Creating a New Engineering Technology Program Using the UbD Approach

Dr. Nancy K. Sundheim, St. Cloud State University

Nancy K. Sundheim is in the Environmental and Technological Studies Dept. where she developed and is now the director of the Manufacturing Engineering Technology program. Her primary interest area is at the intersection of manufacturing engineering and statistics involving lean, continuous improvement, and quality. She also does research in engineering education applying the principles of continuous improvement to her teaching.

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Abstract

Our small group learned and implemented the Understanding by Design (UbD) pedagogy in our courses. The principles of UbD were then adapted to the task of developing a new program in engineering technology. This approach gave direction and, in many cases, solid solutions to numerous hurdles, including curriculum development, selection of textbooks, the development of online labs, and novel approaches to linking program content to courses. Informal feedback from industry indicates students know what they need to know to be successful. The adaptation of the UbD pedagogy was crucial to the development of the program and we believe it could be used successfully by others.

Introduction

An interdisciplinary group of university faculty worked together in a Faculty Learning Community to study a pedagogy called Understanding by Design (UbD). We then implemented it in our university courses. Results were reported in [1].

Just as we were completing this study, I was tasked with developing a new program in Manufacturing Engineering Technology. The school had no engineering technology programs at that time so there was no guideline to follow. But this also meant there were no constraints. Where to start? It seemed natural to turn to the principles underlying the UbD approach and adapt it to use in the development of the program. It was helpful for many aspects of this task providing direction, and in several cases, solid solutions. It even assisted in justifying the program so that the approval process by the state went much quicker than anticipated.

Background

Wiggins and McTighe [2], [3] developed a pedagogy they call "Understanding by Design" (UbD). Briefly, UbD is comprised of three stages:
>   Stage 1: Identify Desired Results
>> The educator identifies the "enduring understandings" – those foundational concepts you want the students to retain even 2-3 years after they complete the course. What knowledge and skills (including critical thinking) should the students master? What is worthwhile for the students to know? What are the "big ideas" underlying the topic?
>   Stage 2: Determine Acceptable Evidence

The educator determines what constitutes acceptable evidence for indicating those results have been achieved. In this approach the assessment is planned *before* the classroom instruction is planned.

Stage 3: Plan Learning Experiences and Instruction
The educator now plans the learning experiences and instruction to meet the goals.

It is sometimes referred to as "backward design" because it promotes the development of a course or unit in reverse of the typical sequence. The method was extended and shown to effectively promote student learning in a variety of settings. See [4] – [12].

The details of the approach strive to move to the higher levels of Bloom's taxonomy, training the student to analyze and evaluate effectively rather than simply remembering and understanding content. Note that Stage 1 is the most critical. The very first place to start is in identifying those fundamental concepts, the big ideas, that must be understood. Another crucial detail in the UbD approach is to constantly loop back, to connect everything, to these enduring understandings.

Method

The principles of UbD were applied to many components of the program development, particularly those from Stage 1. Some involve a pretty straightforward application, some were more inspired.

Program Outcomes. The most obvious application was in developing the student learning outcomes for the program. After consultation with industry representatives, the fundamental characteristics required for success in the field were identified and encapsulated in the program outcomes. A quick search will show these outcomes are not much different from similar programs.

Curriculum Development. It can be a little daunting to develop program curriculum completely from scratch. Required content needs to be identified and then assigned to specific courses. Furthermore, technical fields today consist of too much content for a four-year program. What can be left out? It seemed the best place to start was in identifying the 'enduring understandings' as described in the UbD approach. What fundamental knowledge do students need to know to be successful in the field?

After attempting to develop a comprehensive list of the most critical concepts and skills, there was an 'Aha' moment. This has already been done. The Society of Manufacturing Engineers (SME) has published a Body of Knowledge for this field [13]. Why reinvent the wheel? The entire curriculum for the program was mapped to this Body of Knowledge. While not every topic

listed can be covered in the curriculum in great detail, almost all topics were mapped to a required course to ensure all were covered.

Program Approval. In an era of tight finances, there must be strong justification for the creation of a new program. Rationale was developed by first identifying the main reasons why this was important to the region. In other words, by looking for the "big ideas." Using the UbD approach, each point made was clearly linked to the big ideas. As noted above, the program outcomes and curriculum were also clear and cohesive because of the UbD thought process. The result was approval by the state several months before anticipated.

The development of the program was started in late August and all forms were submitted to the curriculum process by late December. All work was essentially done by one person who had a very full load on top of being tasked to develop the new program. The point is, using the UbD mindset made the process much more efficient.

Course Outcomes. Seven new courses and four significantly revised courses were introduced into the new program. See Table 1. Similar to the program outcomes, the UbD approach of identifying the enduring understandings was used for all courses to determine student learning outcomes.

