University, DUMC 3887, Durham NC, 27710, USA.
E-mail: kevin.caves@duke.edu

CARSTEN KLEINER
Computer Science, University of Applied Sciences & Arts Hannover, Ricklinger Stadtweg 118, 30459 Hannover, Germany.
E-mail: carsten.kleiner@fh-hannover.de

GLEN LIVESAY
Biomedical Engineering, Rose-Hulman Institute of Technology, 5500 Wabash Avenue, Terre Haute, IN 47803, USA.
E-mail: livesay@rose-hulman.edu

JUDITH SHAUL NORBACK
Stewart School of Industrial and Systems Engineering, Georgia Institute of Technology, 765 Ferst Drive NW, Atlanta, GA 30332, USA.
E-mail: jnorback@isye.gatech.edu

RENEE ROGGE
Biomedical Engineering, Rose-Hulman Institute of Technology, 5500 Wabash Avenue, Terre Haute, IN 47803, USA.
E-mail: rogge@rose-hulman.edu

CAMERON TURNER
Department of Mechanical Engineering, Colorado School of Mines, 1500 Illinois Street, Golden, CO 80401, USA.
E-mail: cturner@mines.edu

TRISTAN UTSCHIG
Center for the Enhancement of Teaching and Learning, Georgia Institute of Technology, 266 Fourth St., Atlanta, GA 30332, USA.
E-mail: tris.utschig@cetl.gatech.edu

Following good design practice, capstone design instructors often try out new teaching strategies and activities in their capstone courses, hoping to find useful tools to support student learning. Some of these ideas are a riotous success; others fall completely flat. The "Nifty Ideas and Surprising Flops" panel session at the 2010 Capstone Design Conference featured eight such ideas—some of them nifty, some of them floppy, and some with aspects of both—presented in a rapid-fire manner with rich discussion. Several of the ideas addressed oral presentations in capstone courses: scoring rubrics utilizing engineering executive input, voice-over narratives, and elevator pitches. Two of the ideas focused on mentoring: graduate student mentors for capstone teams, and vertical mentoring. The other three ideas covered a design "boot camp", broader impacts essays, and back-of-the-envelope calculations. This paper provides additional detail about the eight different ideas, including how they were implemented, to what extent they were successes or flops, and how they have been modified as a result. Capstone instructors are encouraged to try out their own versions of these ideas, leveraging the successes and learning from the flops presented here.

Keywords: capstone design pedagogy; oral presentation; engineering executive input; elevator pitch; engineering broader impact; preparation for capstone design; capstone design mentoring; design calculations

1. Introduction

Capstone design courses are a common element in engineering programs [1] and the engineering education literature (such as conference proceedings from the American Society for Engineering Education (ASEE), Frontiers in Education (FIE), the International Conference on Engineering Education (ICEE), the American Society for Mechanical Engineering Design Engineering Technical Conference (ASME-DETC), plus the *Journal of Engineering Education*, the *International Journal of Engineering Education*, and *Advances in Engineering Education*) are replete with papers about capstone design. Many of these publications focus on primary components of capstone courses—projects, teamwork, connections with ABET—or the structure of the entire course. Despite the fact that

* Accepted 15 June 2011.

capstone design instructors often try out new teaching strategies or activities in their courses with the goal of improving student learning, very little of the capstone literature addresses these smaller educational nuggets (good or bad), likely because most of them are not substantial enough to warrant a full paper by themselves.

In an attempt to capture and highlight some of these lesser known pedagogical successes and failures, the 2010 Capstone Design Conference featured a panel entitled "Nifty Ideas and Surprising Flops". The panel was modeled after similar sessions at other conferences [2–4] in which presenters had ten minutes or less to present an intriguing idea or pedagogical practice. Capstone design instructors were encouraged to submit a nifty idea or surprising flop for consideration in this panel; eight submissions were included in the final panel. Each presenter was limited to three slides and a ten-minute slot, including questions; presenters were encouraged to discuss whether their nugget was a nifty idea or a surprising flop—or both. The audience asked a few questions after each presentation, sometimes offering suggestions for future modifications.

This paper provides additional detail on the eight nifty ideas and surprising flops presented in the conference panel, beyond what was submitted in the initial proposals (see the capstone conference website for the proposals: http://www.capstoneconf.org/resources/2010%20Proceedings/NiftyIdeasSurprisingFlops/index.html). The eight "nifty ideas/flops" are grouped into three categories, as shown in Table 1 below. Each nifty/flop is presented in turn, including a description of the concept, the outcome of its implementation, and a discussion of lessons learned and/or plans for future modification.

2. Scoring rubrics for oral presentations utilizing engineering executive input

2.1 Description

This nifty idea addresses student presentation skills development for both academic and engineering workforce related goals. The academic goal is to teach students how to give engineering presentations for capstone design. For the engineering workforce we want to prepare students to get a better job upon graduation and ascend the career ladder more quickly.

Our approach to achieving these goals involves delivering systematically designed instruction that starts with executive input (from executives with engineering backgrounds whose companies hire many engineers) to identify specific areas of focus. This input was then modified using faculty input and piloted to adapt appropriately to academic settings [5–6].

The context for delivery of the instruction is a dedicated Workforce Communication Lab with five fully functional presentation stations where individuals and teams practice and receive feedback. Use of this resource is recommended but not required for students as they prepare for six required presentations. The lab has logged over 11,000 student visits since opening in 2003, with 700 of those visits during the first semester of the implementation of the current instruction.

