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Course development and assessment methods for Computer Aided Manufacturing Course

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Abstract

This paper presents a detailed approach to the design, development, and student evaluation of a Computer-Aided Manufacturing (CAM) course, a core requirement in the Mechanical Engineering Technology and Manufacturing Engineering Technology programs at Farmingdale State College. The course uses MasterCAM, a commercial software, as the primary tool, and focuses on fundamental CAD modeling and toolpath programming. It not only covers essential software commands but also integrates best practices in machining into CNC programing, providing students with a comprehensive understanding of the CNC field. The course is designed to include hands-on experience, ensuring that students gain practical skills.

The paper discusses how the course materials bridge the gap between academic learning and the skills required by the industry, aligning the curriculum with typical industry settings. Various assessment methods, such as self-assessments and project-based evaluations, are outlined for evaluating student learning. Due to limited class time, executing each student's CNC program on a CNC machine may not be feasible; therefore, the paper also explores how setup sheets and simulations can be used to assess student work effectively.

Both the course curriculum and assessment methods can be adaptable for in-person and asynchronous online formats, ensuring accessibility and effectiveness across different learning environments. These methods lay the groundwork for future research to analyze the effectiveness of the curriculum and assessment strategies in achieving the desired learning outcomes.

Introduction

Computer Aided Manufacturing (CAM) and Computer Numerical Control (CNC) machining are the well-known manufacturing methods for producing high-quality precision products, particular in the areas where components can only be manufactured through material removal processes. These methods have become essential for most manufacturers in the field. The industry increasingly relies on skilled individuals to operate advanced CAM software and precision CNC machines for production. Educational institutions are tasked with preparing students to meet these challenges by equipping them with both the theoretical knowledge and practical skills required to thrive in high-tech manufacturing environments [1,2]. In addition, institutions must balance hands-on learning with the integration of cutting-edge technology to ensure students are prepared for the complexities of modern manufacturing processes [3]. Unfortunately, Learning Computer-Aided Manufacturing (CAM) is not just about understanding how to use the CAM software. It requires students to have a background in Computer Aided Design (CAD), enabling them to create accurate CAD models for toolpath programming. A strong machining background is also essential to comprehend the toolpath command applications.

At Farmingdale State College, Computer-Aided Manufacturing (MET 351) is a required course in the Mechanical and Manufacturing Engineering Technology programs. It requires the knowledge of 2D CAD, technical drawings, manual machining, and CNC machining. These topics are taught through three different courses which are the prerequisite courses for the CAM course and serve as the foundation for preparing students for this highly skilled field. Students take these prerequisite courses in their first year. However, due to the program's structure, students learn other engineering topics like Materials Science and Statics in their second year. They do not encounter CAM until their junior year. Since there is a one-year gap between the related topics, the CAM course needs to be designed with proper guidance on the prerequisite materials throughout the learning process.

This paper presents the development and assessment methods of the CAM course at Farmingdale State College. The course teaches students how to use MasterCAM, one of the leading software tools in the industry, for CAD modeling and toolpath programming. The course also incorporates best practices in machining, which are crucial for toolpath programming. Given the wide range of topics covered, the assessment methods for these topics vary. The course also addresses the flexibility needed to offer both in-person and asynchronous online formats, a necessity in today's dynamic educational landscape [4,5]. This adaptability ensures that the course remains accessible while maintaining a high standard of education. Finally, this paper lays the foundation for future research to evaluate the effectiveness of the course in bridging the gap between academic learning and industry expectations as well as the effectiveness of in-person and asynchronous online formats.

CAM Course Development

To enhance student learning in the CAM course, the content is divided into several critical areas. First, students are introduced to the basics of CAM, including file types and applications. Next, they learn how to use MasterCAM to create CAD models. This helps students become familiar with the user interface while also refreshing their CAD techniques and blueprint reading skills learned during their first year. Once students are comfortable with CAD and the MasterCAM interface, they learn the 2D toolpath commands, which they can apply to the CAD models they create. They also review and verify their toolpath programs using the MasterCAM simulator which simulates the toolpath motion. Toolpath simulation in CAM can greatly improve student learn experience [6]. The topic of setup sheets is introduced to further strengthen students' understanding of machining principles. Students has the option of generating setup sheets using the setup sheet generator or sketching it using any drafting tool. In either case, special criteria such as work holding method, stock orientation, and part zero need to be specified. Finally, students learn basic 3D geometry construction methods and 3D toolpath programming for areas that cannot be machined using typical 2D toolpath commands. This course structure ensures that students are familiar with each step of the programming process before moving on to more advanced topics.

