Using Design Portfolios to Improve Design Education

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Abstract

The design portfolio is a useful tool to help engineering educators develop and evaluate student design abilities. Like professional portfolios, an institution's design portfolio features the best student work that results when design instruction is integrated throughout the curriculum. Compared to individual portfolios that illustrate one person's achievements, the institutional portfolio showcases the work of an entire group. This paper introduces the topic of design portfolios and applies teaching portfolio techniques as a content guide for an institution's design portfolio. The value of an institution's design portfolio is discussed, and a template of a design portfolio is presented. Experiences from using a design portfolio at the U. S. Coast Guard Academy are documented to illustrate how design portfolios can improve design education.

Introduction

The importance of the design experience within engineering education is widely acknowledged and accepted, though there is little consensus among engineering educators on how to measure and document performance in this area. Though not a panacea, institutional design portfolios are proposed as a tool to help assess and communicate the design content of an institution's curriculum. The design portfolio can be a useful mechanism for a program to articulate its design philosophy, document how student design experiences have put that philosophy into practice, reflect on successful design exercises and evaluate the students' complete design experience. Creating and using a design portfolio highlights design as a developmental skill within the engineering curriculum and allows the faculty to focus on design as an integrated component of engineering education. Because of this focused attention, the use of design portfolios improves design education.

Design portfolios, like portfolios developed by artists, architects and teachers, area mechanism for featuring one's best work. Portfolios are a selective collection of artifacts that have been assembled to document the extent and quality of one's professional achievements. Differing from an individual portfolio, the institutional portfolio documents the collective achievements of an entire group. For the institutional (or program) design portfolio, the documented professional achievement is the students' design experience within an engineering major. To document this achievement, the portfolio presents the best student work rather than a collection of all work or a range of performance. The selections for the portfolio must be carefully chosen to present the design experience in a concise document, and therefore the portfolio should not include every design exercise that students undertake. In addition to simply presenting the work, the portfolio serves as a forum for assessing student learning and guiding intellectual development.

At the U. S. Coast Guard Academy (USCGA), an institutional design portfolio has been developed and used within the Mechanical Engineering major. The portfolio states the department's philosophy of design education as a developmental process, and documents, using selected design experiences, how that philosophy is put into practice. Two design experiences from each year of the students' engineering education are presented in the USCGA portfolio. The portfolio artifacts themselves include project assignments, reports, photographs, videos, story boards, prototypes and design specimens. Though motivated as a tool to document

the design experience for ABET evaluators, the local portfolio has also been an effective method to describe the developmental nature of design education to visitors (i.e. students, parents, benefactors, and trustees) and encourage continuous improvement of the students' design education.

Background

-Applications of portfolios in engineering education and the teaching profession provide valuable insight for developing an institutional design portfolio. Though common practice in many professions, portfolios have only recently gained acceptance within the engineering profession. For example, some recent work has documented how design portfolios have been used as an assessment tool for student performance in engineering programs.[1,2,3] Not restricted to classroom experiences, portfolios have been used to provide evidence of professional and personal skill development experienced beyond the confines of the curriculum. Skills such as planning, applying technology, evaluating, and accepting professional responsibility - skills welcomed by employers - have been presented using the open forum of a portfolio.

Observations based on experiences with individual portfolios in engineering education have relevance when applied to the institutional design portfolio model. For example, Bramhall[1] points out that though an original goal of using portfolios was to document development, the portfolios often concentrated on achievement and potential. Such concentrations detracted from the portfolio's ability to develop the individuals habit of personal reflection, self assessment, and commitment to continuing professional growth. Bramhall's results indicate that if properly completed, portfolios encourage those assembling the portfolio to review their work and suggest alternative courses of action that could have better achieved their goals.