2.2 Tools

We have developed three tools to support the instruction. The first tool is the scoring rubric, which includes 19 skills falling into four categories: 1) customizing to the audience—for example, describing concepts at just the right level for the

Table 1. Nifty Ideas and Surprising Flops by Category

Category	Nifty Idea/Surprising Flop Title	Proposing Authors/Institutions
Oral Presentations	Scoring Rubrics for Oral Presentations Utilizing Engineering Executive Input	Judith Norback and Tris Utschig (Georgia Institute of Technology)
	Voicethread for Student Presentations	Kevin Caves (Duke University)
	Elevator Pitches	Cameron Turner (Colorado School of Mines)
Mentoring	Employing Graduate Students as Technological Advisors	Carsten Kleiner (Univ. of Applied Sciences and Arts)
	Vertical Mentoring in Design	Renee Rogge and Glen Livesay (Rose-Hulman Institute of Technology)
Other Concepts	Design "Boot Camp"	Glen Livesay and Renee Rogge (Rose-Hulman Institute of Technology)
	Broader Impacts Essay	Cameron Turner (Colorado School of Mines)
	Back-of-the-Envelope-Calculations	Susannah Howe (Smith College)

audience, 2) telling the story—for instance, clearly illustrating major points by linking to additional relevant information, 3) displaying key information—for example, creating graphics that are visually appealing, easy to understand, and include helpful labeling, and 4) delivering the presentation—for instance, adapting tone, volume and pace to emphasize key points.

Executives' behavioral descriptions of "Wow" performances for each of the 19 skills comprise the second tool. Their input for the skill taking questions includes using the following protocol when answering a question: clarify the question if needed, repeat the question if needed, answer concisely, and confirm answering the question (by saying something like "is that clear?").

The third tool is the Teachers' Guide that covers specific suggestions for providing feedback on each skill to students. For example, for the skill personal presence, which is described as effectively combining energy, inflection, eye contact, and movement, tips include 1) be definite about your information, 2) avoid using notes—instead use a great deal of eye contact, and 3) avoid talking only to the audience member with the highest authority.

2.3 Outcome

Our data show evidence of success based on student self-reports. Survey responses indicate the instruction is having a positive impact on student presentation skills in capstone design. First, there is a statistically significant improvement in student ratings of both their confidence and competence in presenting, as shown in Table 2.

Second, survey results indicated specific skills from the rubric on which students received the greatest benefit:

- Graphics are visually appealing, easy to understand, include helpful labeling
- Maps/charts/graphics/pictures/illustrations used clearly support key points
- Links different parts of presentation; uses appropriate transitions
- Information is easily understood due to layout; color is used appropriately

Finally, from our efforts in developing the content [6], executives identified several skills not typically included in presentation rubrics. For example, "consistently refers to how key points fit into the big picture" is extremely important in workforce settings, but often overlooked in academic settings. Of note, students indicated needing more help in this skill.

In order for the scoring rubric and other tools to be used consistently, we provide training to those using the rubric, including our TAs. They rate many videos in conjunction with an instructor and discuss the reasoning behind the ratings until reasonable convergence is achieved.

2.4 Discussion

We have kept a list of suggested modifications to the supplemental materials, and a few on the rubric itself. Additionally, work on improving inter-rater reliability continues. This will result in additional changes to the tools. We will be making the changes after we have completed collecting data from our second and third semester of capstone design—Fall 2010 and Spring 2011—using the current tools.

Other universities have already started using the scoring rubric in part or as a whole. Professors may choose to select only those skills they feel their students need to focus on. Anecdotal evidence indicates the tools can be applied effectively in a variety of settings and in different ways. For example, at one school the professor asked the students to rate his presentation, and now he reports students are using the rubric when preparing their own presentations. A copy of the most recent rubric and supplemental materials may be obtained by contacting the affiliated authors of this idea.

3. Voicethread for student presentations

3.1 Description

The ability to convey a message through an oral presentation is an important skill and an expectation of ABET accredited engineering programs. In the capstone design course called Devices for People with Disabilities, students prepare and deliver three oral presentations: a project proposal, progress report, and final summary presentation. Each presentation has specific goals and is scored according to a presentation rubric. Two primary goals of the presentations include the following: 1) practice in

Table 2. Results of t-Tests Demonstrating Improvement

	Before Instruction		After Instruction			
Survey Statement	**Mean**	**SD**	**Mean**	**SD**	**N**	**P**
I am confident in my presentation skills.	2.73	0.76	3.04	0.73	141	<0.0001
I am competent in my presentation skills.	2.88	0.59	3.16	0.68	141	<0.0002

preparing and giving oral presentations and 2) getting content feedback from clinicians, end users and other content experts.

As noted earlier, the second presentation is the progress report. It typically occurs about 8 weeks into the 16 week semester. At this point in the semester, students have received approval on their statement of needs, project goals and device specifications. In addition, they should have completed a functional prototype of the device. This is a critical time in the planning of the project because any significant changes to the design or approach need to be made while there is still time to deliver the completed device. At this stage, the device as it is conceived may not have been widely vetted.

A major goal of the second presentation is to get feedback from content experts on the design and approach. Students discuss the client, the need and the design/device being proposed to address the problem. We invite content experts such as people with disabilities, therapists and clinicians, teachers, professionals who work with people with disabilities and engineering professionals and faculty. Given that our presentations are conducted during class time in the middle of the day and that parking on a university campus leaves much to be desired, attendance at the presentations by the content experts is usually low.

