Equipping Multi-disciplinary Student Teams to Manage Multi-Semester Design Projects

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Introduction

A challenge facing many institutions is how to bring "real" design experiences into the curriculum. Introducing "real" design experiences, where the purpose is to expose students to open ended problems and multiple solution paths and to encourage creativity, into the classroom, brings many concerns for the faculty. These include guiding the students through the design process over multiple semesters with multidisciplinary and vertically integrated teams that change from semester to semester. Additional challenges are introduced when the projects are driven by an external customer with their own needs and timetables.

At Purdue University, the EPICS - Engineering Projects in Community Service – program does this through long-term team projects that solve technology-based problems for local non-profit community service organizations. The program currently has 29 project teams with over 400 students participating during the 2004-05 academic year. Each EPICS team consists of eight to 20 undergraduate students, a local community service organization that functions as its customer and a faculty and/or industrial adviser. The teams are multidisciplinary; they are composed of students from 20 majors across engineering and the university. The teams are vertically-integrated; each is a mix of freshman, sophomores, juniors and seniors.

To manage the large number of projects and teams that extend across semesters, the EPICS program has developed a design and documentation process to guide students through their designs and to insure that both the community partner's needs are being address and the transition between semesters is managed. This paper will highlight this design and documentation process and present lessons learned and future challenges using this model for design education.

Introduction

The importance of significant design experiences to prepare undergraduate engineering students for engineering careers has been well-documented [1, 2]. These experiences typically emphasize the application of the technical skills as well as the professional or "softer" skills such as communication, working as a team and customer interaction [3-5]. The need for such experiences has spawned many innovative approaches to senior capstone design courses [6, 7] as well as design courses for underclassmen [8-11]. The most common model for these courses has been a one semester experience intended to give the students an intense exposure to the design process.

The model that guided the creation of the Engineering Projects in Community Service (EPICS) curriculum was to involve each student for several semesters or even years on the same long-term project, so that each student would experience varying roles over the course of the project. This emphasis on long-term projects was combined with a goal of undertaking projects that would ultimately be deployed by the customer.

This led to the choice of local not-for-profit organizations as the “customers”. Community service agencies face a future in which they must rely to a great extent upon technology for the delivery, coordination, accounting, and improvement of the services they provide. They often possess neither the expertise to use nor the budget to design and acquire a technological solution that is suited to their mission. They thus need the help of people with strong technical backgrounds. Moreover, the community service agencies will ultimately deploy the teams' systems -- an important final step that few commercial partners would take.

Through this service, the EPICS students learn many valuable lessons in engineering, including the role of the partner, or "customer," in defining an engineering project; the necessity of teamwork; the difficulty of managing and leading large projects; the need for skills and knowledge from many different disciplines; and the art of solving technical problems. In working with community agencies, the students are exposed to these agencies and thereby become more aware of the community needs and how their professional expertise can be used to meet those needs. This awareness of the community comes as a natural byproduct of fully understanding their customer, a critical piece of the design process.

The multi-semester EPICS model has provided a rich learning environment for the students and the kind of long-term partnerships community and educational organizations need. It has, however, provided challenges in managing designs spanning multiple semesters and involving many students. The continuity of the EPICS Program typically ensures that part of each design team returns on each project, but not all. It is not unusual for the students who begin a large project will have graduated and before it is delivered to their community partner.[12, 13]

EPICS at Purdue has seen many successes, including over 150 delivered projects that have been used by the local community. Still, the challenges presented by the transitions between semesters can retard progress on projects. One common scenario is when a team does not produce sufficiently detailed documentation, leaving the next semester’s team struggling early in the semester. Another scenario is when a team has left enough documentation but the next semester’s team believes there is a better way to approach the problem. In this case, the team goes back and repeats steps in the design process that were finished earlier. While this may result in better designs, we have also seen this phenomenon delay delivery of the projects creating hardship for the community partner.

The EPICS model for service-learning seeks a balance between the learning experience of the students and the services it provides to the local community. To improve the experience for the students and the community partners and produce better designed projects (see Table 1), the EPICS program has adopted a systematic approach to managing all of the designs. This paper documents the design process and approach of the EPICS program and discusses the initial results in the first year of implementation.