Table 1 shows the course topics and Student Learning Outcomes for the CAM course. The course is 15 weeks long, with 13 weeks dedicated to delivering course material and the remaining 2 weeks used for exams. This structure applies to both online and in-person settings.

Table 1: Course Topics and Student Learning Outcomes

Topic	Student Learning Outcomes
Introduction to computer aided manufacturing	Students will be able to explain the basic principles of computer aided manufacturing.
2D geometry construction	Students will be able to use the wireframe and transform commands, such as lines and circles to create 2D geometries in MasterCAM.
2D Toolpaths commands and Toolpath verifications	Students will be able to define stock size for CAD models and apply different types of 2D toolpaths on the models. Students will be able to review and verify toolpaths.
CNC setup sheets	Students will be able to create CNC setup sheets that document required cutting tools and initial machine setup.
3D geometry construction	Students will be able to create basic 3D surfaces and create 3D solid.
3D toolpaths	Students will be able to apply basic roughing toolpaths and finishing toolpaths

Class structure for In-Class and Online Settings

The course materials and assessment methods can be applied to both in-class and online settings. There are 10 homework assignments, 10 self-assessed assignments, one mid-term exam, one final exam, and one term project. For self-assessed assignments, students have unlimited submissions, allowing them to self-assess their work. Homework submissions, however, are limited. Table 2 shows a comparison of the grading policies for the in-class and online courses. The weight varies between instructors. The main difference between the two settings is that live lectures are presented in class, while prerecorded videos are used in the online setting. Additionally, the online format requires students to participate in online discussions, where they are encouraged to share challenges and suggestions to help one another complete assignments and better understand the course material. This requirement fosters engagement and collaboration among students in the online setting.

Table 2. A Comparison of In-Class and Online Course grading policy

In-Class setting		Online setting	
Course components	**Assessment**	**Course components**	**Assessment**
10 Homework Assignments	30%	10 Homework Assignments	30%
10 Self-assessed Assignments	15%	10 Self-assessed Assignments	15%
1 Mid-Term Exam	20%	1 Mid-Term Exam	17.5%
1 Final Exam	20%	1 Final Exam	17.5%
1 Term project	15%	1 Term project	15%
		10 Discussions	5%
Total	100%	Total	100%

Assessment methods

CAM toolpath programming requires knowledge of CAD modeling and an understanding of machining principles to apply toolpath commands correctly. Accordingly, students are evaluated based on their CAD modeling skills, CAM programming technique, and knowledge of manufacturing methods.

1) Assessment of CAD modeling

Accurate CAD models are crucial for CAM programming. The location of a CAD model in the CAD space is also important, as discrepancies can lead to significant errors in machining operations. It is a good practice to align the part zero in the CAD models with the zeros used by CNC machines. The alignment ensures MasterCAM generates toolpaths and G-codes that correspond with the machine's reference points.

To assess CAD modeling skills, students are asked to create CAD models and demonstrate their ability to produce accurate drawings in MasterCAM. Figure 1 shows an example exercise where students evaluate the area of the shaped geometry and the Moment of Inertia about X and Y axes based on the indicated origin. Students can use MasterCAM to compute these values. This assessment method quantifies the accuracy of student drawings and ensures they understand the importance of the origin in their CAD models. This method is very accurate and is also utilized in CAD certification programs such as SOLIDWORKS CAD Design Associate (CSWA) [7]. Instructors also can overlay student drawings with the correct geometry to find geometrical errors manually. However, students cannot self-assess their drawings using this method.

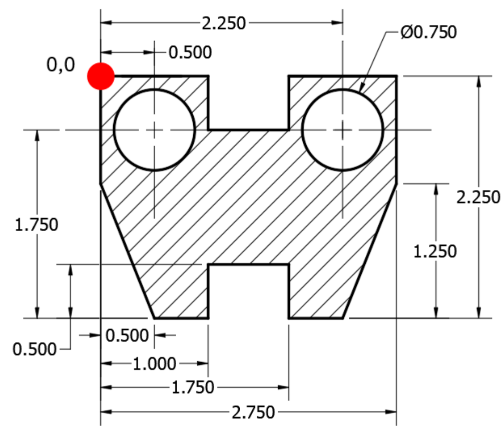

Figure 1: An example of CAD modeling exercise.