In place of traditional oral presentations, we had student teams prepare Voicethread presentations for their second oral report. Voicethread is a tool that enables presenters to upload a Powerpoint presentation and record a voice-over narration, creating a multimedia presentation that can be shared on the internet. The tool is very easy to use and students can include pictures, videos, and documents, and can highlight information by drawing or pointing using the mouse. These highlights are saved and are seen when viewed by others.

The presentations were shared with project advisors and other individuals who could provide feedback to the teams on the design. Sharing the presentations simply requires emailing an internet link. Presentations are viewed through a standard internet browser. No special software or viewer is required. Voicethread also allows those viewing the presentations to make text, audio and/or video comments on the presentation from any PC or Mac, but this feature requires a user account. To facilitate comments by outsiders, we created a generic user account and gave out the login information.

3.2 Outcome

Our goal in using Voicethread was to get more feedback from content experts by eliminating the need to travel to the presentations, or even be available in real time. The presentation links were sent to a list of about 150 content experts including medical/rehabilitation professionals, people with disabilities, engineering faculty, clinicians, therapists and others. We received more than 25 email comments such as "this is great, can't wait to watch them!" though very few people not directly involved with the projects left comments or even emailed project teams. People were intimidated by having to log in to provide feedback.

Using online presentations proved a good way to get feedback from the assigned project advisors and we will likely use online presentations again. Advisors greatly appreciated the opportunity to view the presentations and reported that they would not have been able to participate otherwise due to commitments or conflicts.

Another unanticipated benefit of the Voicethread presentations was the improved quality of the second presentation. All the presentations made good use of multimedia material, effectively communicated their message and ended on time (a rarity in student presentations). Since students needed to write out a script and could re-record, the presentations were more effective.

Finally, the experience was a useful trial with new media. While employees of the future will still need to do formal presentations, more and more work with be conducted using technologies such as Voicethread.

3.3 Discussion

We intend to continue the use of an online, asynchronous, multimedia presentation for a least one of our student presentations. For the next offering, we are developing a Wordpress blog site that will allow us to post multimedia information and presentations. Reviewers will be able to look at presentations as well as other supporting material and provide comments in form of an email or blog post. We hope that this more familiar format, and the fact that reviewers can follow the project throughout development will result in more feedback from the content experts.

4. Elevator pitches

4.1 Description

This nifty idea is an assignment for student teams to deliver a public elevator pitch, scheduled for the sixth week of their project work on a client-sponsored project. Prior to this assignment, the design teams have met with their client to develop an understanding of the project and documented the scope, schedule, deliverables and budget associated with the project in written form submitted to both the client and the course faculty. The elevator pitch assignment asks the design team to develop a concise problem description in the form of a 90-second pitch associated with a single presentation slide.

A classical elevator pitch is a project description that can be delivered during an elevator ride with a prospective client/customer. Successful pitches rely on the ability to concisely describe the problem with limited illustrations. A team must have crystallized and internalized the problem to develop and present a successful pitch. The assignment is defined to mimic the circumstances of an elevator pitch, with severe limits on the time (90 seconds) and material allowed (one slide).

4.2 Outcome

The Colorado School of Mines operates a two-semester, interdisciplinary senior design program for civil, electrical, environmental and mechanical students. Nearly 250 students participated in the program in 2009–10 in either the fall-spring (nominal) or the spring-fall track. During the course, students are introduced to design methods and a reverse engineering project in the first eight weeks of the course, before embarking on a client sponsored senior design project for the remainder of the course. Conceptual designs are expected at the end of the first semester, and the second semester concludes with a trade fair project exhibition, where the students present their designs to the campus community and industrial partners.

Teams were assigned to deliver their elevator pitches toward the end of the first semester, six weeks into the project. The pitches were presented to an audience composed of the other students in the course, the course faculty, and judges from the campus community who attended the end-of-semester trade fair for students completing the second semester of the course. This audience worked on several levels. For the students, it gave them a chance to see what their peers are doing before the first round of public design reviews which were scheduled for the seventh week of the project. From the perspective of course operation, these pitches served as an opportunity to encourage judges to return the next semester for trade fair, if only to see the results of the pitched projects.

Project grading was done by the course faculty and by the other students. Student involvement in the grading encouraged the students to recognize the good and the bad components of each presentation. Mistakes made by teams in the pitch presentations were rarely repeated in the subsequent design reviews.

4.3 Discussion

The creativity of the students in this assignment was astounding. Many used animations within their pitch slides, and the day was one of the most entertaining days of the course. This nifty assignment has been a success pedagogically and as a publicity tool for the course. Slide from the current semester are posted on the course website and can be seen at http://engineering.mines.edu/research/senior-design/ or requested from the affiliated author of this idea.

5. Employing graduate students as technological advisors

5.1 Description

The setting for this idea is a one-year capstone project/course in which a team of about ten students works on a given software development task. This course is often offered in close cooperation with external customers from industry, academia, or non-profit organizations. Most of these partners do not impose any technological restrictions on the product to be developed as they rely on the expertise of the university in these matters.

We have often run into a clash of interests when deciding on a technology to be used in the project to build the software product [7]. The instructor's interest is more long-term, such as obtaining a finished product rather than a partial solution due to unexpected problems with a new and only vaguely tested technology. The final product should be easily maintainable and lead to a satisfied external partner in order to build a sustainable relationship. On the other hand the students in many cases are more short-term oriented. They want to use the newest "cutting-edge" technology because this is one of the rare chances where they will be able to try this in a real-world setting. Also, they focus on performing well in the course itself and do not take the outcome as seriously as does the instructor.