Table 1. Characteristics of Good Design vs. Bad Design[14]

Good Design	Bad Design
1. Works all of the time	1. Works initially, but stops working after a short time
2. Meets all technical requirements	2. Meets only some technical requirements
3. Meets cost requirements	3. Costs more than it should
4. Requires little or no maintenance	4. Requires frequent maintenance
5. Is safe	5. Poses a hazard to the user
6. Creates no ethical dilemma	6. Fulfills a need that is questionable

Curricular Structure of the EPICS Program

EPICS was initiated in the School of Electrical and Computer Engineering at Purdue University in Fall 1995, with 40 students participating on five project teams. The program has grown steadily at Purdue both in size and breadth. In the 2004-05 academic year, over 400 students participated on 29 teams, addressing problems ranging from data management for social services to mitigation of agricultural pollution and from designing learning centers for local museums to developing custom play environments for children with disabilities. EPICS spans engineering disciplines at Purdue and includes students from over 20 departments across the university.

Each EPICS project involves a team of eight to twenty undergraduates, a not-for-profit community partner – for example, a community service agency, museum or school, or government agency and a faculty or industry advisor. A pool of graduate teaching assistants from seven departments provides technical guidance and administrative assistance.

Each EPICS team is vertically integrated, consisting of a mix of freshmen, sophomores, juniors, and senior and is constituted for several years, from initial project definition through final deployment. Once the initial project(s) is completed and deployed, new projects are identified by the team and community partner allowing the team to continue to work with the same community partner for many years. Each undergraduate student may earn academic credit for several semesters, registering for the course for 1 or 2 credits each semester. The credit structure is designed to encourage long-term participation, and allows multi-year projects of significant scope and impact to be undertaken by the teams.

Each student in the EPICS Program attends a weekly two-hour meeting of his/her team in the EPICS laboratory. During this laboratory time the team members will take care of administrative matters, do project planning and tracking, and work on their project. All students also attend a common one-hour lecture each week. A majority of the lectures are by guest experts, and have covered a wide range of topics related to engineering design, communication, and community service. The long-term nature of the program has required some innovation in the lecture series since students may be involved in the program for several semesters. This has been addressed by rotating the lecture topics on a cycle of two to three years and by creating specialized lecture supplements called skill sessions that students can substitute for lectures they have already seen. Example skill session topics include learning to operate a mill or lathe, developing effective surveys, and tutorials on multimedia software. We have found that students use the skills sessions as a way of gaining specific expertise needed for their projects, and also as an opportunity to broaden their experience, for example, a computer engineering student learning to use a lathe or a mechanical engineering student learning web programming.

Sample EPICS Projects

For the 2004-2005 academic year, there are 29 EPICS teams at Purdue University. A description of each team can be found on the EPICS web site at http://epics.ecn.purdue.edu. There are also 14 other universities with EPICS programs, which are listed at http://epicsnational.ecn.purdue.edu EPICS teams work in four areas of the community, access and abilities, education, social services and the environment. A sample description of a team from each area is presented below.

Access and Abilities:

Wabash Center Greenbush Industries
Project Partner: Wabash Center Greenbush Industries
Facts: Began in Fall 1998. Winner of the Fall 1999 and Fall 2001 AMD Design Award. Sponsored by Abbott Labs and TRW.
Mission: Develop aids to help workers with disabilities perform simple manufacturing tasks that address ergonomic, safety and quality control issues while enhancing the cognitive and motor skills of WCGI employees.
Delivered: A machined platform to aid workers with cerebral palsy in feeding a clamp onto plastic tube; Prototype of an electromechanical tube-winding device; Collapsible coiler reel to wind electrical cable; Device to facilitate application of an o-ring to a threaded spring cap; PVC cutting device; Frame to facilitate one-handed insertion of rubber grommets into a heat exchanger panel; Shape-sorting board with electronic score-keeping and feedback that helps workers with physical and mental disabilities to develop skills
Technologies: Electronics, materials, electromechanical devices
Disciplines: Electrical and Computer Engineering, Mechanical Engineering, Materials Science, Industrial Engineering, Special Education, Psychology
Impact: Job experience and employment opportunities for adults with disabilities

Environment

Constructed Wetlands
Project Partner: Purdue Department of Forestry and Natural Resources
Facts: Began in Fall 1998.
Mission: Work with the Purdue Department of Forestry and Natural Resources to develop and construct a test wetlands area to clean up runoff from cattle, dairy, and swine farms and to treat creek water.
Technologies: Environmental engineering, surveying, hydrology, botany, instrumentation
Disciplines: Civil Engineering, Electrical Engineering, Environmental, Chemistry, Biology
Impact: Improved water quality; New techniques for mitigating agricultural runoff

Education

Happy Hollow Elementary School

Project Partner: Happy Hollow Elementary School

Facts: Began in Fall 1997, in Fall 1998, Burtsfield School closed and transitioned to Happy Hollow Elementary School. Winner of the EPICS Team Award Spring 2004, EPICS Leadership Award Fall 2004, AMD Design Award Spring 2000, and Spring 2000.

