Session 2408

# The Wizard of BOD

**Paul D. Schreuders, Arthur Johnson**
**University of Maryland, College Park**

## Abstract
Several years ago, the Biological Resources Engineering Department reexamined and updated the format of its Capstone Design Project. The revised Capstone Design experience was intended to give students an opportunity to manage a product while observing resource constraints. Unfortunately, very few course plans survive intact after contact with the students. This case study will examine the intended processes, the successes, and the failures of the revision. In the plan, the project engineers (students) received funding from the Board of Directors (faculty) to produce a final product at the end of the second semester. The amount of funding was to be determined on the basis of a budget for labor and purchases plus the intended value of the final product. Designs teams were allowed to manage their funding as they saw fit. Designs teams selected a faculty mentor for their project. Projects that were not selected from a list of suggestions were checked by their mentor to assure that the end-product could achieve an "A." The function of the mentor was to assure that all schedules and course requirements were met. However, any other faculty member could be called upon to supply necessary technical assistance. The Board of Directors (BOD) was composed of a minimum of three faculty members, including all faculty mentors. The purpose of the BOD was to ensure even quality and quantity of effort and product value for all teams. The BOD also ensured that the capstone experience included all relevant material learned in prior courses. Students were required to submit work distribution sheets with every major deliverable. This information, BOD input, and project quality was used to assign grades for the individual members of each project group.

## Introduction

Capstone Design in the Biological Resources Engineering Department at the University of Maryland is a two-semester course sequence. The two semesters must be taken consecutively and the students receive one credit for the first semester and two credits for the second semester. During the first semester the students are asked to formulate a design and during the second semester they are asked to execute it.

Several years ago the Biological Resources Engineering Department was faced with a number of challenges regarding this course. The challenges included the failure of the students to complete their projects in a timely manner and at an acceptable level, variations in the expectations of the students by different faculty, unreasonable demands on the support staff at the end of the semester, and an unwillingness on the part of the students to seek help from faculty other than their advisor. As these challenges were examined, we determined that they were the result of several core issues. First was the lack of faculty interaction and consensus on the project requirements. Second, this lack of consensus was then transmitted to the students as unclear expectations and resulted in variable performance. To overcome these challenges the faculty and the curriculum committee chose to restructure the course.

## The Course Scenario

In software packages, "Wizards" are used to lead individuals through a complex process by asking a series of questions. The answers to each question are used to structure the final product. The goal of our revised capstone structure was to lead the student design teams through the process of creating a product. The new structure was formulated around a scenario where a group of faculty acted as a Board of Directors (BOD) and the students acted as engineering design teams working for the BOD. Within this structure, the students followed a design from concept to product. The students were expected to manage the product's development, while observing project constraints.

To provide hands-on guidance, the design teams selected a faculty mentor for their project. The function of the mentor was to assure that all schedules and course requirements could be met. The mentor may or may not have technical expertise in the area of the project. Any other faculty member may be called upon to supply additional technical assistance. The Board of Directors (BOD) was composed of a minimum of three faculty members, including all faculty mentors. The purpose of the BOD was to ensure consistent quality and quantity of effort and product value for all teams. The BOD also insured that the capstone experience included all relevant material learned in prior courses. Engineers could select projects from a prepared list or they could chose another project depending on their interests. Past projects include:

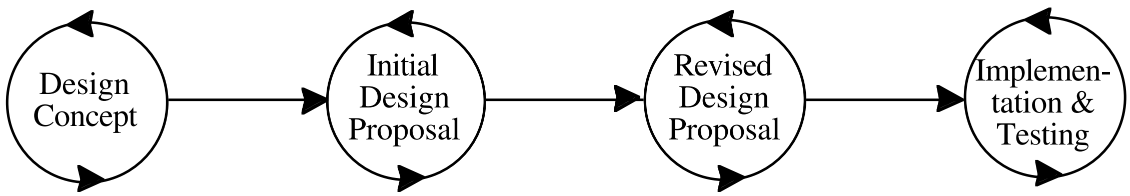
- Design of a Mammography Compression Unit
- Design of a Stormwater Extended Detention Shallow Wetland for Columbia, Maryland
- A Drainage Ditch Biological Filter for Reducing Nitrate Pollution
- Removal of Fats, Oils, and Grease from a Restaurant Wastewater Stream
- The Development of a Best Management Practice Plan for Phosphorus Control in the Pocomoke River Watershed
- Medreminder: The Portable Semi-Automated Medication Dispenser
- Green Shoulder: A Bioengineered Vegetative Road Shoulder Backfill
- Assistive Soda Can Opening Device
- The GlucaGun Auto-Injection Device
- Tissue Culture Roller Bottle Uncapper
- A Bioreactor Temperature Controller

The design teams received funding from the Board of Directors to produce a final product at the end of the second semester. The amount of funding included a budget for labor and purchases plus (initially) value of the final product. The value of the final project was a dollar equivalent to the team's grade. Design teams were allowed to manage their project schedule, personnel, and budget as they saw fit. Any prior Board actions (budgets, projects, course grades, resources, etc.) may be considered for modification upon written petition to the Board. This allowed the faculty to compensate for truly unforeseen problems.