From a motivational point of view [8–9] it is not a good idea for an instructor to superimpose a technological choice on the student project team. Students feel they should be doing such a design themselves. Also, problems throughout the project might be blamed on the unwanted technology. Since students in these projects tend to be advice-resistant towards the instructor for technological choices, moving a student team toward the desired technology can be a great challenge.

This nifty idea is to have a team of two graduate students support the undergraduate project team [10–11]. The graduate students participate as a practical exercise in their own Project and Quality Management class (first semester of the master's degree program) and act as mentors for the undergraduate team. Whenever a technical controversy arises the graduate student mentors and the course instructor meet to discuss the situation and make a technological decision. In the next meeting with the undergraduate project team the graduate students argue to use the desired technology, using arguments related to the technology's applicability to future classes, widespread use in industry (as informed by the graduate students' recent practical experiences), and relative ease to learn.

5.2 Outcome

The nifty idea has worked very well twice already. One time was associated with a project to develop a web-based document management system. The undergraduate team wanted to use PHP to develop the web GUI, but the instructor/mentors wanted them to use Java technology in order to obtain a better manageable product for future extensions. The mentors told them that they would need Java enterprise technology in the upcoming semester and their master classes anyway, which easily convinced the team. In another project the instructor/mentors wanted to use a specific type of database system in order to obtain more experiences with its features and capabilities. This time the mentors argued that in all their practical experiences they had used that particular database system. Again the undergraduate team was easily convinced.

The reason the mentoring process works better than the instructor trying to convince the undergraduate team is probably that the graduate students are very close in age to the others and have a similar background. Obviously the graduate students advice is valued more highly by the undergraduate students than is the advice of the instructor as a long time professional. Maybe students doubt that the instructors really know recent technologies or think that instructors have different interests.

5.3 Discussion

A key success factor is that the graduate students used as mentors must be introduced in the first team meeting. They have to support the project team throughout the whole project, building a trust relationship between the project team and the mentors, which further increases the mentors' credibility. If the mentors attended only team meetings with controversial technical discussions, the project team would not heed the opinion of the mentors. The mentoring also has to be a meaningful task for the graduate students otherwise they might not be sufficiently motivated to convince the project team. Our experiences with paid teaching assistants are far worse than with the graduate students participating as practical exercise for their own graded course.

It is worth mentioning that this mentoring does not work for all graduate students. It is only appropriate for students who are interested in becoming software project managers or system architects later. Mentoring requires very strong communication skills, which are typically more likely to be found in future project managers or architects than in technical experts.

6. Vertical mentoring in design

6.1 Description

In an effort to help students appreciate the importance and depth of their design knowledge through a specific demonstration of this ability beyond their capstone design project, a "vertical mentoring" scheme was implemented in biomedical engineering (BE) design. The BE design sequence is a total of four quarters long, comprising 12 credit hours on the quarter system. The ability to utilize BE seniors to mentor juniors in the spring quarter is embedded in the overall structure of the design sequence.

During the first course in the Spring term, the Juniors learn the design process and complete detail design on a project. During the Fall and Winter terms of the Senior year, students undertake a capstone design experience in the traditional sense; they work with clients, develop and document designs, fabricate, test, and (ideally) deliver a working product to the client. In the Spring term, the Seniors are in their fourth design course as a new set of BE Juniors enter the design sequence. This arrangement has allowed us to implement a mentoring arrangement that fits well with the concluding course in design. In the final spring course, Seniors are learning about larger context issues in design (meaning larger than just their project and regulations, etc.), and at the same time they serve as mentors to Juniors undertaking their first design project. The Seniors are coached on the basics of mentoring and learn about student types and cognitive development, both to help them be better mentors and enable them to identify and correct mismatches in mentoring they may receive in the future.

6.2 Outcome

Although vertical mentoring is challenging to orchestrate, it has been a successful and important interaction for both the Juniors and the Seniors. The Seniors are mentoring Junior teams working on projects with which the Seniors have no prior experience and finding that their design learning is broadly applicable (that is, that they did actually *learn* something in design . . . it wasn't all just "common sense"). The Seniors also get the opportunity to serve as "experts" for the Junior teams, and learn that advising/guiding a design team is more involved than simply telling the Junior teams what to do; in fact, they learn that it is more important (and more difficult) to ask leading questions in order to help focus the team's efforts. To underscore this, we make it clear that their evaluation as mentors is based on the quality of the feedback and guidance that they provide, not on the design performance of the Junior team.

The major benefit perceived by the Juniors, beyond the guidance they receive on their projects, is the immediate vocational relevance that is provided to the design sequence. The Seniors represent where the Juniors will be next year at the same time, and since the Seniors "know what they are doing" this design sequence must be important. One very positive outcome has been the feed-forward mechanism associated with the mentoring process in design; Juniors who receive good mentoring seek to do a good job when they later mentor, and Juniors who (feel that they) received less effective mentoring strive to do a better job as mentors. This has led to an increase in year-to-year expectations of performance as mentors (and also in the entire design course) from the students themselves, which is a nice by-product.

