STRENGTHENING EXPERIENTIAL LEARNING IN DESIGN THROUGH COURSE DOCUMENTATION

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Abstract

The pedagogical approach to teaching mechanical and manufacturing engineering design at the University of Calgary has moved towards one that has students taking responsibility for both the progress of their design projects and their learning. This, in addition to the assignment of "real" projects means that a linear, regimented approach to teaching design has limited effectiveness. Therefore, a fundamental change in teaching and learning methods and materials has been implemented. The primary results of this change are the subject of this paper. In particular, the move from design textbooks to a documentary approach that fosters greater student independence and creativity through the development of instructor and student manuals is discussed. The goal of this approach is to ensure that novice designers learn to synthesize and adapt their knowledge and resources to the needs of the design project rather than try to force the project to conform to a prescriptive process. The use of design manuals has been implemented for senior and freshman design courses.

Keywords: Design Education, Course Manuals, Experiential Learning

1. Introduction

The development of design skills in undergraduate engineering students has taken on an expanded role in the curriculum of almost all North American universities and colleges. This renewed sense of importance for design has come after the realization that North American engineers have lost their preeminence as the world's leaders in innovation. However, those engaged in implementing design programs must battle the legacy of engineering science, where both the program and the faculty providing the instruction have long been entrenched in analysis at the expense of synthesis. In order to develop well-rounded designers, we must introduce both the skills of synthesis and the associated technical knowledge base into the engineering curriculum [1]. In fact, the analytical skills must be completely connected through the exploration of synthesis. Unfortunately, most instructors' natural tendency is to bring the concept of synthesis to the students using the traditional analytical framework. This approach results only in the appearance of design education, but the basic pedagogy, assumptions and methods are still those based on an analytical model.

Clearly, the introduction of design at all levels of traditional engineering programs requires a substantive change in both the content and pedagogy of instruction. These changes must enable a shift from the instructor being responsible for the students' learning to the students being made responsible for their own learning. Experiential learning was at one time the backbone of engineering education. From 1850 to 1950 engineering education was based on the use of apprenticeship, shop work, design laboratories, and analysis. However, around 1950 this changed. A return to the French school of engineering science and its heavy emphasis on mathematical formulation was adopted [2] and resulted in the Grinter Report [3]. The Grinter Report called for a strengthening of the math and science education for engineers. Grinter also recognized the necessity of maintaining a strong design component as

part of a new educational direction. Unfortunately, the primary changes that were undertaken involved the replacing design with more rigorous mathematics and physics.

This situation persisted until approximately 1995 when the American Accreditation Board for Engineering and Technology and the Canadian Engineering Accreditation Board started requiring engineering graduates to have worked on a team-based, open-ended, full-year design project [4]. These efforts have brought a significant focus back onto design education, yet many engineering schools still teach design using a prescriptive approach. The fundamental problem is that, though considerable importance is now given to design education, the long absence of design in the engineering curriculum has meant that little development of tools for advancing skills in synthesis has undertaken. This makes those delivering design courses are even more vulnerable to sliding back into an analytical approach.

The University of Calgary Department of Mechanical and Manufacturing Engineering has developed a experiential learning mode and teaching tools to foster the development of undergraduate engineering design skills. Many of the core components of the design program are echoed in the Boyer Commission Report [5]. The experiential learning concept is based on the participatory-inquiry method developed in the social sciences to develop research methods, questions and results that were relevant at both the academic level and the everyday real world, societal level. The method developed at the University of Calgary shares many characteristics and teaching tools with other engineering schools (real world, team oriented, and practical engineering design projects). However, the method differs in the techniques and tools developed to ensure that the learning and doing of design does not become a prescriptive process.

This paper will describe two tools developed at the Department of Mechanical and Manufacturing Engineering at the University of Calgary to act as a replacement of the course textbook. These tools are referred to as the Student Manual and the Instructor Manual, which provide coordinated course documentation.