**The Capstone Design Process**

One major emphasis of the capstone Wizard was a process of iterative improvement. This was implemented through the series of design phases. Each phase represented one design cycle. At the end of each phase of the course, the students were required to present some documentation of the project's status. This iterative process was often discomforting to the students. In most courses during their academic career, students have been asked to generate a product (whether a design or a problem solution) that involved only a single iteration.

There were four main design phases in the Wizard, a development of a design concept, an initial design proposal, a revised design proposal, and a final project report after the implementation and testing phase. Graphically, this process can be described as:




Each process loop represents a design phase, with design teams exploring multiple possibilities. Deliverables occur for each line segment. Typically, these phases were completed based on the schedule described below:

Capstone Design I

| *Week* | *Action* | *Phase* |
|---|---|---|
| 1 | Select a capstone design project from the list of suggestions or pose an alternative | Design Concept |
| 2 | Mentor identified | |
| 3 | Concept memo due to mentor | |
| 5 | Concept memo due to Board of Directors & First BOD meeting | |
| 12 | Written design proposal due to mentor | Initial Design |
| 13 | Initial design proposal and presentations & Second BOD meeting | |
| 14 | Response by BOD to design team & Third BOD meeting | Revised Design |
| 15 | Revised written proposal due to BOD | |

Capstone Design II

| *Week* | *Action* | *Phase* |
|---|---|---|
| 2 | Submit purchase requests to the department and blueprints/schematics to shop | Design Implementation and Testing |
| 5 | Assembly of project completed | |
| 5 - 14 | Testing/redesign cycle | |
| 12 | Initial written reports due to the mentor | |
| 15 | Final presentations and written reports to BOD & Final BOD meeting | |

Students were required to submit work distribution sheets with every major deliverable. This information, BOD input, and project quality were used to assign grades for the individual members of each project group.

## The Concept Phase

Very early in the semester, the design teams were required to select a project and present a preliminary specification for the product. As is shown in the list of past projects, the projects normally consisted of hardware or software designs. Projects requiring research or new technologies were not considered, since research projects present a potential for failure that was outside of the design team's control.

### *The First BOD Meeting*

The design concept proposal was presented to their mentor and the BOD in the form of a one to two page formal memo. The inclusion of a formal conceptualization phase provided two benefits. First, it required that the design team identify a topic and a mentor. Design teams had, in the past, often waited until much of the semester was over before identifying these two items. Second, it allowed the full BOD to assess the project concept before the design teams had made considerable time investment in a trivial/impossible/unaffordable project.

## The Initial and Revised Design Proposals

Towards the end of the first semester, the design teams submitted two design proposals. The due dates for these proposals coincided with a series of meetings with the BOD. At the end of this sequence, the students were expected to have generated a design that was suitable for immediate production by the departmental shops or by the programmers in the design team. The components of both of these proposals (the initial and revised design proposals) were identical. They consist of a project summary, a project justification, a literature review, a description of the project, objectives, the design's concept and specifications, procedures and methods, a project timeline, a budget, and appendices (as needed). The components had been chosen to be similar to those found in a business proposal and their content and length were tightly defined to help keep the design teams focused on their goals.

While this basic structure is common for project proposals, several of the elements were quite important to the structure of the design process. One of the important aspects of this class was the additional emphasis of several elements of the design process that was carried through each of the deliverables. As such, they were required components of both revisions of the proposals and their importance was carried through to the various BOD meetings and the final report and presentation.

*Budget Planning*

One of the most important changes in the Capstone Design course was the development of the budget process in the proposals. Project engineers were expected to estimate the expected dollar value of required purchases, shop labor value, and their time. The BOD did not accept unrealistic estimates. Within these budgets, the project engineers were allowed to manage their projects with a great deal of freedom. Additional purchases or labor expenditures were allowed as long as the engineers paid for them from their budgets. Expenditures in excess of the budget resulted in a reduction of the group's final grade. Contrarily, if the engineers managed their projects to expend less than the budgeted amounts, the excess funds could be allocated towards increasing their grades. Thus, students were to be rewarded for meeting their budgets and penalized for exceeding their budgets.

The structure of the budgeting process was motivated by three desired goals. First, as might be expected, procrastination was common among the design teams. One of the motivating factors for the revision occurred when a design team handed their project to the machine shop in mid afternoon the day before it was due and to the electronics shop the night before the project was due. By explicitly including shop labor (including overtime) in the budget, the design teams were made aware that the quality and timeliness of their work directly affected the cost of other aspects of the project. It became very clear that there was a financial penalty for poor quality drawings that required extra shop time or for late design deliveries that required shop overtime. The revised budgeting process was successful in meeting this goal.

The second goal was to make the design teams aware of their own time expenditures on the project. During their academic careers, engineers are often unaware that the single biggest cost in most projects is labor. By requiring that the design teams estimate their labor, both prior to and after the project, the engineers became very conscious of their time. The budgeting process also achieved this goal.