6.3 Discussion

The Spring of 2010 marked the 5th year we have had Seniors serving as mentors for the Juniors as they undertake their first design project, and while year-to-year cohorts of students vary, the most notable outcome from the vertical mentoring experience for the Seniors has remained steady; it is not that the Seniors were helping a junior design team, rather that they realized that they were *capable* of helping. Summative feedback from the seniors indicates that they have more confidence in their own ability to mentor design teams, and also in their ability to conduct engineering design. This is interesting, since the Seniors have already completed their capstone design projects prior to mentoring the Juniors, and there is no new technical design information that the Seniors learn during the final quarter. Is it the process of mentoring a design team that is building this confidence in the Seniors' abilities? This appears to be the case, and serving as an expert, and perhaps being that expert for the BE cohort just behind them, makes the learning real for the graduating seniors.

7. Design "boot camp"

7.1 Description

As part of a first course in design taught in the Spring quarter of the Junior year, students learn the design process in preparation for their capstone experience the following year. To make the process more real, and to show the students what they could do, we implemented this course as a design "boot camp", to bring students up to speed in engineering design. The idea was to have student teams undertake the design process on a common design project to practice the design process before tackling a larger, more open-ended design challenge working with a real client in their Senior year. Since the Biomedical Engineering program at Rose-Hulman does not have a Freshman design course, this Junior course represents students' first formal introduction to engineering design, and was intended to help them overcome the traditional fears many students have of Senior design (open-ended problem, documenting the design process, *etc.*) Therefore, to immerse students in engineering design in this two-credit course (one lecture and one lab period per week), the students developed problem statements, generated design alternatives, completed detail design, constructed a prototype, and created and implemented test plans. Students also fully documented the design process and concluded with a formal presentation—all in a 10-week quarter.

When this first course in our four-quarter sequence in design was developed, there were many anticipated benefits to utilizing a boot camp approach to design. After completing the course, the students would know what to expect, in general, from the senior design sequence and the fear of the unknown associated with the capstone design experience would be largely removed (or at least diminished). In addition, and for setting expectations, students would also have a feel for the amount of work required to successfully complete a design project. The boot camp experience was also intended to provide an opportunity to practice the design process in a safe environment where a less-than-exceptional design solution would not be devastating to the student or client. Finally, since all student teams were working on solutions to a common problem, it was anticipated that the demonstration of multiple feasible solutions to an open-ended problem would be encouraging to many students. And finally, from our perspective as instructors, we knew that the students would then be able to hit the ground running with their capstone design projects in the Fall of their Senior year.

7.2 Outcome

As instructors, we were very excited about the depth to which the students were engaged in the design process in this boot camp approach, and we were expecting (naively, it turned out) that our students would be able to look back on what they had achieved during this quarter and be proud of their work. On the plus side, at the conclusion of the course, students were indeed impressed with how far they had come and how much they had accomplished. However, the boot camp approach did not turn out as we had hoped; at the end of the course, our design "recruits" were more than a little beaten up.

In fact, since we have a four-quarter design sequence that started with this boot camp course, students ended up approaching the capstone design experience in their Senior year with dread. Cloying, dripping, acidic, toxic dread. And what is worse, it turned out that the wind sprint in Junior Spring cast a pall over the entire capstone design project, which was nearly impossible to shake.

7.3 Discussion

As with all new ideas and implementations, we tried the boot camp approach twice before substantially changing the Junior Spring course. In the second attempt, we did not incorporate a common design problem, since this appeared to have engendered competition that was perceived as negative and direct competition between teams was not intended. To provide students with more control, we had them develop their own project, with guidelines for it being "an assistive technology in the kitchen or bathroom environment". This tweak, while expected to be empowering in terms of project ownership (we thought), and although we worked with all teams to calibrate the scope of their projects, turned out to be terrifying to the majority of students. Most students felt strongly that there was too much pressure to come up with a "good" project idea, and again, this left most of our rising Senior dreading their capstone design experience.

To avoid the dread, but still prepare students for their capstone experience, we scaled back a little on the boot camp approach (although students still think it is like design boot camp) when considering our four-quarter design sequence as a whole. Specifically, students still undertake the design process, but only through a detailed paper design, in their first quarter of design. We also began utilizing vertical mentoring, as described in Section 6 above, to help guide the Juniors as they learned the design process. This scaled-back approach combined with the vertical mentoring has worked well. As noted in Section 6, the transmission of expectations for design work from the Seniors to the Juniors actually achieves one of the original goals of the boot camp, with substantially less dread, and the Juniors take the information to heart since it is not coming from us (the instructors). If nothing else, our boot camp disaster provides great instructional context (and still a good laugh) when we consider how completely excited we were about it, and how surprisingly badly things went from the student perspective. [It also spurred our interest in the development of a supplemental design course evaluation [12] focused on student perceptions of their design experience (such as ownership, responsibility, and changes with time), which was a positive outcome.]

8. Broader impacts essay competition

8.1 Description

Capstone design programs are generally an area of focus during Accreditation Board for Engineering and Technology (ABET) accreditation visits. ABET visits seek to establish that 11 specified program outcomes are achieved by the degree granting program. In particular, criterion (h) is very broad and presents a challenge in demonstrating that it is met in a particular part of the curriculum. Criterion (h) demonstrates that the program produces graduates with "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" [13].

The challenge in meeting this criterion is that it is typically the product of the education as a whole, not a particular course. Therefore, it is difficult to point to a particular course assignment as a demonstration of this criterion. That challenge was the origin of this particular assignment: a 1500-word essay, due during the second semester of the capstone design course, on the following topic:

> How has your engineering education prepared you to consider the broader impacts of engineering design solutions in a global, economic, environmental or societal context?

