AC 2012-5593: A MANUFACTURING CURRICULUM USING A STUDENT-DRIVEN PEDAGOGY OF INTEGRATED, REINFORCED, ACTIVE LEARNING (SPIRAL) APPROACH

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A Manufacturing Curriculum using a Student-driven Pedagogy of Integrated, Reinforced, Active Learning (SPIRAL) Approach

Abstract

Engineering is continuously evolving and producing increasingly complex systems. The complexity of these systems requires a wider breadth of material to be covered, which makes it more difficult to provide high quality education. Also, while student numbers are vastly increasing, faculty, staff, and resources are dwindling. The Department of Mechanical Engineering at the University of Utah has been focusing on a new curriculum that covers multiple engineering subjects, design techniques, methodologies, and knowledge of skills in professional practice. This is known as the Student-driven Pedagogy of Integrated, Reinforced, Active Learning (SPIRAL) approach. This paper describes teaching manufacturing using the SPIRAL approach and focuses on the first year of the curriculum. This approach will give students more manufacturing experience leading to quicker and better conceptualized designs. To help counter the problem of shrinking teaching resources, with respect to the size of the engineering student body, the manufacturing SPIRAL approach will use carefully designed supplemental materials including a series of teaching videos followed by certification exams based on these videos. The students must pass both a written and in-person practical exam to use university manufacturing equipment. The approach will also allow faculty and staff to better monitor students to ensure safe and efficient working environments. The implementation will undergo initial evaluation this spring through assessment by a small group of users (both students and faculty). Any necessary changes will be made prior to the planned implementation for all freshman during the upcoming 2012-13 academic year.
1 Introduction

Manufacturing knowledge is one of the critical elements of mechanical engineering design, helping to bring designs from concept to prototype in an engineering setting. Our objective is to distribute a single semester of manufacturing curriculum into every year of an undergraduate’s education. This works in parallel with the prior developed SPIRAL curriculum [1–5]. Our goal is to give students a more complete manufacturing knowledge with the idea that they will continuously be receiving hands-on manufacturing experience throughout their education opposed to a single semester.

In addition to the preceding single-semester class, the SPIRAL manufacturing curriculum (SPIRAL-MC) will continue throughout their entire undergraduate career (from Freshman to Senior year). The basic layout of the SPRIAL-MC is portrayed in Figure 1. This figure metaphorically presents progression of the new manufacturing curriculum on a spiral path. The spiral progression illustrates that as students proceed with their undergraduate education, they will be continually be learning new things and revising old topics, all of which are within a similar educational structure. Freshman and sophomores will complete three rings of the spiral. For freshman, this includes manufacturing lab orientation, lab safety, and hand tools. Sophomores will re-visit safety and cover the mill and lathe. The vast majority of the manufacturing curriculum will be covered in the first two years; therefore, the junior, senior, and senior+ years will focus primarily on safety and re-certification. This paper will focus on the freshman level curriculum, which will be tested in small groups this spring prior to implementation for all freshman in Fall 2012.

There are two basic variations of each spiral ring:

1. Educational video followed by a written exam

2. Educational video followed by a written exam, hands-on experience, and an oral exam

As further illustrated by Figure 1, students will follow the first variation if the subject matter is either of a simpler nature or if the material is review. They will follow the second variation if subject matter is completely new in order to ensure that they have practical training and experience. In addition, safety will be highly emphasized every step of the way throughout this process. While providing the students with a higher quality education, this process will also make more efficient use of our already limited resources and help ensure safety though frequent re-certification. The remainder of this paper will discuss all the components need to implement the SPIRAL-MC.

Much study, particularly in the past ten years, has already been devoted toward learning from remote locations [6–24] and multiple, or hybrid, instruction techniques [25–28, 28–42]. New remote learning techniques include development of advanced teleconferencing techniques [6, 8, 11], handheld learning devices [9], and remote hands-on laboratories [10, 13, 14, 16, 17], to name a few. Hybrid learning has distinct advantages for students with increased flexibility of their studies [30, 37] while getting the same results as with face-to-face learning [31].

