Linking Classroom Learning with Real World Practice: Strategies Used in Teaching Machining Processes

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Abstract

Like many manufacturing process courses, there are several inherent challenges in teaching machining processes. This paper will use the design and development of Machining Processes course to demonstrate how Greenfield Coalition has responded to some of the challenges in collaboration with Michigan State University. This paper illustrates a number of instructional strategies and samples of authentic activities. It presents how real world projects are built in the learning sessions of a machining processes course and how web-based media are used in a machining course in order to address the challenges faced by engineering programs.

Introduction

The globalization of manufacturing engineering requires engineering students to be more knowledgeable in the field and more creative in problem-solving. This has raised the bar for how much students have to learn in school and how quickly they can transfer what they have learned in the real world setting [7]. Through conversations with some faculty who are currently teaching machining courses, it is known that there are several challenges in teaching this course, especially on campuses where students do not necessarily have access to machines to operate. One challenge is that despite the fact that students can grasp and retain knowledge about machining processes, they do not seem to be able to apply what was learned in class to meaningful and real-world applications. The apparent difficulty of transferring their learning is partially due to the gap between classroom learning and real-world practice. Very often, students received theoretical instruction on how the machines work, but do not have an opportunity to practice what they learned or solving real-world problems using what they learned. It becomes crucial to deal with such challenge because the real world requires students to be ready to execute their knowledge and skills at the new job. A related challenge is that students may know theoretically how a single machining process works, but have difficulty producing a part that requires the student to balance and incorporate multiple and different machining operations into their work processes. Students are presented with too many machining or manufacturing processes and operations without receiving guidance on how the operations are used together to produce parts. In their future jobs, they are likely to deal with the operation sequence for a given
part. When the design changes, the operation sequence has to be rearranged and redesigned and new operations must be added between appropriate operations. This, in some cases, may be trivial. However, the interactions among the operations can be quite complex. The students who have not planned out the complete sequence of operations are not ready to deal with the process planning under the changes in design, machine and materials. One way to address such challenges is to have students work through the real world problems while they are learning the machining operations. In Greenfield’s authentic learning environment, students are more prepared to deal with the practical problems in their future jobs. This paper will detail how real world projects are built in typical learning sessions in Machining Processes course at Greenfield Coalition (GC) located at Focus: HOPE, Detroit, MI.

One other challenge is that it is very difficult to describe the phenomenon behind the machining processes because the physics underlying the machining process is not explicitly described with sufficient rigorous mathematical models [5]. In addition, the complex interaction of various variables makes teaching machining processes even more challenging. The materials that are used to explain the effect of certain parameters come from experienced engineers and technicians who have had many years of experience in machining. More scientific models are yet to be perfected. Fully aware of these challenges, Greenfield Coalition has experimented using various technologies to enhance teaching and learning machining processes. The web-based media exploited in machining processes include: stream video, simulation, animation, and 3-D graphics. This paper will demonstrate some of the examples of the effective use of media to teach a machining course.

Greenfield Coalition course structure

Greenfield Coalition courses are structured into modules, sessions and activities. Each course is consisted of a number of modules (in some cases, the smaller course may just have one module). Multiple sessions make up a module. A session focuses on a topic, a case or a problem to solve. Each session consists of a set of learner centered activities. In the case of machining processes courses, Machining Processes I (introductory course) contains one module. This module has six sessions. Machining Processes II contains two modules. Each module has four sessions.

Machining Processes courses, like most courses in GC, instructor plays a role of facilitator. What makes GC courses different from traditional classroom-based learning is GC courses integrates three types of learning: classroom instructor facilitated learning, self-directed web-based learning, and experiential learning. A session may have activities of any of these three components. All the decriptions of the learning activities and resources are provided via Greenfield Course Learning System – a database driven web server.

Real world applications in Machining Processes course

Redesigning machining processes course is one of the efforts Greenfield Coalition has made to establish the direct link between what students learn in school with their current and future life in the real world. Using real world applications in classroom will make learning more meaningful and engaging, and increase the retention of what they learn and establish the foundation for a becoming a life-long problem-solver [6].
In each of the many learning sessions in Machining Processes course, students are provided with projects collected from industry. These projects were selected because they provide typical examples of real world problems faced by industries and also because they provide an opportunity for students to solve real subject specific problems. These projects are used as containers which offer context from which the key concepts behind machining processes are introduced. Below is an example of how a typical learning session is structured. The objective for this session, Turning Process, is to develop a process plan for a given part that requires turning operations. At the beginning of the learning session, students are presented with a project they will be working on throughout the session, i.e. producing a process plan for making pulleys (see Figure 1). Students are presented with the raw cast, the final part, and the blueprint for the final part. Students are also given what is required in the deliverables (see Figure 1).