8.2 Outcome

Unlike most of the other assignments, and in particular the writing assignments associated with the Colorado School of Mines (CSM) capstone design program (as described in Section 4 above), this assignment has a strong individual character. Furthermore, this assignment clearly extends beyond the scope of the senior design courses to include the breadth of their educational experience. One of the fascinating outcomes of this exercise was the wide variety of classes that students associated with this topic. This observation further reinforced the perception of the faculty that this ABET outcome is the result of the entire program rather than a particular course or set of courses.

Essays were graded by the course faculty and the top essays were identified and nominated for recognition. Nominated essays were submitted to an alumni panel for further judging. The finalists were recognized at the trade fair judge's breakfast before the start of the trade fair project exhibition. The top essays were also compiled and placed in the Trade Fair Program distributed to the judges.

8.3 Discussion

From a faculty standpoint, this assignment has been a nifty success. It provides a clear pointer whereby ABET Criterion 3h can be evaluated. In addition, the nature of the assignment asks students to integrate their experiences from other courses into their senior design engineering experience. This directly challenges the tendency of students to view courses as silos, where concepts do not carry over from course to course. Furthermore, many of the judges positively viewed the essays and the competition.

However, the student perspective was mixed. Some relished the opportunity to consider their education holistically, while others viewed this as a meaningless ''busy-work'' activity and expressed the opinion in course reviews that the ABET learning objectives had little relation to success in their career. Many students were clearly uncomfortable about their own writing skills (which is not at all unexpected) and thus did not like an individual writing assignment. Overall, we view this assignment as a nifty idea, and believe that senior design is an appropriate course for this type of assignment. However, we would agree that its initial implementation is a qualified success in that it has highlighted the need for further emphasis on individual writing skills and on the role of ABET and accreditation with respect to what students are learning. Several of the top essays can be found in the trade fair program on the CSM capstone design website (http://engineering.mines.edu/research/senior-design/) or requested from the affiliated author of this idea.

9. Back-of-the-envelope-calculations

9.1 Description

For many engineering students, their capstone design course is a first experience with a complex, open-ended, externally-sponsored problem. Some students thrive in this new environment and dive right into their project work, but others do not know where to begin. This idea is intended to encourage students to tackle technical calculations early in their design projects, to identify relevant values and design key calculations underlying their projects, and to make reasonable assumptions when lacking information.

The assignment is introduced just after the project teams have been formed, in the first meeting between each team and the project faculty members. In that meeting, faculty coaches work with the students to identify the important quantitative values to be calculated and/or type of design calculations to be completed for primary technical areas of the team's design project. The most relevant calculations are then assigned one per student to be completed as an informal ''back-of-the-envelope-calculation'' and turned in the following week along with the team's progress report. As a twist, each student is given an actual business-sized envelope on which to do her calculations. This limits how much the students can write/calculate, emphasizes the intent of rough initial calculations, and adds an element of humor. The calculations are discussed at the following week's team/coach meeting, and serve as a jumping off point for continued technical calculations. The faculty coaches also refer to these back-of-the-envelope calculations later in the course, especially when the team is working on related technical issues.

9.2 Outcome

This assignment has been implemented in the capstone design course at Smith College in two different years. The assignment was implemented as part of a set of assignments to encourage students to identify and build on the relevant technical knowledge that they bring to the capstone design class. Recognizing this specific knowledge is especially important in Smith's engineering science program where students all have a common foundation but have taken electives across the spectrum of engineering, and may be working on a project that is not directly related to their previous experience.

Overall this assignment worked fairly well both times. Students were intrigued by the envelopes: having the actual envelopes added humor and successfully limited their work. Many students made a solid attempt to dive into their calculations, though some did not see/make the connections with their design projects. More importantly, most students were able to refer back to these early calculations later in the course, and recognize that they already had a start on a particular technical issue and/or a useful design parameter. In a few cases, the faculty coaches assigned follow-up back-of-the-envelope assignments to particular students or on a particular issue (along the lines of ''Why don't you do a back-of-the-envelope on that for our next meeting?'').

9.3 Discussion

This assignment was intended to force the students to dive in right away, even if in a rough imperfect way, and to understand early on the types of issues and calculations that will be important to their project. The assignment has several strengths: it provides students a starting point in an otherwise open-ended project, it encourages students to deal with unknowns and make assumptions, and it underscores the value of rough calculations/approximations in starting and understanding a design project. Moreover, it provides faculty a window into individual student work at the start of the course. In its current form, however, the assignment needs some structuring to identify appropriate back-of-the-envelope calculations. Advanced students can often identify and frame these themselves; other students may need more assistance. Identifying a wide set of possible calculations in a team setting worked well.

This assignment also lends itself to several variations. Rather than being done over a period of several days, the back-of-the-envelope-calculation could also be given as a 5–15 minute assignment in class or in a team meeting, fitting the more common interpretation of the quick turnaround calculation. The identification of possible calculations could also be extended to have the whole class brainstorm calculations related to the current course material or specific projects. One of the attendees at the panel session suggested that the back-of-the-envelope-calculations be used to inform design requirements. The assignment could also be given at multiple points (for different calculations) during the capstone course, rather than just once at the beginning.