Table 1. New and Revised Courses

Type	Course Topic
New	Metrology
New	Applied Mechanics
New	Thermodynamics
New	Materials
New	Design for Producibility
New	Continuous Improvement
New	Production Planning
Revised	Electronics Technology
Revised	Computer-Integrated Manufacturing
Revised	Mass Production
Revised	Manufacturing Management

In addition, the Capstone design course for other programs in the department was not appropriate for the new program so this was revised into a two-semester project, typically in collaboration with a local manufacturing facility. Expectations for the year-long project were developed using UbD.

Measurable Student Learning Outcomes. Stage 2 of the UbD approach is to develop careful assessment tools that measure what is important, not what is simply easy to measure. As new courses were developed, the techniques promoted by UbD were used to thoughtfully create the assessment tools that attempted to measure the big ideas. There is much literature on good assessment and good student learning outcomes so this is not detailed in this paper. It is simply noted that the outcomes were not just linked to the big ideas, they were also carefully crafted so that they were reasonably measurable.

Course Content. Once the overarching student learning outcomes were developed for a course, the actual content was determined. This was built upon the enduring understandings of the course, but also on another UbD principle: all topics in the course should in some way connect to one or more of the big ideas. Helping the student see such connections is vital to long-term retention.

For example, an existing course was to be revised to incorporate design for producibility. Some of the course content from before did not match the big ideas of the new course. See Table 2 for a partial list of the big ideas. The previous course had students create a 3d model using a rapid prototyping machine. This is nice experience for students but does not directly connect to the big ideas for this course. Although important, adjusting design elements for ergonomic factors and safety also did not directly relate to the producibility of a product. So these content areas were moved to other courses. The previous course had students create and assemble appropriate advertisement brochures for product promotion and write manuals for the products. These topics did not connect at all to any of the big ideas and were eliminated. In the end, so much content was changed that the old course was simply eliminated and a new one developed.

Table 2. Some Big Ideas for Design for Producibility

Some Big Ideas
• Level of producibility significantly affects cost
• Standardization produces new designs faster
• Standardization makes manufacture quicker
• Evaluation for producibility must be done from the beginning of the design process
• Today's market requires flexibility in design

Another example is an existing course, Electronics Technology, that is used in the new program. Three different individuals who had taught the course in the past had vastly different ideas on course content. As the new program was being developed there was disagreement on the content for this course. It was fairly easily resolved by focusing again on the enduring understandings for this course and the program overall. Every topic needed to connect to these big ideas.

Textbook Selection. It can be difficult to find textbooks with the appropriate perspective for Engineering Technology. Most are either at the technician level that does not have enough depth, or at the engineering level with high level mathematics. For some courses, searching for a textbook on publisher's websites or on the web in general did not produce anything acceptable. Then the thought occurred to search for the enduring understandings instead of course title.

This was the case for the Mass Production course. Searching for "mass production" did not produce appropriate textbooks. This course is specifically for high volume production, but searches returned books for production systems in general. That content is in a different course. Again, the enduring understandings came to the rescue. Search phrases were based on the big ideas instead. Examples include "jigs and fixtures," and "mass customization." This resulted in a set of 3 books (not technically textbooks) for a total of about $75 that together cover the contents of the course.

For the course on Electronics Technology the textbooks tended to be completely hands-on electronics appropriate for a technician or hobbyist level or very mathematical at an engineering level. Using the enduring understandings as search phrases, i.e. "simple circuits," "generators," and "circuit diagram," rather than "electronics technology," eventually resulted in the development of a customized textbook produced by a major publishing company.

It should also be noted that one of the characteristics of the UbD pedagogy is a break from dependence on a textbook. The authors of the approach suggest that instructors should not be constrained by the textbook. This attitude was adopted when searching for textbooks and in many cases resulted in the use of books rather than specific "*text*books."

Course Resources. Two courses produced no appropriate books even using the big ideas as search phrases. However, UbD principles were used to create detailed resources for the students on the topics of the course (these have evolved into booklets for the courses). For one course the booklet is supplemented by a collection of readings found using enduring understandings as search phrases. Although not ideal, this appears to be the best solution at this time.

Equipment Purchases/Donations. The new program has required some additional equipment. For example, there is a desire to develop a strong metrology component to the program since there are a number of high precision manufacturing companies in the region. Industry is quite willing to donate some equipment and we have written grants as well. Even so, there is a limit to how much we can request. To generate a wish list of equipment, the fundamental principles the students really need to master were first identified (those enduring understandings yet again). This made it easy to prioritize the wish list.

For example, a company has offered additional equipment for our metrology lab. Looking at the big ideas of metrology, along with the equipment already owned, it became clear the priority items were an optical comparator and a profilometer, rather than an increased variety of sensors or an x-ray machine.

At-home Labs. The trend is to move to online programs. Yet engineering technology is traditionally a very hands-on program, especially in manufacturing. Two courses were selected to explore creating labs that could be completed at home with inexpensive, readily available materials. How does one teach automatic assembly using nuts, bolts, paper clips, and butter dishes? It can be done! But to do so required serious thought about the concepts being explored in each lab. See Figure 1 for one example. The big ideas had to be communicated clearly without the use of the typical lab equipment.