Applications from the field of teaching portfolios can also guide institutional design portfolio development. The artifacts chosen for the portfolio must be carefully selected and presented to clearly convey the portfolio's intended message. To place each individual portfolio work in the correct context of the portfolio itself, each artifact may require a narrative to illustrate how the presented work pertains to the portfolio theme.[5] Analogous to the observation that there is no one standard for the teaching portfolio, the institutional design portfolio can vary in content but its intent must be well defined.[4]

The value of developing a portfolio has been documented by Seldin[6] who commented that the process of assembling a teaching portfolio forces faculty members to think about their teaching. For the institutional design portfolio, the process of assembling the portfolio similarly forces the faculty to focus on the role of design in the engineering curriculum. Faculty confidence in the validity of portfolios to improve one's teaching (and similarly to improve an institution's approach to design education) has been a critical factor to gain faculty acceptance of this technique. Only after that confidence is established will the faculty devote the necessary time needed to develop a useful portfolio.

A complete understanding of portfolios can be obtained by examining portfolios in terms of what they are and what they are not. Portfolios are unique, but have no standards for content and format. Portfolios display the best work, but do not display all work. Portfolios tell a story and are organized in sections that have a common theme, but are not unstructured collections of work. Portfolios area collective selection of work, but are not simply "pack-ratting" run rampant.[4] Portfolios promote peer review of work, but are not defensive.

Portfolio contents vary and can include the traditional documentation associated with academic work (syllabi, papers, etc.) as well as other objects that are not produced as text. Urbach[5] presents a comprehensive list of documents and artifacts that can be included in a teaching portfolio and his suggestions for student work are applicable for an institution's design portfolio. Included in this list of suggested student work are papers, photographs, project displays, videos, exams, and student feedback.

Design Portfolios and the Developmental Nature of Design Education

Based on the above-guidelines, an institutional design portfolio was prepared to publicize the USCGA Department of Engineering's design philosophy, document how individual design experiences have put that philosophy-into practice, and improve the individual exercises and the design experience as a whole. The design portfolio was created to be more than a mere presentation of work, but more significantly to serve as a valuable tool for assessing cadet learning and the institution's development of design skills.

The local design portfolio was assembled for three fundamental reasons:

- to document part of the design experience for US CGA Mechanical Engineers,
- to reflect on the individual components and overall content of the design effort, and
- to improve the design effort for following classes.

Urbach's advice that "over documentation is as unwise as too little documentation"[5] was followed while assembling the US CGA portfolio. Selections were carefully chosen to present the design experience in a concise document, and therefore the institutional design portfolio does not document every design exercise that cadets experience. By design, the USCGA portfolio is thin on words and thick on examples and conveys its message to the reviewer in a short period of time (approximately 15 minutes).

An important aspect of the USCGA design portfolio is a reflection section that accompanies each exercise. In the reflection section, the instructor steps back from the work, examines the results, evaluates the experience, and makes recommendations for the future. As suggested by Edgarton, the combination of examples and reflections on each exercise's ability to meet educational goals enables the portfolio to be used as a feedback mechanism for improving future efforts.[4] In this light, the portfolio is as an important design tool as the outputs of each design experience improve the process in the future. This aspect of the portfolio is perhaps its greatest strength, for it encourages the continuous improvement of the student design experience.

A primary goal of the USCGA institutional design portfolio was to demonstrate how an institution's design philosophy was put into practice. Locally, the USCGA Department of Engineering design philosophy recognizes that the graduates will be constantly involved in engineering design projects as designers and as supervisors of contracted design services.[7] Because design is an important component of the Coast Guard engineer's profession, it is imperative that the engineering graduates of the US CGA are proficient in this critical job element.

At the U. S. Coast Guard Academy, design education is viewed as a developmental process. Cadets can best develop their design skills if design education is included in each engineering course during every year of their education. Through this gradual exposure to design, students learn that to design, they must have a solid foundation in science, math and engineering, be creative, and be comfortable solving problems that don't have a single solution. During their four years, cadets realize that design is not accomplished by following an algorithm, but is rather an application of a methodology in response to the given problem statements and operational constraints.

The design experience at the USCGA has been broken down into four independent steps, with one step for each year. The design education goal of the first year is to enable each engineering student to answer the questions "What is design?" and "How do I design?". During this first year, design is portrayed as a process where the individual components of the problem must be studied and understood before moving to the next stage of the problem. The design education emphasis shifts during their second year to one that stresses that engineering problems are often ill-defined at the onset, and certainly open-ended with respect to feasible solutions. The goal of the second year is to boost student confidence in solving problems that have more than one valid answer.