Mission: To promote and develop learning at Happy Hollow Elementary School by creating a classroom where inner-active, inquiry based exhibits expand math, science, technology, and engineering concepts and applications to fourth, fifth, and sixth grade students. These hands on science museum type activities and displays are life-size and reflect sound engineering design theories and processes. They are complimented by instructional guidelines for teachers and activities for fourth, fifth, and sixth grades students that align with the science curriculum and state academic performance standards.

Delivered: A large variety of projects have been completed and implemented into the interactive Rainforest Room: An Air Cannon that shoots tennis balls and helps apply concepts such as force, gravity, air pressure, friction, and trajectories; A Laser Harp that uses lasers in place of strings to play notes; The Memory Basketball Game that demonstrates how memory affects learning via shooting baskets off an electronic-based backboard with and without vision distorting goggles; A Weather Station and instrumentation that feeds meteorological data to the elementary school's science lab; The Water Garden highlighting a waterfall that promotes environmental awareness; A Flash Wall that uses strobe lights and phosphorous sheets to capture a student's shadow cast on a phosphorescent wall; A Color Wall that demonstrates principles of colored light; The Tornado Box that simulates a miniature tornado in a Plexiglas box.

Technologies: Electronic hardware and software, mechanical hardware, and educational development

Disciplines: Aeronautical Engineering, Civil Engineering, Education, Electrical and Computer Engineering, Industrial Engineering, Health Sciences, and Mechanical Engineering

Impact: To promote and develop learning in and interest for engineering by creating a classroom where inner-active, inquiry based exhibits expand math, science, technology, and engineering concepts and applications to fourth, fifth and sixth grade students.

Social Services

Habitat for Humanity

Project Partner: Habitat for Humanity's Lafayette Affiliate and Habitat for Humanity International

Facts: Began in Fall 1996.

Mission: Improve the efficiency of Habitat for Humanity's operations. Improve data management and access to resources for Habitat affiliates through the use of modern software solutions. Design systems, structures, and floor plans to minimize home construction and energy costs.

Delivered: New design for house corners to minimize air leakage; Brochure for homeowners that describes how to compute the cost of using different types of light bulbs; Thermal imaging of Habitat homes to determine efficiency of Habitat construction techniques; Pressure door to detect areas of heat loss; Web-based home selection guide

for prospective homeowners; analysis of projected annual utility costs for available floor plans; parametric studies on home options (led to the addition of central air conditioning for all homes in Lafayette); Solar powered attic fan for resale store
Technologies: Power electronics, solar cells, energy-modeling, energy-efficient structures, construction, databases, cryptography, communication, software
Disciplines: Mechanical Engineering, Civil Engineering, Computer Engineering, Computer Science, Electrical Engineering, Industrial Engineering
Impact: Lower cost houses and lower home operating expenses for the working poor

The EPICS Design Process Model

Design is one of the defining characteristics of engineering. Good designers follow a series of systematic steps during the development of their designs. In teaching good design practices, the design process is typically broken into distinct steps. The specific steps taken during the design process are modeled in different ways. Oakes, Leone and Gunn divide the design process into 10 steps[15].

Stage 1: Identify the problem/product innovation
Stage 2: Define the working criteria/goals
Stage 3: Research and gather data
Stage 4: Brainstorm/generate creative ideas
Stage 5: Analyze potential solutions
Stage 6: Develop and test models
Stage 7: Make the decision
Stage 8: Communicate and specify
Stage 9: Implement and commercialize
Stage 10: Perform post-implementation review and assessment

Ullman breaks the design process into six distinct steps [16].

