2006-1138: SENIOR CAPSTONE: A CROSS-DISCIPLINARY, STUDENT-CENTERED APPROACH

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Senior capstone: A cross-disciplinary, student-centered approach

Abstract

Recently, the Engineering & Design department at Eastern Washington University examined and revised its Senior Capstone curriculum. The new curriculum enables the department's multiple disciplines to effectively collaborate in a problem-based, student-centered learning environment.

The Engineering & Design department offers eight undergraduate degrees. The diverse degrees include Bachelor of Science degrees in Mechanical Engineering Technology, Manufacturing Technology, Construction Technology, Design Technology, Computer Engineering Technology, Electronics Technology, and Electrical Engineering and a Bachelor of Arts in Visual Communication Design. The class and coursework are divided into two sections: production and promotion. This division of disciplines and tasks closely resembles industry practice. The production group models itself after a "manufacturing company" that designs and produces a marketable product and the promotion group takes on the roll of an "advertising agency" that promotes the product. This authentic experience gives students the opportunity to participate in the partnership of production and promotion, while gaining insight into their particular role in the relationship.

Thus far, after three quarters of the new Capstone curriculum, student work, comments, and course evaluations reflect that the collaborative, problem-based class provides a unique learning experience for the students. In addition, it is evident that the revised curriculum fosters the successful interaction of multiple disciplines resulting in new levels of synergy, creativity, and productivity. In the revised Capstone, disciplines join together to blend expertise and create an experience that is more comprehensive than any could provide alone.

Introduction

The goal of any university student when he or she graduates is to be able to find a job that they enjoy and can perform successfully. On the receiving end of the graduating student is a company that expects that their newly-hired graduate will have the necessary skills and background to perform the work that they have hired them to do. As education evolved from a professional trade-apprenticeship model to the institutionalized university model that we enjoy today, there have always been concerns that students may be learning the wrong thing. Specifically, there is a worry that students may become successful at solving homework problems (analysis) and yet not be successful at solving 'real-world' problems that they will face after graduation (design).[9] In response to this, many institutions developed a senior design course to provide students with an opportunity to work on more open-ended problems. This concept evolved and eventually became the capstone concept that we have today. A capstone course gives the students the opportunity to merge the different areas of knowledge learned in their major studies and use them together to

solve a problem. For the capstone to be successful the experience needs to resemble the problem solving that the students will experience once they graduate. This usually requires that the capstone problem have some of the following characteristics: the problems that the students address should adequately mimic those they will encounter in industry, the students should work together in teams to help advance their abilities to successfully function with coworkers like they would in industry, the students need to solve problems subject to certain constraints such as budgets and deadlines, and so on.[9] Many university programs have developed very successful capstone courses that address these issues but the Engineering & Design department at Eastern Washington University (EWU) has been able to take advantage of its unique make-up and add an additional step towards this goal of realism. The Engineering & Design department at EWU graduates students both in Bachelor of Science and Bachelor of Arts programs. Combining these degrees into a single capstone course creates a diverse student mix that adds additional authenticity to the experience and also creates an enhanced learning environment for the students. This mix of B.A. and B.S. degree seeking students allows us to create a cross-disciplinary, student centered approach to the capstone course.

Capstone details

The Engineering & Design department currently offers eight undergraduate degrees. These diverse degrees include Bachelor of Science degrees in Mechanical Engineering Technology, Manufacturing Technology, Construction Technology, Design Technology, Computer Engineering Technology, Electronics Technology, and Electrical Engineering and a Bachelor of Arts in Visual Communication Design. The department's capstone curriculum involves valuable interaction across disciplines but does not attempt to integrate very different skill sets. Instead, the students collaboratively draw on disciplinary strengths in a constructive teamwork approach to problem-based learning.

The class and coursework is divided into two sections: production and promotion. The production group (made up of the Mechanical Engineering Technology, Manufacturing Technology, Construction Technology, Design Technology, Computer Engineering Technology, Electronics Technology, and Electrical Engineering majors) models itself after a "manufacturing company" that designs and produces a marketable product. The promotion group (made up of the Bachelor of Arts in Visual Communication Design majors) takes on the roll of an "advertising agency" that promotes the product. This experience, modeled after industry practice, gives students the opportunity to participate in the partnership of production and promotion, while gaining insight into their particular role in the relationship. Research demonstrates that when students participate in applied, multidisciplinary learning experiences, they are engaged and value the educational and personal experience.[5]