![Figure 1: Turning process project description](image)

Once the students are clear about what they are expected to produce at the end of a learning session, the instructors will use the remaining activities to walk them through developing the process plan. In this case, students need to consider the following areas in order to develop a process plan:

- Application of turning operation
- Work material properties
- Cutting tool geometry
- Cutting tool materials
- Cutting parameters and cutting tool selection
- Holding a workpiece on a lathe

Each of the above bulleted areas is represented by an activity which contains information about the concept to be learned, resources and tools students may need, discussion questions, and/or what the students need to do or produce in this activity (see figure 2).
After students navigate through activity 2–7 (areas to consider in developing process plan) (see Figure 2), they can use the outcome from each activity to compile a report on the process plan and then present it in class. Sharing solutions will help students learn from each other and be aware of alternative solutions to solve the problems.

One other example of real world application is making press tube. This project was taken from the tier-1 supplier Focus: HOPE at Detroit, MI. The context of this project is that Tool Room at Focus: HOPE received a request from the shop floor to produce a manual insertion tool to hold a bent tube. Producing this part requires a sequence of different types of operations. This project simulates a common scenario in engineering field: when design changes, the sequence of the operations will change correspondingly. In this case study, students are first asked to work in group to produce a trial part, which has simpler geometry (Figure 3 (a) and (b)). To help students find the solution to produce the part, instructors pose some questions as hint and guidance.

![Image of a press tube](image-url)
Building on the trial part, students, still working in the same group, are asked to produce the process plan for producing the final manual press tube (Figure 4 (a) and (b)). In the process of developing process plan, students are provided with web links to the different types of machining processes. At conclusion of the project, students will post their deliverables to class discussion board. They will be asked to critique each other’s process plan. Sharing findings and critiquing each other help students to learn from each other and to reflect what they have learned.

To incorporate real world cases and projects in the classroom learning, there are a few guidelines to follow. These guidelines were developed based on the synthesis of literature on problem-based learning [1] [3], adult learning [4], and collaborative learning [2]. The problems/cases used in Machining Processes course and their designs include the following characteristics:

- The problems must be complex enough, but manageable for students. One needs to consider the level of difficulty of the problem, the time it takes to solve the problem, and the scope of the problem.
- The problem should have practical value. If it is only an intellectual exercise, students will be less motivated to solve the problem and will have difficulty transferring their learning into real situations.
- Instructors need to provide students with guidance as needed. In the activities demonstrated in this paper, specific action verbs are used to guide students through the appropriate steps in order to apply the concepts and techniques just presented. Instructors, instead of lecturing, play the role of facilitator by posing questions, modeling problem-solving as needed, and providing tools and resources.
- Instructors should encourage students to work collaboratively to solve the problem as much as possible. Encouraging collaboration during the learning stage will prepare the students to an effective team members and problem-solver, assist students to build and leverage their own expertise during problem solving and, at the least, to seek out feedback and verification from others.

Instructors can employ a variety of techniques to facilitate active participation in the problem-solving process. In a typical session of the GC machining course, students will first be involved in an instructor-facilitated discussion related to the real world project or problem. After students make connections with what to be learned, they are given resources, tools, and guidance to solve the problem. These resources and tools take the form of interactive web activities, instructor presentations, self-study materials, class or group discussions or brainstorming. At the end, students share their learning through class presentation or posting their findings/solutions onto a
discussion board. To help learning transfer to different situations, the instructor holds a debriefing session to help student summarize and reflect what they have learned. This can also be achieved through online discussion board, where instructors pose reflective questions for students to respond. This structure of a learning session reinforces students’ active role of controlling their own learning and helping instructors to facilitate instead of lecture.

Appropriate use of media

As mentioned above, instructors struggle with describing the machining processes to students who have never worked in a machine shop which comprise a majority of GC’s students. Additionally, some concepts are very difficult to describe because of the interaction and abstract nature of the various variables and factors in the machining process. To address these difficulties, Greenfield has exploited various ways of using web-based media. These include streaming video, simulations, animations, 3D graphics, and interactive online tool.

Web-based media examples

One of the steps in developing a machining operation process plan is to determine the parameters of cutting conditions and how these parameters (i.e. cutting speed, feed, and depth of cut) are related to chip formation. The best way to present the relationship is to simulate how these variables interact together (see the prototype below. This simulation is currently being programmed). In such a simulation (see Figure 5), as students manipulate the various parameters, different shapes and sizes of the chips are generated based on the varying parameter values. This visual manipulative interactive allow students to make better sense of abstract concepts, to learn how the parameters interact to produce the final product, and makes it easier to grasp the abstract concepts for future use.

![Figure 5: Turning simulation prototype](image)

One other example of effective use of media is to simulate the relationship between temperature change as result of changing cutting speed, rake angle of cutting tool, and work materials (Figure 6, (a) and (b)).
These are two simulation results with same material (aluminum), depth of cut (1.00mm), feed rate (0.01mm), and rake angle (−5°), but different cutting speed (one is V=100m/min (see figure 6 (a)), the other is V=2000m/min (see figure 6 (b)). With these simulations, students can easily see the temperature change as a result of changing the cutting speed. Therefore, the simulation enables the students to learn how these variables interact as would an expert would have done through actual experience.