Phase 1: Specification development/planning
Phase 2: Conceptual design
Phase 3: Product design
Phase 4: Production
Phase 5: Service
Phase 6: Retirement

While authors will break the design process into a different number of steps, most design processes are very similar, covering the same concepts in the same order. During the early years in EPICS, students were exposed to the different models and encouraged to follow the one that best fit their project. One reason for this approach was the diversity of the EPICS students and their projects. Students, for example, in Mechanical Engineering are taught Ullman's Mechanical Design model for design. This does not always translate into other areas, such as software design. To be more accommodating to the multidisciplinary nature of the EPICS program, freedom was given for teams to adapt the appropriate model to their own designs. What we found, however, is that by not following a single model, many teams followed none of the models presented. This resulted in slower progress on projects and less understanding of the design process.

To improve on the progress of the projects and to improve student learning, a common design model was introduced in the Fall semester of 2004. The design model that was chosen is tailored to student-driven projects and breaks the design process into seven steps.[17]

Phase 1: Problem identification
Phase 2: Specification development/planning
Phase 3: Conceptual design
Phase 4: Detailed design
Phase 5: Production
Phase 6: Service and Maintenance
Phase 7: Redesign or retirement and disposal

We have found that student resist early steps in the design process. They are on a rush to build, sometimes before they fully understand the design constraints. The principle of going slow to go fast later is emphasized as good design practice by imposing deliverables in the early phases. A systematic approach insures that our community partners' needs are being addressed to their best ability and the students are applying all of their technical skills and tools to the development of the design.

While the seven phases are presented as a linear list, the process is taught as a cycle. The cycle may be repeated over an over during the life of a part as a product is fielded and redesigned and refined. Within each phase, there are smaller cycles that may be repeated. Within the design cycle itself, there may be repeats and smaller cycles. For example, when the detailed design begins, a problem might be identified that requires a reexamination of the specifications, which brings the team back to that phase. A miscommunication between the design team and the community partner may result in a revisiting of the problem identification and specifications. Iterations are part of the design cycle and process. Students are also exposed to concepts of concurrent design and how to consider future phases of the design process in earlier phases.

The EPICS teams are multidisciplinary, involving about 20 disciplines in any typical academic year including many students from outside of engineering. During discussions and presentations of the design process, the multidisciplinary audience is taken into consideration and emphasis is placed on the benefits of diverse design teams.

The Design Process

The seven steps in the design process are outlined below with a brief description of each phase. Further details can be found in Lima and Oakes[17].

Step 1 - Problem Identification

The first phase of the design process is to identify the problem that they are trying to solve. This may at first appear trivial, but it is a crucial step and one that if done wrong can result in disaster for the rest of the process. EPICS students are involved in the discussions with the community partners at the very beginning of projects including problem identification. They typically start the process with a problem statement given by their advisor and community partner, but they go back to verify that they are truly identifying the real problems. This often requires a slightly different way of thinking for the students. In most classes, the instructor is considered the expert; anything she or he says must be right and there is no reason to go further. When addressing designs for community needs, there may not be any single expert. The faculty advisor may not have all the expertise required to meet all the needs of the requested project. The community partner may not fully understand all the technologies that are available and may have asked for something based on their understanding of what is possible. For example, they may have asked for a database management system for part of their organization but not for other parts because they didn't realize how easy integration of the different parts could be.

Step 2 - Specifications Development
Once the problem is identified, a solution needs to be addressed. The first step in generating a solution is to identify the constraints and boundaries for the solution. Constraints include who will need to use the product, cost, ease of use, safety and environmental impact. What is the scope of the solution? What part of the larger community issues will the design seek to meet? The answers to these questions are called specification and their development is the second phase of the design process. In this phase, the goal is to generate a set of specification or goals that can be measured so that they will know when the design is successfully completed.

Step 3 – Conceptual Design
The conceptual design phase begins the design team's generation of solutions. This is the phase when ideas of how to meet the needs of the community partner using the specifications developed in the prior phase. As with all phases, this phase starts with a divergent component where ideas are generated using techniques including brainstorming. A common mistake for design teams is to immediately look at the design as a whole and to begin the brainstorming on solving the whole problem at once. While this can lead to good solutions, it is much more effective to break the project down into the smallest pieces using methods such as functional decomposition. The best concepts for the different components of the design are assembled into an overall concept.