10. Conclusions

Building on the conference theme of capstone pedagogy, the "Nifty Ideas and Surprising Flops" panel at the 2010 Capstone Design Conference featured eight pedagogical strategies tested by capstone design instructors in their classes. This paper presents the details behind each of the strategies, with candid discussion of whether they worked or flopped, and how they might be modified in the future. Table 3 presents a summary of the ratings for all the ideas, based on observations and experience of the affiliated authors. The N/F column positions each idea as either a Nifty Idea (N) or a Surprising Flop (F). The usefulness column (5 = high, 1 = low) reflects whether the pedagogical strategy yielded the impact and student learning expected and desired by the faculty. The effectiveness column (5 = high, 1 = low) reflects the level of this impact/learning and the associated cost to achieve it.

While the ideas vary substantially, two main conclusions can be drawn from their collection. First, capstone design instructors are clearly

Table 3: Ratings for Nifty Ideas and Surprising Flops

Nifty/Flop Idea	N/F	Usefulness (5=high, 1=low)	Effectiveness (5=high, 1=low)	Notes
Scoring Rubrics for Oral Presentations	N	5	4–5	Rubric and "wow" descriptions helped students. Initial development costs were high, but tools can now be implemented elsewhere easily.
Voicethread for Student Presentations	N	5	5 for student engagement	While there was a learning curve, the online presentation format enabled students to produce better presentations.
			1 for obtaining stakeholder feedback	Although stakeholders commented that they liked the online format, few gave any feedback.
Elevator Pitches	N	5	5	The Elevator Pitch assignment proved effective as a marketing tool for judges and as a tool to force teams to achieve a clear concise project understanding. Student feedback is also positive.
Graduate Students as Technological Advisors	N	5	3	The goal of having students use a specific technology has been convincingly achieved, but the implementation requires using graduate mentors throughout, implying a rather high investment of time, money, and/or effort.
Vertical Mentoring in Design	N	5	4	Vertical mentoring greatly benefits both juniors and senior and results in a unique design experience. Establishing course structure/logistics requires initial time investment but yields good results.
Design "Boot Camp"	F	5	2	The students did learn and do a lot in the 2-credit design boot camp, and could see how much they accomplished in a 10-week quarter. However, the perception of dread that this initial level of effort instilled in many students cast a pall over their entire capstone design experience. Perception is an important instructional consideration!
Broader Impacts Essay	N	4	3	Assignment raised student concerns about individual writing skills, leading to additional work in grading and managing the class. Students did integrate experiences from other courses.
Back-of-the-Envelope-Calculations	N	5	4	Some assistance with framing appropriate calculations may be needed. Assignment costs little to implement and has many possible variations and follow-up points.

invested in their students' learning; they are willing to try out new ideas, even if the ideas do not always work at first. Second, the capstone community benefits from broader sharing of pedagogical strategies (whether successful or not) for widespread improvement of capstone courses. Future Capstone Design Conferences, as well as other engineering education conferences and journals, should create space for informal and rapid sharing of smaller effective (and ineffective) ideas for capstone design.

Acknowledgements—The authors gratefully acknowledge our many students for their patience during our implementation of these nifty ideas and surprising flops. We intend these pedagogical strategies to improve their learning and enhance their capstone experiences. We also thank the audience at the Nifty Ideas and Surprising Flops panel session at the 2010 Capstone Design Conference for their attention, questions, and suggestions.

References

1. S. Howe, Where Are We Now? Statistics on Capstone Courses Nationwide, *Advances in Engineering Education*, **2**(1), 2010.
2. N. Parlante, J. Zelenski, Z. Dodds, W. Vonnegut, D. J. Malan, T. P. Murtagh, T. W. Neller, M. Sherriff and D. Zingaro, Nifty Assignments, *Proceedings of the 41st ACM Technical Symposium on Computer Science Education,* Milwaukee, WI, USA, 10–13 March 2010, pp. 478–479.
3. D. J. Moore, D. R. Voltmer and D. J. Walter, Special Session—Have You Tried . . . ? The Sequel, *Proceedings of the 37th ASEE/IEEE Frontiers in Education Conference*, Milwaukee, WI, USA, 10–13 October 2007.
4. D. D. Brock, W. Deutsch, J. Kickul, S. Hernstadt, M. D. Meeks, C. Pratt and M. Vasquez, Sharing the Teaching Wealth: A Clearinghouse for Best Teaching Practices, *Proceedings of the 2006 USASBE/SBI Joint* Conference, Tucson, AZ, USA, 12–15 January 2006.
5. T. T. Utschig and J. S. Norback, Refinement and Initial Testing of an Engineering Student Presentation Scoring System, *Proceedings of the 117th American Society for Engineering Education Annual Conference and Exposition*, Louisville, KY, USA, 20–23 June 2010.
6. J. S. Norback and T. T. Utschig, Building a Stakeholder-based Rubric to Enhance Student Communication Skills, *International Journal of Process Education*, **2**(1), 2010, in press.
7. T. Clear, M. Goldweber, F. H. Young, P. M. Leidig and K. Scott, Resources for Instructors of Capstone Courses in Computing, *SIGCSE Bulletin*, **33**(4), 2001, pp. 93–113.
8. Y. Khmelevsky, SW Development Projects in Academia, *Proceedings of the 14th Western Canadian Conference on Computing Education*, Burnaby, British Columbia, Canada, 1–2 May 2009, pp. 60–64.
9. K. A. Alshare, D. Sanders, E. Burris and S. Sigman, How Do We Manage Student Projects? Panel Discussion, *Journal of Computing at Small Colleges*, **22**(4), 2007, pp. 29–31.
10. Å. Cajander, T. Clear and M. Daniels, Introducing an External Mentor in an International Open Ended Group Project, *Proceedings of the 39th ASEE/IEEE Frontiers in Education Conference*, San Antonio, TX, USA, 18–21 October 2009.
11. K. Hagen-Hall and M. Verhaart, Mentoring Students to Improve Academic Performance, *Proceedings of the 21st Annual NACCQ Conference*, Auckland, New Zealand, 4–7 July 2008, pp. 59–65.
12. G. A. Livesay, R. D. Rogge and K. C. Dee, Development of a Supplemental Evaluation for Engineering Design Courses, *Advances in Engineering Education,* **2**(1), 2010.
13. ABET, *Criteria for Accrediting Engineering Programs, 2009–2010*, ABET Inc., Baltimore, Maryland, 2008.

