**Ensuring Success in Interdisciplinary Externally Sponsored Capstone Design Experiences**

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The Textile Engineering (TE) Program at North Carolina State University has long been utilizing external sponsors for senior design projects. Since our program is multi-disciplinary and the faculty have diverse backgrounds (ranging from chemists to mechanical engineers), we have the opportunity to pursue a wide range of projects. Today, senior design projects in our department focus on diverse fields such as material science, information systems and electro-mechanical design. Here we discuss how to find and incorporate external sponsors into the design program; how to evaluate potential projects to ensure success; strategies for carrying out project work; and specific examples of successful projects.

***Finding External Sponsors***:

Finding external sponsors for focused, semester-long projects can be a daunting task. There are two types of external sponsors, those outside the university and those within the university community. We have found that there are many opportunities for excellent design projects using external sponsors *within* the university community. These sponsors not only help to start a Capstone program but provide an opportunity for faculty (especially junior faculty) to gain experience and confidence in guiding a team to successful completion of a short-term project. Specific opportunities to seek sponsorship include faculty who may want to fabricate custom devices for existing research equipment or automate a manual process using a computer interface. There are several advantages for choosing projects from faculty within the university. First, there is typically a pre-existing relationship, which makes initiation more convenient. Second, faculty members generally have a reasonable perception of what kind of projects can be accomplished in one or two semesters. In addition, faculty sponsored projects can be used to develop a new program or enhance an existing one, since the risks are lower and the interaction between the design team and the sponsor can be better facilitated. Challenges include ensuring the project has measurable outcomes and has a specific design component (rather than a purely research focus).

Establishing contacts with sponsors outside the university community can be facilitated by pre-existing relationships between a company and the university, college, program, and/or faculty within the program. We have found that using established relationships to discuss the design program, show examples of previous projects, and generate discussions about potential projects within that specific company has been well received and has helped initiate design projects. Here it is essential for the design course facilitators to have a good gauge for project scope and potential success within the specified time period. Again, experience with faculty sponsored projects will help in establishing these judgments. Evaluation techniques for potential projects are discussed next.

***Potential Project Evaluation and Keys to Success***:
Here we will discuss strategies to evaluate a project description in order to facilitate success whether the sponsor is a manufacturing company, a faculty member or a student. We have found that a successful project requires more than finding a sponsor with a project. The project must be well thought out and successful completion must be achievable within the specified timeframe. Therefore it is essential to critically evaluate all potential projects before accepting them as part of the program to ensure project success. It is also essential for the facilitators to negotiate with the sponsor what the project deliverables will be before the project is initiated. This way, the sponsor will have a realistic understanding and expectation of what will be achieved. (The student team will further communicate with the sponsor to develop the criteria, constraints, and project deliverables.) Specific questions that need to be addressed to ensure success include:

1. Can this project be realistically completed in the prescribed timeframe?
2. Is the project compatible with the students' curriculum?
3. Is there a demonstratable design component?
4. Are the deliverables clear?
5. Will the sponsor support (both financially and through mentoring) the project?
6. Will the team have access to the resources necessary to solve the problem?

Additional elements that will help ensure the success of the project and the students involved include: sponsor involvement, student support, setting/achieving milestones, and providing peripheral instruction. We have found that strong sponsor involvement is a key to achieving success. Regular interaction between sponsor and team will ensure that the sponsor is aware of progress and setbacks and will help build rapport. In the absence of strong sponsor support, the facilitators need to fill that role as an intermediary. It is therefore essential for the facilitators to know what the sponsor's expectations are for project success. In addition, it is essential for the facilitators to provide, what we call, peripheral instruction. The level of peripheral instruction may depend on the level of sponsor involvement. Projects which have a high level of sponsor involvement generally require less facilitator support and vice versa. Peripheral instruction also focuses on the development of skills to effectively perform and manage the design experience. Examples of these skills include effectively establishing a plan of action, using technical and management tools (such as concept selection and task charts), strengthening the team dynamics (including individual ownership of the project and constructive feedback to team members), and providing specialized support on a project-by-project basis.

***Project Outline***:
An important part of the peripheral instruction includes providing a clear path for the project. In general, we have found the following approach to be successful. (Each task below requires a written documentation and/or an oral presentation.)

1. What is the need? Here each team member writes an essay on why this particular project needs to be done. This is an individual assignment to ensure buy-in from each team member.