The third goal of the budgeting process was that we had hoped to explicitly link the student's grades to their budget. This was to be achieved by providing a defined budget and a final payout at the end of the project. Student's grades would be allocated based on the amount of funds that remained at the end of their project. We failed to meet this goal for several reasons. First, the method turned out to be too complex for the student's to easily understand. Thus, there were often significant errors in their proposed budgets. Secondly, the cash available at the end of the semester was sensitive to the initial cost of the project and to external funding. Groups that had an expensive project or received external funding, such as a grant, were more likely to have additional funds at the end of the project. Groups that chose an inexpensive project such as software were very unlikely to have extra funds at the end of the project.

The explicit budgeting process had two serendipitous side effects. The first was that the development of detailed budgets required a level of specificity beyond that normally found in student designs. When the design teams had to identify part numbers and prices as part of their design, they were much more careful in the initial submissions. The second beneficial side effect was that the Department was able to modify teams' design decisions based on price. For example, we discouraged the students from excessively using the overcommitted electronic technician (as opposed to the machinist) by making his services more expensive. We were also able to encourage students to consider whether to build rather than buy by defining a high overhead on purchases.

*The Second BOD Meeting*

The initial proposal was due around the thirteenth week of the first semester of the course. This design proposal was pitched by the design team to the BOD (ten minutes of presentation plus five minutes for questions). In addition, the students provided a 2 page executive summary and a summary budget sheet to the Board of Directors. In most cases, this was the only information reviewed by the entire board. Therefore, the quality of the presentation and handouts to the BOD was critical. The full version of the proposal was reviewed in detail by the project's mentor. The second BOD meeting was, essentially, an information-gathering meeting for the third meeting.

*The Third BOD Meeting*

In this meeting, the BOD evaluated each of the design teams' projects, with the mentors acting as advocates for their teams. The feasibility of each design was examined and the potential for successful completion determined. The budgets were reviewed for completeness and appropriateness and revised based on available funds and BOD feedback. The results of this review were conveyed back to the design teams.

This feedback was used by the groups for their revised design proposal. Only the revised design proposal was graded and used for funding decisions. The decision to not grade the initial design proposal allowed the teams to view the board's critique as constructive.

**Implementation and Testing**

We hoped that early feedback would also motivate the students to move quickly from the design stage to the implementation stage. The funding for the project was made available to the student groups at the end of the first semester, so that they could place orders over the semester break. Similarly, the design teams were told that they could give blueprints and schematics to the technicians in the machine and electronics shops, respectively, at the end of the first semester. To date, this availability has not been used and typically, the students began purchasing their supplies and working with the technicians two to three weeks into the semester. Approximately half way through the semester, the first implementations of the designs began to be assembled. This is often the first time that the students have had the opportunity to build and hold one of their designs. On several occasions, we have had students exhibit surprise when the machinist built what the designer specified, instead of what the designer desired. Almost immediately, the first redesigns of non-functioning/non-fitting parts began.

As noted in the description of the proposal contents, the teams are required to develop tests to determine whether the product of their design met its functional requirements. The results of these tests form the basis for design revisions. In some cases, the designers themselves easily made the revisions "on-the-fly." In other cases, the revisions required trips to the machine or electronics shops for further assistance. The results of the redesigns were then tested. This design/testing/revision cycle continued until the end of the semester. It was through this cyclic process that the design teams became truly aware that design was not an event but rather a process.

*The Final BOD Meeting*

The second semester culminated in the generation of a final report and a presentation by each design team. This report contained the following elements, an abstract, a summary of the project proposal, a description of the project and product, performance of the project tested against the specifications, final report of expenditures compared to budget, and a justification of final product. Drawings and/or specifications and test data were attached as appendices. Grading for each project was performed based on the quality of the final presentation, the conscientious of the BOD as to the quality of the product, the final design report, and an evaluation by the group's mentor of the contributions by individual team members to the product.

## Final Outcomes

This course requires the design and construction of a student chosen project. We have chosen to structure the project as a series of phases reminiscent of a software wizard. Each phase represents an increase in the understanding of the students and an increase in the specificity of the project's implementation. The students are asked to set the specifications, design the testing regime for their product, and analyze and interpret the processes occurring in their systems. The students are required to redesign and re-test their design. The iterative failure and redesign cycle results in stronger designs and increases the student's confidence in their design abilities.

The projects' quality is ensured by a Board of Directors, who regularly reviews the projects. In addition, the behavior of the student design groups was successfully modified through a budgeting process that rewarded desired behavior and penalized undesired behavior. Adherence to the budgets was enforced by linking final grades to (among other quality criteria) success in meeting the budgets.

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**PAUL SCHREUDERS**
Paul Schreuders is an Assistant Professor of Biological Resources Engineering at the University of Maryland. He teaches Biological Systems Controls and Biological Responses to Environmental Stimuli to seniors and has developed a collection of fast food toys that is the envy of his students. His research interests include cryopreservation and the structure and function of bacterial biofilms.

**ARTHUR T. JOHNSON**
Art Johnson is a Professor of Biological Resources Engineering at the University of Maryland. Best known for his design work on the life support systems for Noah's Ark, he continues to tell bad jokes and to teach Biological Process Engineering to juniors and Bioinstrumentation to graduate students. His research interests include breathing and watching students run on a treadmill.