Susannah Howe, Ph.D. is the Design Clinic Director in the Picker Engineering Program at Smith College, where she coordinates and teaches the capstone engineering design course. Her current research focuses on innovations in engineering design education, particularly at the capstone level. She is also involved with efforts to foster design learning in middle school students and to support entrepreneurship at primarily undergraduate institutions. Her background is in civil engineering with a focus on structural materials; she holds a B.S.E. degree from Princeton, and M.Eng. and Ph.D. degrees from Cornell.

Kevin Caves, ATP, RET, ME is an Instructor in the Pratt School of Engineering at Duke University and a Clinical Associate in the Department of Surgery at Duke University Medical Center. He coordinates Duke's Assistive Technology Clinic that provides assistive technology services to people with disabilities. In addition to teaching and working with people with disabilities, he conducts research in the area of rehabilitation engineering and assistive technology.

Carsten Kleiner, Ph.D. is a full professor for secure information systems in the computer science department of the University of Applied Sciences & Arts in Hannover, Germany. He holds a masters degree in Computer Science from Purdue University (1996) and a Dr. rer. nat. (German equivalent of Ph.D.) from the University of Hannover, Germany (2003). His main research interests are in database and information systems and their applications. His recent research has focused on information systems for mobile devices and more specifically security and privacy issues in mobile information systems. Another line of research is concerned with service-oriented architectures (SOA), in particular repositories for SOA. He has been teaching capstone courses in the bachelor program in software engineering since 2005. He has published several posters on improving teaching of capstone courses in software engineering on recent ACM SIGCSE symposiums.

Glen Livesay, Ph.D. is a Professor of Applied Biology and Biomedical Engineering and the Samuel F. Hulbert Chair at Rose-Hulman Institute of Technology where he is one of the course coordinators for the design sequence in Biomedical Engineering. Glen's educational research interests include student learning styles, the statistical evaluation of assessment instruments, and student perceptions of capstone design. His area of disciplinary research is soft tissue and joint mechanics; he holds a B.S. and M.S. from UCLA, an M.S. from UCSD, and received his Ph.D. from the University of Pittsburgh.

Judith Shaul Norback, Ph.D., is general faculty, a Senior Academic Professional, and the Director of Workplace and Academic Communication in the Stewart School of Industrial and Systems Engineering at Georgia Tech. She has worked in communication skills enhancement for 25 years and founded the ISyE Workforce Communication Program at Georgia Tech in 2000. Norback has designed, taught, and assessed communication instruction based on interviews with engineers, managers, and senior executives. She has published in journals such as IEEE Transactions on Professional Communication and INFORMS Transactions on Education and is writing a book for Wiley on "Oral Communication Excellence for Engineers." Her research interests include performance assessment for presentations and improving engineering communication.

Renee Rogge, Ph.D. is an Associate Professor of Applied Biology & Biomedical Engineering at Rose-Hulman Institute of Technology. She is one of the course coordinators for the Biomedical Engineering design sequence and is an active member of the Design in Engineering Education Division of the American Society for Engineering Education. She is the principal investigator for an NSF RAPD (Research to Aid Persons with Disabilities) grant that provides support for senior design teams to develop assistive technology. She received degrees in Biomedical Engineering from Tulane University and the University of Iowa.

Cameron Turner, Ph.D., P.E. is an Assistant Professor of Engineering at the Colorado School of Mines. At CSM, he is the course coordinator for the Capstone Design Program and operates the Design Innovation and Computational Engineering (DICE) Laboratory. He is a graduate of the University of Texas at Austin (MSE 2000 and PhD 2005) with a BSME from the University of Wyoming in 1997. He has 13 years of experience in engineering design at Los Alamos National Laboratory and is a Registered Professional Engineer in New Mexico. His research interests include design optimization, system modeling and metamodeling, automation and robotics, and engineering design education.

Tristan Utschig, Ph.D. is a Senior Academic Professional in the Center for the Enhancement of Teaching and Learning and is Assistant Director for the Scholarship and Assessment of Teaching and Learning at the Georgia Institute of Technology. Formerly, he was Associate Professor of Engineering Physics at Lewis-Clark State College. Dr. Utschig has regularly published and presented work on a variety of topics including assessment instruments and methodologies, using technology in the classroom, faculty development in instructional design, teaching diversity, and peer coaching. Dr. Utschig completed his PhD in Nuclear Engineering at the University of Wisconsin—Madison. His technical expertise involves analysis of thermal systems for fusion reactor designs.