2) Assessment of CAM Toolpath Programming and Knowledge of Machining Methods

The CAM assignments and term project are designed to simulate real world CNC projects, allowing students to apply their skills from start to finish. These tasks ensure students not only learn how to use the software but also understand the principle of machining. Unlike CAD assessments, CAM assessments are qualitative. Important elements of a CAM program can be grouped into two main categories: program parameters and machining methods.

Program parameters include cutting parameters like spindle speed and feed rate, and cut parameters like depth of cut and stepover, which influence the quality of the machined part and machining time. Students need to define them properly for high quality surface finish. Unfortunately, these parameters are different between toolpath commands and can vary slight to obtain the same result. Therefore, instructors will need to review these parameters individually to assess student learn. A rubric as shown in Table 3 is used to assess student learning in CAM.

Machining methods refer to the procedures required to machine the part, including proper command selection and application, as well as correct procedures. Toolpath Simulator and setup sheets are used to assess student learning in this area. Toolpath Simulator simulates the toolpath motion, allowing instructors to evaluate the overall machining process. Setup sheets document essential information, such as work-holding methods, part zero locations, and cutting tool information. These parameters are critical for CNC setup machinists, as they are not included in G-code programs. Inaccuracies in the part zero or the holding method can result in accidents during machining.

Figure 2 shows a setup sheet example created using PowerPoint. This type of setup sheet does not require precise drawings, and work-holding method along with other important details can be quickly indicated on the setup sheet. Although MasterCAM can automatically generate setup sheets, students will need to create 3D models of both the fixtures and parts. This can be challenging for beginners, especially when they need to complete both CAD modeling and CAM programming within the limited time of an exam.

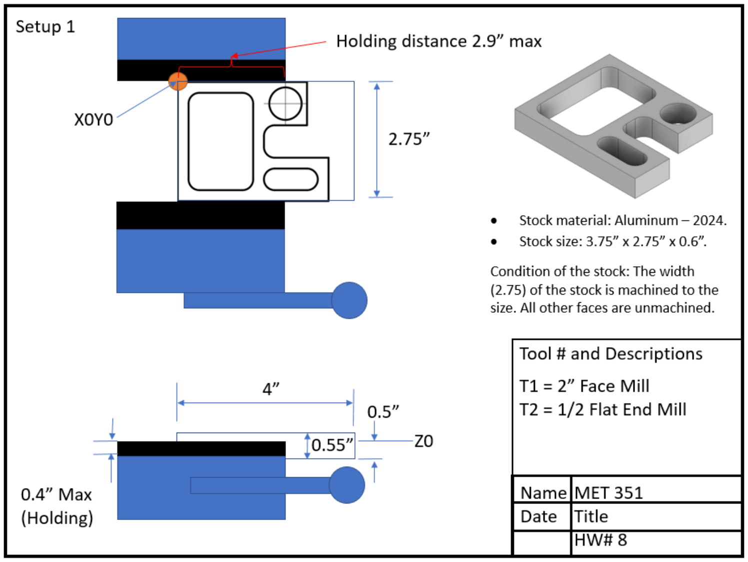

Figure 2: An example of setup sheet

By assessing setup sheets and simulations, instructors can determine whether students can relate their MasterCAM programs to actual setups, such matching XYZ zeros in the program to those on the machine without requiring actual machine runs. This method effectively assesses student understanding while minimizing the time and need of CNC machines. Unfortunately, the evaluation methods mentioned above cannot be easily quantified and need to be assessed independently. The rubric, as shown in Table 3 is also used to assess student learning in machining methods.

Table 3: CAM program assessment rubric

	Satisfied	Unsatisfied

Program parameters	10	7.5	5	2.5	0
Cutting parameters	Are the parameters suitable for the program?				
Cut parameters	Are the parameters suitable for the program?				
Machining methods					
Cut verifications	Evaluation of machining methods; Can the program machine the part properly? Will the method cause accidents?				
Setup sheets	Include basic information; Does the information match the program? Will the setup cause accidents?				

Conclusion and Future work

This paper highlights the structure and assessment methods of the CAM course. The course blends CAD modeling, toolpath programming, and machining best practices, equipping students with the skills needed for real-world applications of CAM technology and preparing them to meet the demands of modern manufacturing industries. Various assessment methods are discussed, offering instructors multiple ways to evaluate student learning in the course.

Future research will focus on evaluating the effectiveness of the CAM course in bridging the gap between academic learning and industry demands. This will include conducting longitudinal studies to track student success in industry roles and collecting feedback from both students and employers. Additionally, comparisons between the in-person and asynchronous online formats can be explored to determine their impact on student learning outcomes and engagement.

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