2 Educational Videos

For the freshman year, we will be using multiple sources of educational videos: those produced in-house to elaborate on practices specific to the University of Utah (U of U), and those published by the Massachusetts Institute of Technology (MIT) to elaborate on techniques general to educational machine shops.
2.1 In-House Videos

Videos produced in-house will cover orientation of shops at the university, and shop safety. Although shop safety is also covered in the MIT videos, we feel safety should be highly emphasized as well as specific to our practices at the U of U. We will create two in-house videos covering:

1. Safety and Shop Orientation. This video will covers the general safety rules of all U of U ME machine shops, and tours of all the shops. Some safety rules include: requiring the presence of a shop supervisor, wearing safety glasses, keeping loose hair and clothing away from the machines, and keeping a clean workspace. The shop tour first shows a map illustrating the locations of all ME shops, and second takes a physical tour of all the shops highlighting locations of machinery, small tools, first aid and safety supplies, as well the shop supervisor’s office.

2. Hand Tools. This video gives basic tours and description of all the major hand tools available in all of the shops. This video describes tool geometry, tool operation, and safety. Tools included on the list of hand tools are: pliers, vise grips, files, vices, hand drills, taps, tap handles, hammers, screwdrivers, wrenches, and scribers.
2.2 MIT Videos

The MIT videos used for certification come from the following: http://techtv.mit.edu/collections/ehs-videos/videos. Freshmen will watch videos 1-3; and sophomores will watch videos 4-10. In addition, freshman will be responsible for watching the supplemental videos on safety and lab tours described above. Because this paper focuses on the freshman curriculum, we will go into depth explaining only videos 1-3 at this time:

1. *Fundamental machine shop practices.* This video covers basics in machine shop operation, laying out parts in preparation for manufacturing, and introduces some basic operations using the drill press, belt sander, and grinder. It goes into depth discussing the drill press by covering how to locate and drill holes and also how to tap holes.

2. *Advanced drilling operations, the bandsaw, and the drill press vice.* This video continues basic drilling operations and goes into specifics about drilling various materials as well as covering limitations of the drill press. The video then covers bandsaw operation and discusses using the correct feeds and speeds depending on the cutting medium. Finally, it covers correct use and the importance of using a drill press vice.

3. *Machine shop courtesy and finishing techniques.* As far as shop courtesy is concerned, this video focuses primarily on clean-up practices and the importance of keeping a clean and clear workspace. For finishing techniques, it covers proper use of the belt sander, buffer, and de-burring tools.

3 Certification

3.1 Written Exams Based on Videos

After students watch educational videos, the next step in the certification process will be to take a written exam on the covered material. The written exam is straightforward and will consist of ten or twenty multiple choice questions. The questions will be randomly selected each time the student takes an exam from a greater list of twenty to forty multiple choice questions. The exam will be given on-line using the university’s Canvas Learning System (CLS), described in the following sections, so as not to occupy valuable instruction time. To pass the exam, students must get at least 90% of the questions correct. If need be, students can take the exam as many times as necessary with the stipulation that they must allow at least 24 hours between exam attempts. The purpose for the 24 hour gap is to help ensure academic honesty and help make sure that students are learning the material rather than just learning how to take the test. CLS will ensure that students wait at least 24 hours between exam attempts and will also update an instructor list to indicate the certification level of each student.

3.2 Hands-On Supervised Experience, Practical Exams, and Certification

After passing a written exam, students will attend a short instructional clinic and practical exam limited to six students per clinic. Each session will be about two hours long and will consist of the
instructor/examiner going through safety and procedures of each machine followed by hands-on experience and exam of each student. Each student will have three allowed attempts to complete the task; in most cases, the tasks asked of the students will be simple in nature such that it will be easy for the students to complete the task in one attempt. The instructor/examiner will be a thoroughly trained instructor or teaching assistant. There will be at least one practical exam per week which will increase depending on the level of demand. Students must sign up for the practical exam at least 24 hours in advance using the CLS. After students pass the practical exam, their name will be updated on the CLS, clearing them for use of certified machines according to the practical exam they took.

3.3 Spiral Ring Certification

The idea behind Spiral Ring Certification is that students will have to pass sub-certifications to an overall certification. Freshman level certification implies that students must obtain the lab orientation, safety, and hand tools sub-certifications. Sophomore level certification implies that students must obtain the safety review, mill, and lathe sub-certifications. Since junior, senior, and senior+ levels have only one ring of certification, this implies that the sub-certification and the certification are the same at that level.