Step 4 – Detailed design and development
Once the concept is defined, the details must be determined. There is a saying that *design is done by top down specifications, bottom up implementation*. When we started defining the problem in Steps 1 and 2, we asked what the broader issues were and worked down to the details. In the detailed design phase, we begin with the specific details and work up into the larger overall system. For a physical design, detailed drawings will be made for all components. Computer aided design, CAD, software packages are used to make component drawings that can be compiled into assembly drawings. For a software design, the overall architecture of the system is determined, specifying the interface and interaction of the sub-modules of the program.

Step 5 – Production
In the production phase, the design is actually built. For physical products, materials are purchases, parts are manufactured and the design is assembled. For software designs, the full code is written and debugged. In a commercial design process, there would actually be two production phases, the development or prototyping phase and the full-scale production phase.

For many EPICS applications, the prototype is the final design and is the delivered product. In other cases, the prototype is a model to evaluate for a future production run or second generation prototype.

Step 6 - Service

Service and management of delivered products has become an important part of many company's design and production plans. The model of a long-term partnership with local community partners commits EPICS to servicing and maintaining delivered products with our community partners. How a product will be serviced is an essential part of the design and is considered early in the design process. The documentation each team leaves behind becomes even more critical part of the design process. Service and operating manuals are delivered with the finished design and have to be clear enough for the people who will maintain the products.

Step 7.a - Redesign

Redesign is presented as a natural part of the design cycle. Almost any product that has been in service for a significant amount of time has undergone a redesign of some level. Redesigns might be small in nature and involve small components or they be major and associated with a new version of the product released to production. The software industry has established a system to identify how significant a redesign is by the digit that is changed with new versions

For a version 1.00, redesigns would be classified as:

- 1.01 = A minor redesign involving small aspects of the design
- 1.10 = A redesign that is more significant but integrated into the same overall design
- 2.00 = A redesign that significantly changes the design or adds new features

Redesigns in service-learning projects may be additions or fixes to keep a fielded project in operation or they may involve a new prototype to replace a defective or obsolete project.

Step 7.b - Retirement/Disposal

Redesigning is not always the best solution for an existing design. After analysis of a product and the costs and resources needed to either maintain the current design or to replace it with a new design, a team may conclude that the existing product needs to be retired from service. This is also a natural part of the life cycle of a product. The decision to retire a piece is be made in conjunction with the community partner and team advisor and is based on the value it is adding and the costs to maintain the current version.

The new approach to managing designs and documentation

An important component of the EPICS courses is the production of artifacts that can be used in the continuity of their designs between semesters as well as in the assessment of the individual students, the teams and the overall program. Each semester, EPICS teams have documented their work individually and as a team through individual design notebooks and team reports. These have been very useful and teach the students an important discipline for later in their professional development.

Design Notebooks – Each student is required to maintain a design notebook. Guidelines are given to the students for completing the notebooks. To quote one of our team leaders "basically, we put everything we do into the notebook". The notebooks are evaluated three times during the semester, in weeks 4, 8 and 15, by the teaching assistants. The first evaluation is often a time to point out formatting issues and the level of detail that is expected. The content of the notebook is an excellent record of the students work.

Weekly Reports – Each student is required to fill out a weekly report. These reports ask the student to summarize their accomplishments for that week, provides page numbers in the design notebook that document these accomplishments, and the work they have planned for the following week. The reports are entered into a web-based tool that compiles the reports by teams and allows the advisors to view a given team's report each week and to comment on the reports. The software allows students to enter their reports any time but marks reports as late if entered after the weekly deadline. Another feature of the software is that an individual's reports can be viewed by the advisor over the whole semester.

Reports – Each team completed a midsemester and end of semester report. Each report had a technical appendix that contained all of the relevant technical details for each project.

While these systems of documenting have been valuable for student learning and assessment of individual and team accomplishments, they have not been as conducive to providing the necessary information to allow teams to transition projects from semester to semester. Information needed from the design notebooks was often difficult and time-consuming to locate. The chronological nature of the semester reports gave primarily incremental progress in the design and did not insure that each step in the design process had been adequately addressed.

When the move was made to bring all of the teams into a single model for design, the documentation was also changed. The previous model for documentation followed the semester schedule. The new process follows the development of the project and tries to put students into the mode of documenting as they go. At each phase of the design process, there is material that needs to be documented. Decisions made at each phase lay the groundwork for future decisions. Each phase of the design process has a deliverable that must be completed before the next phase is begun. This structure is shown in Table 2. Descriptions of the design process documentation deliverables are given below.