Component design and system design are stressed during the third year. Here, within a particular course, a component of an engineering system may be designed. Student development progresses to the point where entire systems are designed by the cadets, though the chosen systems are applications that fall within the

confines of an individual course. The fourth year allows design to be experienced in its fullest content, as the capstone design experience requires the students to apply knowledge from a wide variety of engineering, math, science, social studies, and humanities courses. Facing many of the same forces they will see after graduation (i.e. challenging projects, limited time, lean budgets, motivated (at times) work force), the cadets are provided with a final chance to practice their profession before joining it upon graduation.

Institutional Design Portfolios - An Example

The USCGA design portfolio illustrates the four year developmental process of design education. The portfolio itself contains three sections: an introduction that presents the Department's design philosophy and defines the purpose of the portfolio, selected examples of student work, and an epilogue that examines if the goals were met. Student work examples were selected from each year of their undergraduate education to illustrate how the particular assignment addressed that year's design education goal. For consistency, the following outline was used to present each design exercise contained in the portfolio:

- a review of the US CGA design education goal for the subject year,
- a synopsis of the selected exercise,
- the student results, and
- the instructor's reflection on whether the results achieved the desired outcome of the exercise.

The USCGA design portfolio was assembled using existing materials from courses within the Mechanical Engineering major. Two examples were prepared from each academic year to illustrate the developmental nature of the design experience. For the first year experience, examples from an introduction to engineering course were used: a performance based student designed boat competition,[8] and a paper beam exercise. The text portion of the portfolio for the boat building exercise is included as an appendix to this paper. For these two exercises, the collected artifacts included photographs of the design, construction, and testing phases of each project, a spreadsheet designed and used by a winning team to augment their design evaluations, and the completed designs (a Styrofoam boat and a paper beam).

For the second year examples, an open ended problem from a statics course was used to show how the students addressed a problem having more than one solution. The artifacts for this example included the project assignment and one project report. The second example from this year documented independent research projects completed in a material science course. With the focus on building student confidence for solving open-ended problems, this example included a description of the independent research project and results of their work including student created and tested Kevlar/fiberglass samples, an iron casting, and its pattern. This portion of the display was augmented with photographs from off-site visits to a local smithing shop where the castings were poured. Of note for this example, the reflection section was completed by the laboratory technician (instead of the instructor) for the project, and his comments offered a fresh insight of the students' learning process.

To document the students' ability to complete component design, the examples from the junior year courses included a homework problem from a thermodynamics course and student designed experiments from an experimentation course. In the thermodynamics examples, three assignments and a complete student solution for each problem were presented to illustrate how students were able to design an automobile jack that operated on thermodynamic principles. The portfolio included artifacts from student experiments such as a student built experimental apparatus, a poster-board describing experimental results, and videos of students presenting their results.

The capstone experience in the senior year was used to select examples for the last section of the portfolio. Two projects were highlighted: a remotely operated vehicle and a solar powered boat. In each case, components from the design process were included as artifacts to show how the designs progressed from ideas on paper, to computer simulations, to prototypes, and finally to the final product. In addition to these artifacts, a presentation entitled "Leadership Through Engineering" which was delivered at a student paper competition and a photographic record of the iterative nature of design were included in the portfolio.

The completed portfolio consisted of one three ring binder and the assembled artifacts displayed in chronological order as experienced in the curriculum. Each artifact was labeled with a short description of the presented work, with a more thorough description detailed in the portfolio binder. The entire display was assembled on tables in a main hallway inside the engineering building.

Conclusions

The institutional design portfolio has been useful to quickly "tell the story" of design within the Mechanical Engineering curriculum. The display has helped portray information to accreditors, benefactors, parents, students, and faculty. The display and explanation of work allowed students to view their individual assignments as part of a comprehensive effort. The portfolio presented each assignment as one component of a careful plan to transform students into design engineers. Such awareness of this grand scheme helped students appreciate the value and purpose of their individual experiences.

