Leveling the Playfield: Development of Multimedia Resources for Hands-On Learning

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Abstract

Though the central premise of engineering is to design artifacts, processes, and systems to solve problems informed by science and technology, at the most rudimentary level, transforming the design into a physical object completes the solution. While Grand Valley State University (GVSU) engineering program emphasizes theoretical development, it also promotes transforming the design into a physical system by hands-on-teaching. The hands-on philosophy is so ingrained in the curriculum that it is expected that all students, at any level undergraduate or graduate, are capable of operating common machine tools and equipment to translate their design projects into a functioning prototype. Students who enter GVSU Engineering with no hands-on knowledge may struggle to participate in their projects. This negatively impacts the confidence of the student, making it a difficult skill gap to recover from. Inspired by initiatives like 'Khan Academy' and recent success of online courses, an attempt is made to address the hands-on knowledge gap.

A GVSU-hosted website was developed as a learning tool that teaches safety, scientific theory, and operation of the processes and equipment used by engineering students to create projects. Development of the web based modules are targeted to two groups of students. The first group needs background knowledge for a class or certification to safely operate a machine tool. The second group is students that need guidance and resources for design projects which are often sponsored by external industry partners. A how-to video series demonstrates the basic concepts, theory, tips and tricks, safety, and operation of various processes. A cheat-sheet style PDF accompanies each video for rapid learning. Lastly, a "web of knowledge" space on the website allows users to converge on resources specific to their needs. This paper describes the modules of this non-intimidating learning environment which will address the skill gap issues.

Introduction

The essence of GVSU-Engineering curriculum is project-based learning via hands-on industry sponsored or class projects. It is stipulated that students at any level, undergraduate or graduate, are capable of operating common machine tools to translate their design projects into a functioning prototype. Currently, students learn safety and operational instructions for the particular machines or equipment in a group setting as the process is demonstrated by a laboratory staff. The current method provides only one opportunity for simultaneously observing the operation in parallel to grasping the critical verbal instructions. For complex processes and heavy machine tools, this one time demonstration fails to provide adequate proficiency. Thus, the need for supplemental material for hands-on learning is established. Figure 1 outlines the differences between GVSU's classic hands on training approach and a new approach incorporating additional resources.

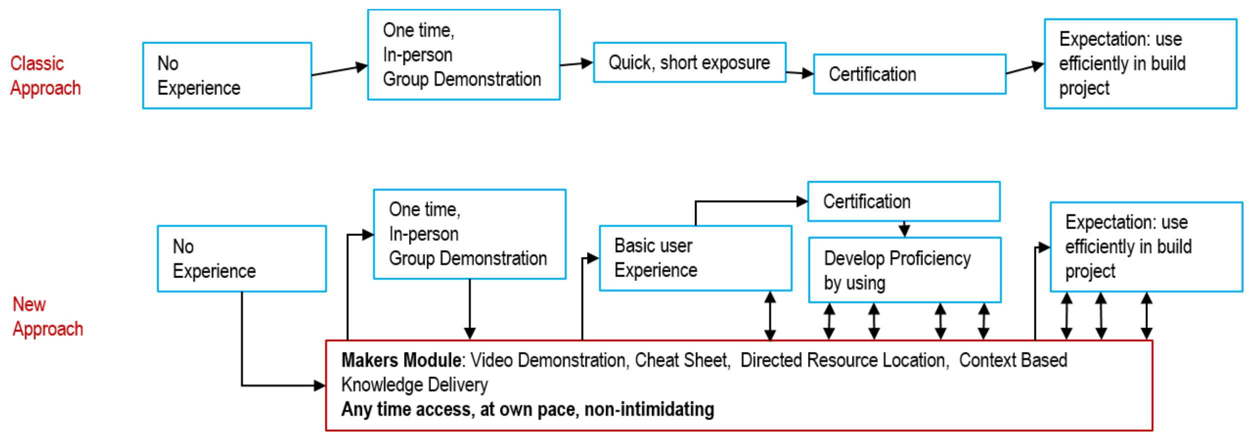


Figure 1: Flowchart of GVSU's classic and new approaches to hands on learning.