Project Charter - The Project Charter document describes the problem to be solved, the project objectives, the outcomes or deliverables and the expected duration of the project. It identifies the motivation for the project and how the project meets the mission of the community partner. It further identifies the beneficiaries and stakeholders of the project.

Project Specification Document - The Project Specification Document includes a more in-depth analysis of users and beneficiaries of the project. It defines the customer and user requirements in such categories as functional performance, human factors, physical requirements, reliability and cost. It considers such factors as economic, environmental, ethical, health and safety, political, social, sustainability, aesthetics and manufacturability constraints. It establishes quantifiable and measurable criteria that can be used to evaluate benchmark and preliminary designs, as well as design targets.

Table 2: The EPICS Design Process

Tasks	Deliverables
Problem Identification Phase	
- Identify problem	- Project Charter
- Determine project objectives	
- Determine motivation for project	
- Identify outcomes or deliverables	
- Determine duration of the project	
- Identify community partner contact	
Specification Development Phase	
- Complete users and beneficiaries analysis	- Project Specification Document
- Define the customer requirements	
- Evaluate design constraints	
- Develop engineering specifications	
- Compare to benchmark products (prior art)	
- Determine design targets	
Conceptual Design Phase	
- Complete Functional Decomposition of project	- Project Conceptual Design Report
- Complete Decision Matrix of requirements	
- Define how users will interact with project	
- Analyze/evaluate potential solutions	
- Choose best solution	
Detailed Design Phase	
- Complete top down specification/ bottom-up implementation (freeze interfaces)	- Project Detailed Design Report
- Analysis/evaluation of project, sub-modules and/or components	- Prototype version of project
- Prototyping/proof-of-concept of project, sub-modules and/or components	
- Field test prototype/get feedback from users	
- Complete DFMEA analysis of project	
- Determine what user training is necessary	
Production Phase	
- Complete production version of the project	- Delivered project
- Complete user manuals/training material	- Delivery Report and Checklist
- Complete delivery review	- User manuals
Service/Maintenance Phase	
- Evaluate performance of fielded project	- Fielded Project Report
- Determine what resources are necessary to support and maintain the project	

Project Conceptual Design Report - The Project Conceptual Design Report summarizes the different solutions that have been considered for the design and provides a systematic comparison and evaluation of the ideas. It defines how the user will interact with the project. It explores potential solutions that are already available that would satisfy the community partner's need. It further considers such factors as economic, environmental, ethical, health and safety, political, social, sustainability, aesthetics and manufacturability constraints The report should finally identify the design approach that best meets the specifications that have been established.

Project Detail Design Report - The Project Detail Design Report provides an overview of the design, illustrates how the sub-modules are interfaced, and provides the design details of each of the components or sub-modules. It also includes any information learned from prototypes or proof-of-concept designs and any Design Records that were completed. It further considers such factors as economic, environmental, ethical, health and safety, political, social, sustainability, aesthetics and manufacturability constraints. This report should also include a comparison of the project to the design specifications. Design decisions should be summarized in a Design Decision table for easy reference. Finally, it should contain a bill of materials.

Project Delivery Report - The Project Delivery Report should include all final production design details, such as circuit schematics, PCB layouts, piece part and assembly drawings and CAD models, bill-of-material, assembly instructions, packaging information, location of final version of software and user manuals, training information, and part replacement information. It should also contain any Design Records of any changes that were implemented from the Detailed Design.

Fielded Project Report - Each semester the team should evaluate the performance of fielded projects to determine if the design should continue to be deployed as is, or is redesign or retirement required. Resources required to support and maintain the project should be identified and allocated.

Design Record - A design record is a (short) report of an engineering analysis that has been completed regarding the project. Examples of the type of activities that should be supported by a Design Record are circuit simulations, CAD modeling of the project, safety calculations, experimental measurements, design rational, and component selection.

Design Decision Table - A design decision table summarizes design decisions which have been made regarding the design. In most cases, they should reference a Design record. Design decisions could include decisions regarding the architecture, algorithm, tools, environment, component selection, and material selection related to the project.

Results and Conclusions

The results of the move to a uniform design process has been very positive but not without challenges. Since EPICS projects are in different phases of design at any given time, it was a challenge for some teams to start the process in the middle of their designs. We made accommodations for these teams and asked them to follow the new model for the rest of their designs. We allowed teams to use equivalent documentation of work completed in earlier semesters. We observed many continuing teams identified gaps in the design process and were able to address these before they ran into trouble later in the process. The teams that benefited the most were in the beginning phases.