2. Course Manuals

One of the keys to creating and maintaining a experiential environment is the structure and use of the course materials. These materials consist of an instructor/TA manual, a student manual and a design toolbox. In this paper, the student and instructor manuals will be discussed. A detailed description of the development and use of the design toolbox is available from Brusse-Gendre [6].

The function of the instructor manual is to make available a compendium of concepts, exercises, teaching and learning tools that avoid a sense of process but allow the instructor to respond to the unique needs of each class and even of each team while establishing an overall structure for running the design course. The function of the student manual is to provide a clear framework for deliverables as well as a user guide for accessing resource materials that link their project with the overall running of the course. Both manuals are used to keep the industry partners abreast of the academic needs of the project while providing ideas, tools and the flexibility to adapt to the real world needs of the client/project.

Use of the manuals is not enforced but coaches (graduate teaching assistants) are instructed to send the teams to the manual when problems arise rather than solving the problem for them. Some teams may never have a need for the manuals as they develop their own version of methodological concepts presented to them. Other teams, especially those with a difficult

project, internal problems or lacking in design experience and confidence make extensive use of the student manual in order to keep the difficulties from becoming overwhelming.

Therefore, the experiential nature of the course is reinforced by providing information to the design teams but allowing the students to determine what, when and how to use the information. The students then construct their own description of the progress of the design project.

2.1 Instructor Manual

The instructor/coach manual provides design information in self-contained modules that consist of an explanation of the concept, an indication of what has or has not worked in past encounters, potential class notes and overheads as well as reference materials and ideas for case studies or training exercises. The manual differs from a text in many ways. First, it is a living document in that it relies on continuous revision to keep the topics fresh and to benefit from critical review. While a textbook has been painstakingly refined until it contains a single, cohesive approach and style, the manual makes use of different approaches and styles of presentation that can be adapted to the unique needs of a class or a team.

Secondly, the textbook approach assumes that succeeding generations of students will all be the same (the empty vessel assumption) and will benefit in the same way from the same information. The manual approach allows the unique participation of each class to be exploited as new information is continually developed and the students gain a sense of their own worth as they participate in the generation of their own design knowledge.

Thirdly, the textbook approach gives the impression that one should proceed in an orderly manner through a design project because that is how one works through a textbook. The manual approach allows the instructor/coach to present information in any sequence deemed necessary without worrying about contradicting the text or upsetting the students by jumping around the text. Also, the course developers found that design textbooks tend to focus on slight variations of the prescriptive design process. The goal of the manual approach is to keep the students focused on the needs of their project rather than the “correct” design process. Since the students see only the parts of the manual presented in class, they cannot read ahead or second-guess the design coach. Therefore, the progress of their design education is influenced most strongly by the needs of the project rather than the dictates of the text. Some have referred to this as “just in time learning”. The value of this approach is that each design class and each design team develops its own story of design through constantly modifying design techniques. This creates a unique design narrative that holds together by virtue of its good reason and rationality rather than by attempting to conform to a pre-packaged process.

Through the experiential concept, the design class becomes a continuous learning process for the instructors, coaches and undergraduates. The role of the graduate students as design coaches is also beneficial to their development as teachers, as highlighted in the Boyer Commission Report [5]. The instructor manuals allow the graduate students to take on specific modules and present them to their own design teams and eventually to the entire class as their confidence grows [7]. The manual structure provides a quick overview of a particular design concept, potential problems and teaching tools. The information is therefore geared toward developing and enhancing teaching skills rather than simply providing textbook style, factual information.

2.2 Student Manual

The student manual is intended to provide each student, and design team, with documentary support for navigating their design project. The student manual does not provide course content (i.e. use of a Kano Model), but rather provides information on course deliverables, project management requirements and access to technical resources. The student manual is provided to every student with the expectation that they read it and become familiar with its contents.