The current Engineering & Design capstone course at EWU evolved from a couple of different courses. One of these courses was a senior project course where students in the varied Technology and Engineering disciplines would work either individually or in small groups on projects. It was already noted at that time that the desired learning outcomes were better addressed when the students from the various programs worked together. Another course that

was melded into the capstone course was a production laboratory course. In this course the students learned about production methods and had to design a product that they then produced in large quantities. This production class put the students together in a teamwork environment but the course was mainly directed towards the manufacturing majors. The capstone, as it exists today, was created by merging these two courses into a common course for all of the Engineering and Technology majors, and then marrying it to the senior project course for those students majoring in Visual Communication Design. Putting students together across educational disciplines presents a more realistic model of what students will encounter once they graduate and enter the workforce. The production group understands more clearly that it is not sufficient to merely design and successfully manufacture a product if it is not effectively promoted, and the promotion group experiences the challenges of working directly for what could be considered a real client, unlike the somewhat artificial relationship when the instructor functions as the client. Both groups learn that success for their individual group depends upon the successful interaction with the other.

How the cross-discipline capstone course functions

As previously stated, the capstone course consists of two major groups: a production group and a promotion group. The production group students are given the task of coming up with a particular item that they are going to manufacture. They make a prototype and must then manufacture the item over the course of three separate production runs carried out on three separate days. In each of those runs, the students must manufacture a lot of 5 items. Depending on the size and scope of the item there may be some variance to this number as determined by the instructor. After each production run, the students evaluate the strengths and weaknesses of their processes, as well as any changes that they feel they might need to make in the product itself. The students have substantial freedom in the selection of the item that they want to produce, but they must work within some typical constraints. First of all, there is a budget for the raw materials that comes from the lab fee that the students pay when they register for the course. Currently that fee is $35 per student, of which the students are allowed to spend $30 towards materials, and the remainder goes towards replenishing shop supplies that are used during the manufacturing process. There are two separate budgets, one for the production group and one for the promotion group. Another constraint is that the product must have an Eastern Washington University theme. Usually this requirement is met both by putting some form of the university logo on the item and by selecting an item that would appeal to a student, alumnus or employee. In addition to these constraints, there are other more obvious ones such as completing production within the timeline of the class and taking into consideration production equipment that is available in the building. Both groups are free to use outside facilities and vendors if they can do this within their budget and timeframe.

Objectives of the course

In creating this course several pedagogical prerequisites were determined to be necessary to facilitate student success in the cross-disciplinary classroom:

First, expectations must be clear. A major impediment to student success is a lack of understanding of exactly what they are being asked to do. Students must clearly understand learning objectives and they must be given opportunities for practice and feedback. The production group understands that they must ultimately create a marketable product and that they must be able to produce it in a mass production scenario. Everything else revolves around the very clear expectation that if there is no product then they have failed to meet the primary objective of the course. The promotion group very clearly understands that they must create packaging, promotional materials, corporate logos, and stationery that meet the needs of the production group. All promotional materials produced must be approved by the production group.

Second, the workload must be reasonable. If the scope of work is too broad, students will spend their time tackling quantity instead of quality. The production group's primary task is to manufacture the design they decide upon. Multiple production runs create an environment in which students can continually self-critique the scope of their product and make revisions to the design and process until it meets the criteria of a reasonable manufacturing time. Finally, what might be considered the ultimate incentive, each student in the group will receive one of the production items for his own personal use. The importance of thisfactor is evident as students strive to make a quality product that they would be excited to own. The promotion group's primary task is to promote the product. This involves planning and ideation, production and presentation. Ultimately, the promotion group must satisfy the needs of their client.

The third pedagogical prerequisite is that the students should have a choice in how the tasks will be accomplished. When students are involved in the planning and decision-making, and feel they have some autonomy over the process, they are more likely to make an effort and follow through on their investment of time and energy.[10] Often in a problem-solving type of course the students are given the problem by the instructor. They are allowed creativity in how they achieve a solution but the problem is identified for them. In the Engineering & Design capstone course student teams are given a goal, an expected outcome, and must identify the scope of the problem as the first step toward achieving their goal. The knowledge that effective organization, communication, planning, and collaboration will make their problem solving task easier is a strong motivating factor driving the problem identification process. According to Peterson, problem-based learning presents the students with a problem with no clear solution, or as Gallagher suggests, problem-based learning must be initiated with an ill-defined problem.[14,11] The open-ended nature of the problem puts students' problem-solving skills to good use. The teams must navigate the essential skills of collaboration, communication, planning, resource allocation, management, documentation, and presentation with very few specifics at the outset.