Assessments of the new process included surveys of the students. One set of questions asked the students to compare the quality of the team's technical documentation at the beginning of the semester and at the end of the semester using the new tools. They rated the documentation using a Likert scale with 5 corresponding to complete, all information easily accessible and 1 as poor and very incomplete. The results are shown in Figure 1 under question 1 and show an improvement from 3.1 to 3.4.

A second question, labeled Questions 2 in Figure 1, asked "Where was the most relevant documentation located?" Students still kept individual design notebooks as well as the team reports. The scale that was used had 5 corresponding to the team's reports and 1 to mostly in the individual notebooks. Figure 1 shows the responses moved from 3.6 to 4.0 which show a move away from having to search the individual notebooks, one of the intentions of the new design process.

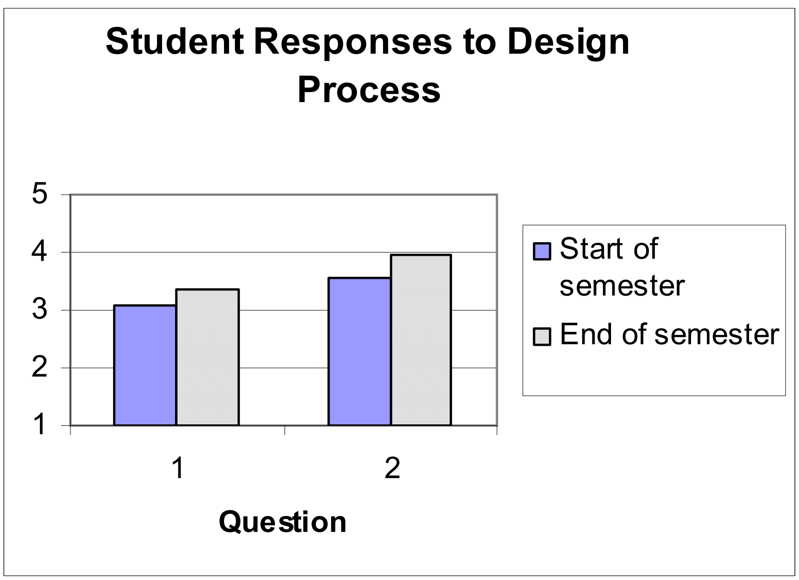

Figure 1: Assessment Questions on the Design Process Documentation

Students were also asked to comment on how helpful the new design process and documentation has been during their work on their projects. Representative quotes from students include:

Without the design projects, we would be using the "hobbyist" approach to design [Part of the design documentation contrasts a "hobbyist" who builds and tinkers until a design works to an analytical engineering approach that plans and predicts the success of a design using the appropriate computation and analytical tools]

It has helped us identifying where we are and where we are heading. It has also helped us to speed up each passing stage.

The design process helps us identify problems and design solutions for them, then come back and repeat the cycle. It helps with identifying stages of design and helpful in documentation.

It has helped by keeping our projects on track and to keep us from going from idea to production and skipping the design phase.

It has helped us see thins that we may have missed, such as meeting all the partner's needs and safety issues. It has also made the design easier to acquire info from the past because it is more organized.

The initial step of problem identification helped us to know where to begin.

One of the challenges we have faced is the resistance some students have to using this process. This is especially true for students that have been exposed to alternative models through co-op, intern experiences or other classes. An example quote is:

This design process has had no positive impact on our team. We ignored it in favor of the superior, industry-standard USDP.

Other challenges and barriers to implementation that we noted by students included

Team does not understand the design process

Clearer template for documentation

Examples of good documents for each phase

Centralized database for documentation that forces submission for documents

Have someone to "clear-up" and keep things organized on the team's shared drive

Make sure specifications are concrete and complete very early in the semester

Because this was the first semester of the new design process, we did not have a history and could not provide examples of good documents. This has been addressed and is being implemented for the Spring semester of 2005.

Overall, the move to a common design process across all of the EPICS teams has been a success. It has allowed a more uniform means of assessing the progress of the teams and has provided a clearer set of expectations for the community partners during the development of the designs. There continue to be challenges to refine the process to be inclusive of the wide diversity of students participating in the EPICS program.

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