The student manual is intended to provide the basics of an organizational structure for the student groups, within which each group can develop their unique project and explore a wide range of creative problem-solving skills. The student manual is organized so that a linear progression through the manual, as for a textbook, is avoided. Each team will access the various sections of the student manual at different times in the project. Whether or not a team uses a particular section of the manual is also highly dependant on the project itself. Again, the students will need to decide what information is important to their project and what can be disregarded. The instructors and design coaches can help guide the student to additional information.

The student manual also allows instructors to respond to student inquiries without directing their project. Instructor and coaches will send teams to the student manual to seek answers to organizational questions. The experiential nature of design is strengthened by this approach, where the students have resources available to them and must use them to find answers to their questions.

2.3 Examples of Course Manuals

Table 1 provides an outline of the contents of the instructor manual. Each section is a stand alone document. As well, no particular path is implied in the order of the sections. There are significant differences in the style of the sections which reflects a broad range of input as well as providing different techniques and points of view. Some sections take a more factual, academic approach while others provide a more free-wheeling flavour. Often both approaches will be found within one section. Therefore, the instructor or coach can use the approach that is most suitable for the occasion.

Table 1: Contents of Instructor Manual

0. Preface
1. Understanding the Team and its Situation
2. Projects
3. Project Management
4. Project Startup
5. Functionality
6. Design for X (DFX)
7. Targets & Specifications
8. Brainstorming, Creativity & Idea Generation
9. Proposals

10. The Cycle of Design
11. The Humanism of Design
12. Evaluation
13. Course Timetable
14. Second Term Information & Supplementary Material
15. Course Notes & Tools

Table 2 lists the contents of the section of the instructor manual that deals with targets and specifications. It begins with a critique of the previous year's experience followed by descriptions of the relevant issues that surround the topic. The intention is always to keep the information relevant to the students and their own design projects rather than presenting the more general and academic point of view. Finally, potential class notes, assignments and references are provided. Given the high level of student-coach-instructor interaction and the ever-changing day to day needs of the course, the manual format provides the instructor with the ability to pull the necessary information together very quickly. Therefore, the delivery of the material can always be geared to what is happening at the moment rather than relying on a set pattern of lectures that may or may not have relevance to the needs of the class.

Table 2: Contents of *Targets & Specifications* in Instructor Manual

7.1 CRITIQUE OF LAST YEAR
7.2 TERMINOLOGY
7.2.1 NEED
7.2.2 GOALS
7.2.3 OBJECTIVES
7.2.4 CONSTRAINTS
7.2.5 CRITERIA
7.2.6 FUNCTIONS
7.2.7 SPECIFICATIONS
7.2.7.1 Targets
7.2.7.2 Design Specifications
7.2.8 CUSTOMER REQUIREMENTS
7.2.9 DESIGN PARAMETERS
7.2.10 PERFORMANCE PARAMETERS
7.3 ORIGIN OF TARGETS & CONSTRAINTS
7.4 THE EVOLUTION OF SPECIFICATIONS
7.5 THE PDS & THE CUSTOMER

7.6 PDS ASSIGNMENT
7.7 REFERENCES
7.8 SUPPLEMENTARY INFORMATION

Table 3 lists the contents of the student manual. The focus is to provide a guide to the general activities that occur within the design course.

Table 3: Contents of Student Manual

Section I: Welcome to Engineering Design
Section II: Team Matters
Section III: Communication
Section IV: Project Documentation
Section V: Legal Matters
Section VI: Resources & Contacts
Section VII: Reference Materials
Section VIII: Toolbox

Table 4 provides a more detailed view of the contents of a section of the student manual covering Communication. Guidelines are provided for activities that occur in any properly managed design project. Meetings and documentation are the primary avenues of contact between the design team and the client, supervisor, coach and instructor. The modes and expected standards of communication through personal logbooks, project logbooks and meeting records are described.