Learning Strategies of the course

In addition to pedagogical goals, several strategies underlie the capstone's approach to learning:

First, students must develop solutions to complex problems. The problem must have many parts that make up the final solution. Students who are presented with a problem that cannot be easily

resolved are challenged to draw on their critical thinking skills. According to Ali, critical thinking is necessary to challenge the student's "ability to evaluate and interpret information, make predictions, identify assumptions, and draw conclusions from the data."[1] Successful critical thinking is reliant upon knowledge the student already possesses. In this way, they can identify what they need to know to better understand and solve the problem.[1].It is sometimes difficult for students to let go of the idea that problems have a single solution and can be solved using memorized knowledge. The complex problem should be compared to the kinds of problems a student will encounter in both professional practice and research. As these types of problems often make students uncomfortable, there should be ample opportunity for practice/trial and error and feedback from peers and instructors.[10] Besides the open nature of the problem they are given, additional complexity that students need to address is related to the rapid change brought into the marketplace by technology. Markets and processes that were once local or regional can now find themselves expanding rapidly across the globe through the influence of the internet.[13] Students in the promotion group of the capstone are charged with developing a promotion campaign that involves the creation of a company website designed to market the product. Students in the production group get to see how their product is presented on a website and gain some understanding into the global nature of the current market.

The second strategy acknowledges that learning is a social process. Vygotsky's approach to education sees learning as a primarily social interaction, taking place within communities of practice in which meaning-making is a collective activity.[16, 8] The Capstone teams are communities of practice that provide intellectual and social support for the individual members of the group. The entire group is responsible for the actions or inactions of any one particular member. Successful participation in a student group can be compared to/described as responsible community membership. Students must be explicit in their communication, they must navigate each other's beliefs and knowledge, they must acknowledge each other's strengths and tolerate each other's weaknesses, in the attempt to solve problems and make progress. Vygotsky's premise that learning is an inherently social phenomenon driven by students' inquisitive needs necessitates equipping students with the appropriate tools to successfully participate in the collaborative learning environment. [16, 8]

After several quarters using the cross-disciplinary collaborative capstone model, several things have become a standard part of the teamwork process. First, peer evaluations are conducted twice during the quarter. Students are asked to give a letter grade as well as a reason for the grade assigned. This is a time to reflect on what each person is doing well, what could improve, and what should be done differently. Second, teams are asked to develop a communication plan at the beginning of the quarter. This plan details how, when, and how often members will communicate. It provides contact information and describes what will happen if a group member fails to communicate as expected. Third, the entire process is documented. From the initial group meeting to the final presentation, including time sheets, meeting notes, job assignments, etc., all individual and group activities are documented. And, finally, grades for process, product, presentation, and documentation are given as a group. This makes the actions of the group the predominant grade determinant. In a university environment peer evaluations are often the exception but we have found that this allows for individual student accountability.

The final learning strategy requires that the students takes responsibility for what is learned and how. The practice of "scaffolding" sets up the expectation that a student gradually takes increased responsibility for their own learning.[16] In the beginning, an instructor provides the necessary amount of support for peer interaction and group problem solving and the scaffolding, or level of support, is gradually decreased as groups become independent and self reliant in their actions and endeavors. The following items are characteristics of scaffolding: 1) it provides emphasis on the students' current difficulties and concerns, 2) it requires immediate availability of assistance, and 3) adequate amounts of explanation and guidance to match the learners' competence, and 4) it facilitates the students' awareness of their role in the learning process.[1, 8] In collaborative, problem-based learning, students are progressively given more responsibility for their own learning and become increasingly independent of the instructor.[1] In the scaffolding process, an instructor's role changes during the process. Felder sums up this idea as follows, "In the well known phrase from the cooperative learning literature, the instructor moves from being the "sage on the stage" to becoming the "guide on the side."[10]

The Capstone class begins with a presentation of the open-ended problem and class expectations by the instructor. During this period, the instructor shares observations of and knowledge from previous Capstone classes. This discussion helps students formulate ideas about best practices and helps them develop insight into what lies ahead. This brief presentation is followed by group work: establishing job assignments, a communication plan, a time line, etc. And finally, students establish a pattern of individual and group work in the context of realistic and productive problem-solving. This approach, according to Felder, "lead[s] to increased motivation to learn, greater retention of knowledge, deeper understanding, and more positive attitudes toward the subject being taught."[10] Students are engaged in critical thinking. This is not a new idea in pedagogical practice. In 1956, Benjamin Bloom developed a classification of levels of intellectual behavior important in learning. He identified six levels within the cognitive domain, from the simple recall or recognition of facts, at the lowest level, through increasingly more complex and conceptual levels. Students in the Capstone class, through the process of scaffolding, are guided through the levels of Bloom's Taxonomy: from knowledge to application to evaluation.[2]

