Evaluating the Effectiveness of Changes to Hands-On Training in an Academic Machine Shop

6th International Symposium on Academic Makerspaces

ISAM 2022 Poster No.: 110

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INTRODUCTION

The Grainger Engineering Design and Innovation Labs within the College of Engineering at the University of Wisconsin-Madison comprise several distinct lab spaces, including a machine shop [1], makerspace [2], automotive shop, and composites lab [3]. The machine shop, called the Technical Education and Manufacturing (TEAM) Lab, is managed by 6 full-time and 25 student staff members. Every year, TEAM Lab provides over 1100 engineering students, faculty, and staff formal training in the use of fabrication equipment including drill presses, bandsaws, wood saws, milling machines (manual and CNC), lathes (manual and CNC), and welders (MIG, TIG) through a combination of videos, online quizzes, and hands-on small group instruction. Passing a training assessment for a particular type of equipment is required before a user may return to fabricate parts.

This poster will examine the changes made to the formal mill and lathe training during the pandemic and the challenges faced in assessing the effectiveness of these changes. Among other components described in more detail below, the pre-pandemic formal mill and lathe training included a live, in-person demonstration. This demonstration was replaced with a multi-camera video replica, and the effects of this change on the training assessment pass rate were measured. The pass rate improved from 74% before the change to 87% after the change. This figure, though encouraging, leads to questions about what the pass rate is actually measuring and which other metrics may better assess student outcomes.

PRE-PANDEMIC FORMAL MILL AND LATHE TRAINING

Every year, approximately 700 students, faculty, and staff complete the formal mill and lathe training, which gives them access to the machine shop. Often, this is a student's first experience in a machine shop environment. A flipped lab model like those described in [4-6] is used wherein students review online content before coming into the shop for in-person activities. Pre-pandemic, the steps to complete the training were as follows:

1. *Self-Paced Content:* Students read online content, took several quizzes, and watched two short videos demonstrating test part fabrication on the mill and lathe.

Fig. 1 Manual mill with a computer used by students completing the formal mill and lathe training

2. *Live Demonstration:* Students attended a two-hour-long, 8-person maximum demonstration of the test part fabrication on the mill and lathe.
3. *Individual Fabrication:* Students fabricated the test part on the mill and lathe by consulting a technical drawing for reference. Students could also watch the demonstration videos on demand using the 24-inch computer monitors mounted to each machine (Fig. 1).
4. *Assessment:* Shop staff verified that the part met the specifications and logged the attempt as a pass or no-pass. Students whose parts did not pass inspection could re-attempt fabrication up to two more times before needing to restart at Step 1.

PANDEMIC-NECESSITATED TRAINING MODIFICATIONS

In response to conditions that made small-group training sessions impossible, the live demonstration was removed (Step 2) and the short videos replaced (Step 1) with two new videos demonstrating the test part fabrication on the lathe [7] and mill [8]. The new videos attempt to replicate the in-person experience by detailing every step of the fabrication process and showing each step from multiple angles at once. No other modifications were made to the training. The video development project began in August 2020, and the final videos were released to students in January 2022.

Table 1: Formal Mill and Lathe Training Pass Rate

	Total Passing	Total Attempts	% Passing
Pre-Pandemic	1061	1440	74%
Post-Video Deployment	248	285	87%

RESULTS

The formal mill and lathe training was unchanged between 2013 and February 2020, during which time the overall pass rate was 74%. Six months after deploying the new training in January 2022, the overall pass rate stood at 87%, representing an 18% improvement (Table 1). Anecdotally, students enjoyed being able to follow along step by step with the video as they fabricated their test parts, and staff enjoyed a decrease in questions answered pre-emptively by the video.

DISCUSSION

WHAT DOES (OR DOESN'T) THE PASS RATE INDICATE?

The data show a clear improvement in students' ability to fabricate the test part using the new video, but what can be learned from this? The pass rate seems to measure a student's ability to follow directions to complete a specific task with new tools. It follows, then, that improving the quality and accessibility of those directions would improve the pass rate, which is indeed observed. Students who pass the current training may be masking a lack of fundamental understanding of new concepts by compensating with excellent attention to the detailed directions.

Additionally, there may be lost benefits to the in-person demonstration that are not reflected in the pass rate. Without more complete metrics, it is impossible to assess whether removing the in-person demonstration improves student learning outcomes.

DOES THE PASS RATE REFLECT THE PURPOSE OF THE TRAINING?

The purpose of the training is not to improve students' direction-following abilities. Rather, the purpose is (or should be) to expand students' design and fabrication competencies, giving them the confidence and skills needed to design and fabricate new parts. The pass rate fails to measure changes in either students' confidence or their ability to apply their new knowledge and skills to a new task.

SHOULD SUCCESS METRICS CHANGE FOR DIFFERENT STUDENT GROUPS?

Two groups of students complete the formal mill and lathe training: those fulfilling a course or program requirement with no intention of returning to the shop; and those learning skills required for future fabrication projects (who may also be fulfilling a course or program requirement). What does success mean for each group, and is a student's ability to fabricate the test piece a good measurement of that success on its own? How might a student's contextualization of the new tools and processes they have learned and their ability to apply this understanding to new challenges be measured? The training is currently used to gate access to the mills and lathes, but it may be that additional, more focused training would be more appropriate for the group of students seeking advanced fabrication knowledge.

FUTURE WORK

Development and deployment of the new video for the formal mill and lathe training took seventeen months. This was exacerbated by several factors unique to campus life during a pandemic, but even under more normal circumstances, a project of this magnitude represents an enormous investment of time for the staff. Given that high cost, any future changes should be guided by meaningful metrics that are tied directly to desired student outcomes and institutional learning goals.

If the purpose of the formal mill and lathe training is to expand students' design and fabrication competencies, the training should have meaningful, measurable effects on students in both the short- and long-term. Short-term assessments would provide immediate feedback about the student experience in the shop, and long-term assessments would inform better integration into the overall engineering curriculum to satisfy institutional learning goals and ABET outcomes.

SHORT-TERM ASSESSMENTS

Student satisfaction shows how closely students' expectations are aligned with their learning experience [9]. Measuring student satisfaction with the training would invite students to reflect on their training and help identify student expectations. Workplace thriving theory [10] as interpreted in an engineering design context [11] is a framework for evaluating how well students adapt to a new environment. A machine shop environment with unfamiliar sights, sounds, and smells can be intimidating and disorienting, and this framework could assist in both understanding and improving the student experience.

LONG-TERM ASSESSMENTS

Engineering classroom belonging is a good predictor of future grade performance [12]; how this principle applies to students' success in the training and whether the training itself could affect students' engineering classroom belonging could be examined. Longer-term assessments could examine how well the training prepared students to apply the tools to new contexts by measuring the number of students returning to the shop post-training or the number of senior-level design projects making use of the tools.

Any future work must account for the growing engineering student population [13] and the limits that puts on the type of training it is possible to provide. Training in an academic machine shop tends to exist along a spectrum: on one end, an apprentice model where students are taught individually according to their needs and interests; on the other end, a model accommodating larger student populations which relies on asynchronous content to offload instructional duties from staff in short supply. Future work should continue to characterize approaches for shops with large student populations to maximize the benefit of hands-on lab experiences.

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