Figure 1. Example of Automatic Assembly At-Home Lab

Simulate a vibratory bowl feeder   Repeat with more open part
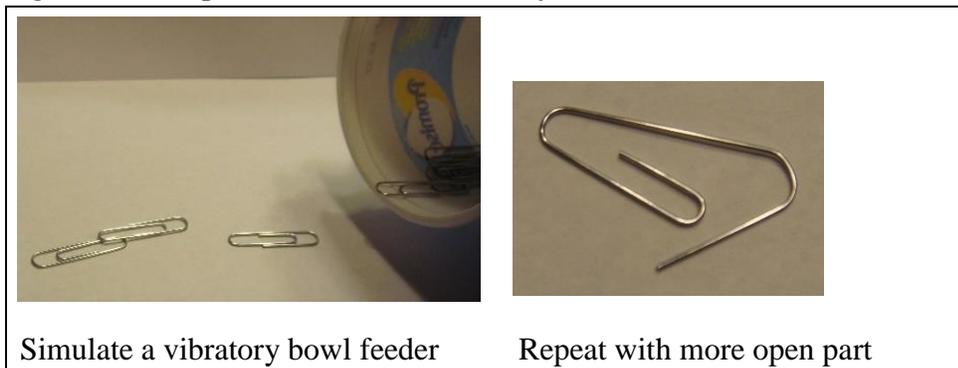
It also requires Stage 2 of the UbD approach, creating useful assessment that ensures the student understands the big ideas being explored. Figure 2 illustrates an assessment to determine if the student discovered that parts that tangle easily do not make good candidates for automatic assembly (thus Part A in Figure 2 is the correct choice).

Figure 2. Assessment for Task in Figure 1

Which is the better design for automatic assembly?

Part A   Part B
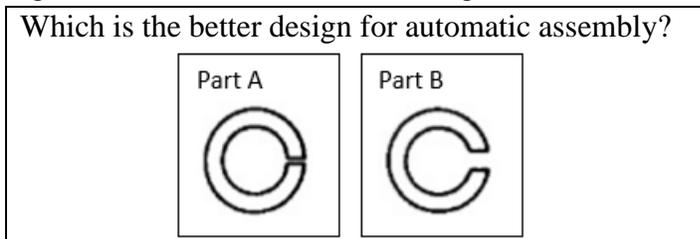
The result was no difference in performance between the students completing the labs on campus with traditional equipment and those completing the labs at home. The details of this experiment were reported in [14].

Lean Manufacturing Content. Perhaps the most inspired application of the UbD philosophy concerns lean manufacturing. This set of manufacturing principles introduced by Toyota in the 1970's [15] has become very important to the industry. Graduates of this program need to be well versed in it.

After thoughtful consideration, it was decided there would be no course on "lean." A major UbD principle is that all topics should somehow connect to the big ideas. Lean manufacturing is certainly a fundamental idea and all topics in the program should in some way connect to it. So rather than a course on lean, it was decided lean would be taught in *every* course.

This was not haphazardly implemented. Every element of lean, from simple tools to the major ideas, were listed and then assigned to specific courses. The major ideas were assigned to more than one course. Since most of lean is interrelated (you cannot talk about just-in-time inventory control without talking about continuous flow and pull systems) this means even those elements not specifically assigned would often be alluded to in a course.

The result is that by graduation students know lean very well. They have explored the 5S tool from numerous perspectives including management, production flow, and safety. They have used the PDCA (Plan Do Check Act) tool in continuous improvement, in production control, in mass production, and more. The industry advisory board supported the idea. It seems to be effective as the first two graduates secured jobs immediately specifically because they were so adept with lean. One student reported that on at least three occasions a job/internship interviewer expressed shock at how well she knew lean.

Assessment

It is difficult to truly assess the effectiveness of this approach for developing a new program since the first graduates of the program graduated less than a month prior to the writing of this paper. However, informal feedback indicates students know what they need to know to be successful. This feedback has come from course projects completed with local companies, summer internship supervisors, and job interviews. In several cases the prospective employer was surprised at how well the students were prepared.

Furthermore, the industry advisory board for the program has been very supportive of the program content. They provided valuable input that shaped the list of "enduring understandings" and continue to strongly support the program. After several had the opportunity to work with the students on a course project or with their senior capstone project, the board has even suggested we do not need accreditation. They have seen first-hand the quality of the program. (Nonetheless we are preparing to seek ABET accreditation.)

We hope to gather more formal feedback after we have more graduates and the first graduates have had some time in the profession. Feedback from the alumni and their supervisors will help determine how effectively the program meets regional needs. We have just developed a more focused survey to gather such feedback from internship supervisors as well.

But another measure of success is evidenced by the relatively short timeline for development and the quick approval by the state.

Conclusion

The UbD approach was an indispensable tool for developing many components of a new program and could be used successfully by others. The result is a program focused on what is truly essential. The field of engineering is enormous. It is not possible to teach everything in four years. Staying focused on the truly essential is truly necessary today.

Despite the lack of much formal proof (yet), UbD will continue to be used as the program continues to develop. And, yes, it was even used to develop this paper.

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