Table 4: Contents of *Section III: Communication* from Student Manual

1. Instructor-Student Communications
2. Meetings
2.1 Team Meetings
2.2 Meetings with Project Sponsor
2.3 Meetings with Project Supervisor
2.4 With Instructor
2.5 Design Review Meetings
3. Correspondence
3.1 Long Distance Phone Calls
3.2 Sending/Receiving Faxes
3.3 “Official Correspondence”

3.4 Receiving Courier Packages
4. Poster Presentation
4.1 Guests
4.2 Awards
Design Meeting Evaluations
Progress Reports
Design Project Work Evaluation Form
Project Supervisor's Evaluation of Progress

Therefore, the general form, time frame and expected quality of communication are established leaving the students with the responsibility to decide what the content should be in the context of their particular project.

3. Outcomes

The current senior year design course has been run for five years. During the first three years of the course the instructor manual was developed by a core group of instructors and graduate students with the input of industry clients who brought design projects into the program. The instructor manual has recently been adapted into electronic format, as well as the traditional paper version. In the third year, the instructor manual was in a well developed state but the course was taught by the same group of instructors/coaches, so the instructor manual was not able to be tested as a stand alone resource. Over the past three years, an entirely new team of graduate student design coaches were involved in the senior design course. In that time the instructional staff also changed, with new people taking a greater role. Therefore, the instructor manual, in particular, was put to the test.

Additionally, the University of Calgary began a new full-year, open-ended design and communication course for all freshmen engineering students this year. This course engages almost 600 students in the development of creative problem-solving and written and graphical communication skills. While there are two primary instructors, there are also two part-time instructors and 14 design coaches. The first-year design and communication course is built on the foundations of the senior-year design course. As a result, the instructor and student manuals have been used to address the difficulties associated with instructing 600 students in design. The instructor manual allows people with a diverse background to present material to the students and maintain a common tread. Specifically, the coaches take a greater role in presenting material to the students, but do not need to spend a great deal of time developing their own material. The student manual sets out the minimum expectations of how project communication, including assignments and coach interactions, are to be conducted and what documentation is required. The first-year student manual is very similar to the fourth-year student manual, but addresses the rationale behind the course and assessment methods to a much greater extent.

In both design courses, the instructor manual works well as a guide for both running the classes and training the design coaches. This has been especially important in the first-year course. One of the practices established is regular, weekly meetings of the design coaches. During these meetings the coaches outline and discuss the problems that have arisen in class

or during design team meetings. Based on these meetings, the instructors determine which modules from the manual will be the most appropriate for the upcoming week. The coaches all have access to the manuals and can quickly be brought up to speed on any aspect of the course, either during the meeting or before the next class.

The student manual is intended to ensure that there is enough structure and uniformity in the deliverables to allow each team and each student to have a reasonably clear view of how they are progressing in the course. The student manual was originally introduced to the capstone design course two years ago. At that time the student manual was primarily available through the course website. That approach was not as effective as had been anticipated. This year the student manual was printed and distributed to each student. In the senior-year course, this approach to the student manual has alleviated some of the line-ups at the coaches' door for answers already available in the student manual. In the first-year course, however, the student manual is not significantly reducing the number of questions the coaches are fielding. This is most likely due to the uncertainty first year students feel when confronted with open-ended problems resulting in their need for confirmation from a real person. In any case, as with the instructor manual, the student manual is intended to provide structure without compromising the needs of the individual design project.

In general, the students are pleased with the greater amount of autonomy and creative license they have in running their design project. However, along with greater autonomy comes less clear guidelines for exactly what to do to get a good mark. This of course causes problems for students who are used to being told exactly what to do for the majority of their engineering education, especially for first-year students. If the results to date are an indication of the effectiveness of the instructional method, the results produced by the students has consistently demonstrated a high level of quality, pride, teamwork and client satisfaction. This is true for both the first-year and fourth-year courses.

4. Conclusions

The experiential learning approach to teaching and learning engineering design is difficult to maintain within the traditional methods of engineering education. The use of instructor and student manuals provides a strong base for establishing and maintaining what might be described as a fundamental shift in the culture of engineering education. The manual approach allows the instructional and student teams to maintain a high degree of flexibility and responsiveness to the needs of the ever-changing landscape of real world design projects.

5. References

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