This course also uses a number of streaming video and animations to illustrate the complex machining operations. For those students who have not had hands-on experience on machining, this video on turning operation (Figure 7) and the animation on horizontal milling machine (Figure 8) provide a much richer description than a verbal explanation how the machine works.

On-line interactive tool

One innovative way of using web technology is to model the problem-solving process through online interactive simulation. Below is the storyboard of an online interactive parameter selector: Turning Tool Parameter Selection – introduction (This simulation is being tested) (see figure 9 (a)). This introduction section provides students with the functions of the tool and how to use it.

You are a manufacturing engineer and you are asked to develop a process plan for machining the part given below. The project requires producing 1000 units per month. Your process plan should include the time for machining one part, total time required to make 1000 units and the material scraped.
This exercise will help you understand how to develop a process plan, see the effect of material on the machining parameter and calculate the time required for machining. This machining time and the scrap removed will enable the manufacturing engineer to calculate the time, manpower and money required to produce the part.

*Each time you select a parameter, based on the recommendations criteria, the tool will guide you make the right decision. Any time you make a mistake in selection, the tool will provide you with reasons and the guideline for a better selection.*

**Inputs for a Given Part:**

Outer Diameter = [ ] (inches)  Inner Diameter = [ ] (inches)

Length of cut = [ ] (inches)  Material = [ ] (inches)

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**Workpiece Material**

<table>
<thead>
<tr>
<th>Cutting Tool</th>
<th>Cutting Speed</th>
<th>Feed Rate</th>
<th>Depth of Cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughing</td>
<td>Finishing</td>
<td>Roughing</td>
<td>Finishing</td>
</tr>
<tr>
<td>Max</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
</tr>
</tbody>
</table>

- Cutting tool #1
- Cutting tool #2
- Cutting tool #3

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*Figure 9 (a): Design protocol for turning tool parameter selector*

The first step of the Turning Tool Parameter Selection is to select a particular cutting tool for a given work material. Students select the corresponding workpiece materials from the drop-down list and the cutting tool from the list given. Based on their selections, the value range of cutting speed, feed rate, and depth of cut will dynamically change and is displayed in a table similar to the one below (see figure 9 (b)).

*Figure 9 (b): Design protocol for turning tool parameter selector*

The second step of Turning Tool Parameter Selection is to define rough cut and finish cut. Students select a value from the drop down list. The interactive tool checks the decisions they made and provides corresponding feedback. Students can either proceed to the next step or re-enter the value (see figure 9 (c)).

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**Define the number of rough cuts**

1

**Enter Rough Depth of Cut from Step#1**

**Define the number of finish cuts**

1

**Enter Finish Depth of Cut from Step#1**
After students make their selections in step 1 and the correct decision in step 2, these values feed into step 3, which are used to produce the following output (see figure 9 (d) and (e)):

<table>
<thead>
<tr>
<th>Selected Rough Depth of Cut</th>
<th>Selected Rough Cutting Speed (RPM)</th>
<th>Selected Rough Feed Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selected Finish Depth of Cut</td>
<td>Selected Finish Cutting Speed (RPM)</td>
<td>Selected Finished Feed Rate</td>
</tr>
</tbody>
</table>

After students complete the process of selecting the appropriate parameters and examining the output values of those parameters, they will be asked such stretch questions as:

- What are the effects of depth of cut on MRP?
- How do you increase MRP during rough cut?
- How would you increase or decrease machining time? Or what are the parameters on which machining time is dependent upon?
- What is the effect of cutting speed and material diameter has on MRP?

This online interactive tool will not only guide student through developing the process plan, but also play a role of expert checking students’ understanding. The advantage of providing such tool is apparent: students can work on their own and still get help when instructors are not present.

The above examples demonstrate how Greenfield Coalition utilizes various web-enhanced technologies to assist teaching and learning and how these technologies can be integrated in an active learning environment.

Conclusion

The Machining Processes course is one of several courses in Greenfield Coalition that have blurred the boundary between real world practice and classroom learning. By focusing on real-
world applications, learning becomes meaningful and real. While students actively participate in solving real world problems, they are also able to make full use of the capabilities of web-enhanced technologies to make their learning more efficient and engaging.

Using web-based media will not only combat the challenges mentioned above, but also makes it easier for other engineering programs to access and share courses and resources created by Greenfield Coalition. Free access to Greenfield’s courses and resources is extremely beneficial to those engineering programs that are not equipped with adequate facilities to offer students hands-on experience.

For more information about Greenfield Coalition courses, visit the website at http://www.greenfield-coalition.org.

Bibliography


Biographies

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