The assembled portfolio was also useful as a reminder to faculty members that their individual courses fit into a larger game plan within the major. Although many were aware of their course's role in developing design skills, the displayed portfolio renewed interest in each faculty member's contribution to the process. Like students, sometimes faculty can tend to focus too much on present tasks (lecture, homework, project, course, etc.) and forget the global perspective (student development).

'As an assessment tool, the physical evidence of design work assembled as a portfolio allowed individuals the chance to easily assess the program's design content. Beyond that, the reflection section of each documented exercise forced the faculty members to review each exercise, document how the work met its goal, and identify improvements. Again, without the portfolio, such self critiques by the faculty often were not performed in their rush to complete for the "next" project (whether that be a course, experiment, or paper). B y assembling and displaying the portfolio, the program itself maintains a focus on design, and the design initiative is kept fresh as new exercises replace old examples in the portfolio.

Similar to teaching portfolio experiences, benefits of the institutional design portfolio result from the actual process of building the portfolio and from the completed portfolio. By assembling the design portfolio, the faculty must examine their teaching to extract examples of student work that validate the design education goals. Though only a few examples are included in the portfolio, each faculty member is invited to examine all their assignments to see how they achieve the broader goals of education. Once the portfolio is assembled, it acts as a dynamic document to explain past performance and promote ideas for future growth. The success of portfolios to document an institution's ability to integrate design across the curriculum makes the portfolio technique attractive as an assessment tool for other outcome based initiatives within education.

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Appendix:

A Sample from the USCGA Design Portfolio

An Example of Design Work From the Freshman Year

Year One design as a process - boat building

Year **Goal:** To introduce cadets to the engineering design process, and show them that they can conduct meaningful design work though only equipped with limited knowledge of engineering fundamentals.

Exercise Synopsis: Within the IED course, the fundamentals of Naval Architecture are first presented in the classroom. Following these lectures, the class moves into the lab, where each cadet designs a hull form (using a CAD package) that satisfies specified design constraints and maximizes a performance criteria. Specifically y, freeboard and stability are maximized, while weight and drag need to be minimized. Because these individual parameters are related, design tradeoffs must be made. After each cadet makes one pass through the design process, 4-person teams are assembled. Each group evaluates the 4 designs of their team, and uses a decision matrix to select one of the 4 hulls to be constructed. Using full size section, plan and profile views from the CAD package, the hulls are then created using foam. The performance criteria of each team's boat is then determined in a "competition environment" and a champion design is determined within each section. Oral and written reports on the design process are required.

Reflection *" I continue to enjoy this module of the class since for the first time the students get to walk through, and actually do, each step* of *the design process that we cover during the first four days of the course. They really get excited seeing how the information from the Naval Architecture lectures is applied and of course they are motivated to "build a better mousetrap. " Doing the individual designs and then having each team evaluate* and *select that design they want to build is a fun process to watch. After people get over having their design "rejected," the "team mentality" really kicks in as each team member starts to carve out "their team design. " This early team experience helps set the mood for the rest of the semester's team design exercises. Testing day is always a big event, and rightly so since the fruits of their labor are allowed to sink or swim. This one lab is a big draw to show the 4/c what the NAME major is all about.*

This one "lab" is a long process and we are always looking for a way to accelerate the exercise. Maybe that isn 'f *a* fair thing to think about *since the* event covers so *many areas:* the *design process, Naval Architecture, teamwork, CAD, experimentation, written and oral reports, . . .* We *demand much in a short period of time. The weakest link in the exercise is the CPU program we use to design the boats - MacSurf is a bit clunky and can cause un-needed aggravation for the cadets.* We *have made some improvements here and can continue to do so. Also, the text book coverage* of *the subject matter* for *this module* can *stand to be rewritten. "*

LCDR Patrick H. Knowles

Student Results:

Photos of a winning design.

The spread sheet used by the team to automate their calculations.

The fruits of the design effort - the created hull.