2. What are the criteria and constraints? Here the team as a group writes an essay on the criteria and constraints of the project are and why. This ensures that the team and the sponsor are in agreement about what is required.
3. What is the state-of-technology? The team as a group writes a technical document defining what has been done in the literature (including technical journals, patents, and other technology resources). This is designed to ensure the team becomes knowledgeable (in a technical framework) about the technology and the necessary background.
4. How are the concepts generated and selected? The team presents how they went about concept generation and the criteria they used to rank and select the top concepts. This presentation is given to the sponsors and the sponsors provided direct feedback on how the project should proceed.
5. How was the prototype developed and how was it evaluated? The team presents (to the sponsor) the process of developing the prototype and demonstrates the functioning prototype. Evaluation and suggested future work is also discussed.

All of the above elements are also incorporated into a final report, which serves as a comprehensive project report. In addition, each team member is required to submit a project journal and all electronic materials (presentation files, CAD drawings, etc.).

We typically have a unique project for each team (with a total of between 5-7 teams during the semester). For cases where we find the project to be very demanding and/or complex, we may assign more than one team to work on the same project. Here the teams will develop the criteria/constraints and the state-of-technology as a large team and then break into their individual teams to develop concepts and follow through with selection and prototype development. We have found that this helps maximize creativity and the number of potential solutions available to solve the problem.

***Specific Examples***

Here we highlight two specific examples of past design projects, one from a faculty sponsor and one from an industrial sponsor.

*Dynamic Sample Holder and Fluid Sample Holder for the Hysitron Triboindenter*
*Sponsor: Faculty in Textile Engineering*

Drs. Krause and Gorga, along with three additional professors from the College of Engineering were recently awarded a grant from National Science Foundation to acquire and state-of-the-art nanoindenter (a $250,000+ instrument) to make nano-mechanical measurements of novel materials and composites. To be able to make even more specialized measurements, Drs. Krause and Gorga wanted to design, fabricate and evaluate custom sample holders (fixtures) for the nanoindenter. Two fixtures were required. The first will be used to hold samples under a liquid layer. It is envisioned to be a fixture that tightly holds a film-like sample allowing a liquid to be kept over the sample. Krause intends to use this fixture to evaluate the coefficient of friction and wear of substrates (the sample) under a liquid lubricant. For example, she plans evaluate the lubricating properties of model synovial fluids. The second will be used to hold fibers/fabrics/thins films under tension. Specifically, it is envisioned that the samples be held under a constant tension, a known tension be applied as desired, the tension be raised or lowered without removing the sample, and be used for small samples of varied geometry (fiber, film, fabric). This fixture will allow us to evaluate the mechanical properties of individual fiber junctions of nonwoven fabrics as a function of applied tension. The greatest challenge is that the fixtures ***must*** fit in the sample area of the nanoindenter instrument (which is only a 6 x 6 inch area with a height clearance of just over one inch)!

At the beginning of the Spring 2006 semester, three senior Textile Engineering students at NC State's College of Textiles were given the opportunity to help Drs. Krause and Gorga design and build these fixtures. Three and one half months later, on April 28$^{th}$, the team presented a solution and working fixture for each fixture. Brainstorming, benchmarking other industries, and applying a great deal of hard work and perseverance resulted in the design and fabrication of each fixture. These fixtures are now a part of the professors' laboratory equipment and are currently being implemented for cutting-edge scientific research.

*High-strength Cord: Cutting and Termination*
*Sponsor: Local Industry*

A local cord manufacturing company makes cord for many different applications, such as pull cord for lawn mowers and other engines. Usually these cords are made from nylon filaments since nylon is tough, strong, and relatively easy to process. The nylon cord is cut into specific lengths using a conventional stainless steel blade system and the cut end is heated to melt the filaments together to prevent unraveling. An advanced high-strength filament, which is stronger than steel, cut and burn resistant, and has the flexibility of ordinary polymeric materials has significant potential for cord applications requiring high strength, toughness, and flexibility. The primary obstacle to using this cord also happens to be what makes it so attractive; specifically, the cut and burn resistance makes it very difficult to manufacture into cut length cords using conventional techniques (cutting with a blade and terminating with heat). Hence, the primary challenge this company had to overcome to use this material in the cord market was to determine how to cut and terminate the cord using processes other than the traditional method.

At the beginning of the Spring 2006 semester, senior Textile Engineering students at NC State's College of Textiles were given the opportunity to this local company find a solution for cutting and terminating high-strength cord. Three and one half months later, on April 28$^{th}$, the team of four students presented a solution which included a functioning prototype to the company. Brainstorming, benchmarking other industries, and applying a great deal of hard work and perseverance resulted in a solution in which the company was very confident would work. So confident, in fact, that they have begun implementation of the solution in their manufacturing facility and plan to produce a new cord product by the end of the year.