Students understand from the beginning that what counts in the capstone course is their ability to create and produce a product. This ultimately places the success of the course in the students' hands. The capstone's student-centered learning environment presents students with questions, problems, and project assignments; students work in teams to define and answer the questions and clarify and solve the problems; and they are guided and supported by the instructor throughout the process of learning and sharing knowledge in the context of the project they are attempting to complete. Information is not transmitted to the students, rather it is constructed by them during the class experience. Ali asserts that in a passive learning environment, students have a declined concentration level after 15 minutes in the classroom.[1] The text *How People Learn* describes the benefits of active learning as: "the excitement of discovery enhances students' motivation to learn, and improved motivation leads to student success."[8, 3] While it is true that the students are working toward a grade that is assigned by the instructor, the day-to-

day success of their work depends on the interaction between the production and promotion group. They are not working for the instructor as much as they are working to meet the needs of the other student group. As the two groups work on a common goal they learn things about each other's abilities and challenges that furthers the educational discovery process.

Conclusions

A recent report, *Student Learning Outcome Initiatives*, a collaborative effort among 27 four-year public and private colleges and universities, funded by the Pew Charitable Trusts, provided a description of four characteristics of student-centered learning. The four items are: achieving clarity about learning outcomes; coordinating teaching and assessment to promote student learning; aligning structures and resources to serve student learning; and working continuously to improve the environment for learning.[7] The revision of the Engineering & Design department's capstone curriculum attempts to continually align itself with these characteristics. Highlights of how this is accomplished are as follows:

The capstone's iterative pedagogical process and real-world expectations have helped achieve clarity about learning outcomes. For example, student teams are expected to work within the framework of a corporate structure. Because the course involves both a production and a promotion group students learn how to work with/for a client. An increasing enrollment in the Visual Communication Design program created an interesting situation in a past quarter where there were three promotion groups with only one production group. This created the opportunity to put the students into a real-world situation where the production group had to work with three potential promotion firms and ultimately choose one to promote their product, and conversely, the three promotion firms had to compete with each other to try and best understand and meet the needs of their production team client. Many of the desired learning outcomes (i.e., higher academic achievement; improved critical thinking skills; enhanced comprehension of learned material, increased motivation to learn and achieve, greater ability to work in teams, and applicable job-related skills and knowledge[6]) are connected by the simple idea that the production group will have a product to show the promotion group and vice-a-versa. The students want to create something they will be proud to share with the other students.

The success of the Capstone curriculum depends upon regular and rigorous assessment and adapting course content as necessary. Faculty members are evaluated by students every quarter and peer reviews of the course are also conducted. Student and colleague comments are very valuable to improve teaching excellence.[1] Data gathered from these evaluations, student peer evaluations, course documentation, and projects are used to continually improve the course. Additionally, the Mechanical Engineering Technology and the Computer Engineering Technology majors at EWU are ABET accredited. Students in the capstone course are evaluated against the criteria established by this national accreditation board. Ultimately, as the students put to use what they have learned throughout their college experience, the results are evaluated by the entire faculty of the department. The student groups present their final product to the faculty in a formal presentation. The quality of the product and the presentation are evaluated alongside the effectiveness of the student teams to work and collaborate together.

The Engineering & Design department's recent move to a new, state-of-the-art building has helped align structures and resources to serve student learning. Larger student work areas and project area rooms have further enhanced the student experience. Also, the availability of instructors for help and clarification creates a supportive classroom environment that enhances academic achievement and intellectual development. It is important to explain to the students at the outset the teaching method that is used in the Capstone class and why the department has chosen to use it. Students will be working in teams to solve problems, a situation that is similar to what they will encounter in professional practice. Industry Advisory Board members and other related professionals are invited to watch and evaluate the students when they give their final presentations.

The capstone's curricular revision to better serve a multidisciplinary department is one example of continuous work to improve the environment for learning. The capstone class takes advantage of the multidisciplinary nature of the department and combines distinct experiences into a unified curriculum. Thus far, after initial efforts to create this combined capstone, student work, comments, and course evaluations reflect that the cross-disciplinary, student-centered class provides a unique learning experience for the students. In addition, it is evident that the revised curriculum fosters the successful interaction of multiple disciplines resulting in new levels of synergy, creativity, and productivity.

In all, evidence of the success of this approach can be seen in the many and varied products that the students have created[10]. Products as varied and as ambitious as high-performance, steerable snow sleds, to coat hangers numerically machined from aluminum billet in the shape of the EWU Eagle, to soothing, wall-mounted waterfalls have come from the work of these students. And each product had an ambitious marketing campaign with a website and product packaging to go with it. The success of the program is easily seen in the faces of the students at the end of the quarter as they proudly present their work.

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