3.4 Re-certification (Junior, Senior, and Senior+)

Beyond freshman and sophomore level certifications, students must continually be re-certified to use the machine shop equipment. Besides requiring students to have received freshman and sophomore certifications, this will require students to re-watch the certification educational videos and take a re-certification exam using the CLS. The procedure for taking the re-certification exam is the same as for taking the certification exams with the exception that re-certification exams will be sixty questions to account for the vast amount of material covered throughout the certification process. Certification automatically expires at the beginning of the junior, senior, and senior+ years requiring these students to take the re-certification exam. Once the exam is passed with a score of 90% or above, the certification is valid until the beginning of the next academic year.

3.5 Transfer Student Certification

Another great advantage of this spiral evaluation process is that it will be easier to ensure that transfer students have the same manufacturing knowledge and skills as students who have been at the university since freshman year. All transfer students will be required to pass freshman and sophomore level written and oral exams to be certified.

4 Integration into the Canvas Learning System (CLS) and Course Evaluations

Online Course Management Software (OCMS) has proved to enhance courses by providing online handouts, assignments, evaluation materials (e.g., quizzes), and most importantly enhancing com-
munication between instructors and students. Use of the OCMS will alleviate the intense need for human resources while keeping the education quality high.

Of the available OCMS options available, we are electing to use the Canvas Learning System (CLS) due to it’s high customizability and they ability to perform all of our education and certification goals as described above in Sections 2 and 3. We will be implementing a test run on the system on a selection of five undergraduate students, five graduate students, and five faculty members to determine the effectiveness of this manufacturing curriculum. This pool of individuals does not include any developing investigators of SPIRAL-MC curriculum (although the input from the investigators will be considered when evaluating the SPIRAL-MC).

5 Assessment Plan

Beyond publication of this paper, development of this curriculum will aggressively be moving forward. At a minimum, freshman level course materials will be developed and evaluated by our 15 reviewers between the dates of January 16th - June 1st, 2012. Video Materials will be completed by the end of March. After completion of videos, freshman level written and oral exams will be composed in the following two weeks. During this time, we will gather 15 evaluators, and test their impressions of the SPIRAL-MC. By the end of April, when evaluators have seen all the available SPIRAL-MC materials, they will be asked to answer a questionnaire (shown in the next section) to make necessary improvements. After receiving feedback from evaluators, we will make necessary changes and then re-evaluate the course materials by the beginning of June ideally with the same evaluators and questionnaire.

6 Course Evaluation Questionnaire

This questionnaire will evaluate the course by focusing on University of Utah standard course evaluation questions:

- The course objectives were clearly stated
- The course objectives were met
- The course content was well organized
- The course materials were helpful in meeting course objectives
- Assignments and exams reflected what was covered in the course
- I learned a great deal in this course
- Overall, this was an effective course.

In addition, the questionnaire will also ask the standard ABET accreditation questions:

- This course helped me gain an understanding of and ability to: apply mathematical, scientific, and engineering knowledge to solve materials related problems.
• This course helped me gain an understanding of and ability to: Design a system, component or process to meet a desired need.

• This course helped me gain an understanding of and ability to: Function on multi-disciplinary or cross-functional teams.

• This course helped me gain an understanding of and ability to: Identify, formulate and solve engineering problems.

• This course helped me gain an understanding of and ability to: understand the professional and ethical responsibility of engineering.

• This course helped me gain an understanding of and ability to: recognize the need for, and an ability to engage in, life-long learning.

• This course helped me gain an understanding of and ability to: develop a knowledge of contemporary issues.

• This course helped me gain an understanding of and ability to: use techniques, skills, and modern engineering tools necessary for engineering practice.

• This course helped me gain an understanding of and ability to: Use modern computer-based design tools for solving engineering problems.

Each question will ask for a given numerical response each values on a scale from 1 to 6 (where Strongly Disagree has a value of 1, Disagree has a value of 2, Mildly Disagree has a value of 3, Mildly Agree has a value of 4, Agree has a value of 5, and Strongly Agree has a value of 6). To get more personal feedback, an additional question will ask assessors to List two things about the course content, materials or design that were effective for your learning, or make constructive suggestions for improvement. All of these questions were taken directly from the University of Utah’s Campus Information System.

7 Conclusion

The proposed SPIRAL-MC curriculum will help effectively integrate important manufacturing concepts while relieving valuable human resources. This will help reserve human resources for the most important manufacturing instructional needs, thereby increasing the quality of education. It will also help implement important shop safety, control, and cleanliness by ensuring that only qualified individuals are allowed to use machine shop equipment. Understanding manufacturing is an integral part of mechanical engineering design, and improving manufacturing curriculum will produce high quality engineers.

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