The overall purpose of expanding resources for hands-on learning for GVSU Engineering is multifaceted. Functionally, the intent is to offer the information needed by students surrounding GVSU specific resources in the easily-accessed e-learning environment. Two primary types of students were identified:

1. Students who are unfamiliar with a subject area or machine and need to learn prior to the certification process. Students from this group are not seeking specific information, but want to familiarize themselves with a new concept prior to hands-on demonstration. One example is a student that does not currently know what a manual milling machine is, but is required to attend certification and learn how to use one for a class project. Therefore, the learning needs for this type of student are primarily educational.
2. Students who need answers to specific questions they have. Often, they are familiar and comfortable with an overall machine or concept but may feel uncertain about the details. An example of this is a student wondering which steel welding process in the GVSU machine shop is the best choice to join two of their parts. This means the learning needs for these students are primarily functional in nature.

Since the level of experience and confidence between students can also vary widely among undergraduate and graduate students, catering to a wide range of experience was determined as a requirement. For example, an undergraduate freshman working on an introductory robot may need to determine if their motor will move the robot. A graduate student or senior doing advanced project work for an industry sponsor may need help in correctly setting up a machine to make their component. Each of these students may have different engineering or "hands on" experience levels, yet by having a specialized set of multimedia e-learning resources available the playfield among peers is leveled.

Background

The incorporation of multimedia e-learning resources into higher education classroom environments, and research about their effectiveness, has been occurring for over a decade [1-2]. Overall, the Maker Modules as a specialized set of multimedia e-learning resources aims to level the playing field between all levels of GVSU engineering students. Though the finer points and advantages of e-learning are still under research, some common benefits are agreed upon [3]:

1. Flexibility of material and the time
2. Accessibility to the material
3. Visibility of multimedia
4. Availability of data

In 2008, the National Academy of Engineers in collaboration with leading technological minds of the nation, published 14 grand challenges of engineering [4]. One of them is 'Advance Personalized Learning' to optimize the learning experience considering individual need and complexity of brain. Academics are aware of the benefits of 'individualized instructions' for many, many decades [5]. The effect of e-resources as a complement to traditional lectures in medical education is well established [6]. Following the model, "Maker Modules" are developed to provide individualized learning environment in addition to the existing in-person demonstration.

Even for subjects involving hands-on experience, these advantages of e-learning environments persist. This allows students with little to no hands-on experience to privately familiarize himself or herself with the concepts without fear of judgement or risk of injury. One specific focus of the Maker Modules e-learning environment is to increase student knowledge and confidence with a manufacturing process prior to in-person demonstrations. In turn, the student is less intimidated by unfamiliar concepts during the hands-on learning and is able to learn more effectively from the experience. The concept of hands-off "flipped" learning online prior to in-person discussion already exists in university curriculums [7]. It is reported that e-learning resources in flipped university coursework "increased motivation, engagement, increased learning, and effective learning" and that the offering of videos improved overall attitudes towards learning [8]. This research [8] also found that low-achieving students perceived greater learning from videos than high-achieving students, indicating that video learning was a way to level the playing field for university classrooms. With the widespread implementation of computers and mobile devices into educational institutions, the e-learning environment plays an increasingly important role in the delivery of educational content to students. Educational tools such as BlackBoard [9] serve as customizable, creatable spaces used to structure learning. Some groups such as Khan Academy [10] have seen great success in offering free lecture-style videos online. For hands-on, technical environments, there are many video-makers that publish "how-to" videos for certain machines or manufacturing processes. In the field of engineering, there are also online databases such as EngineeringToolBox.com or MatWeb.com that serve as easy reference materials for a wide range of real-life applications. Datasheets, mathematical derivations, diagrams, and tables are some of these resources offered.

Development

The Maker Modules learning resources will be implemented on a website that is accessed through the main website for GVSU Engineering. As of February 2019, the website is still under development. By May 2019, the website is expected to be fully implemented. The intended functionality of the site is described below.

The header of the main page explains the purpose of Maker Modules as discussed in the introduction. Below the header, there are two distinct areas on the main page. The first section targets students who need to watch certain content for a class or certification, so the thumbnails for different videos are listed. Accompanying each video is a “cheat-sheet” style PDF that summarizes the most important information in the video. An example of the thumbnail layout and cheat sheets that could be accessed by students are shown in Figure 2, respectively.

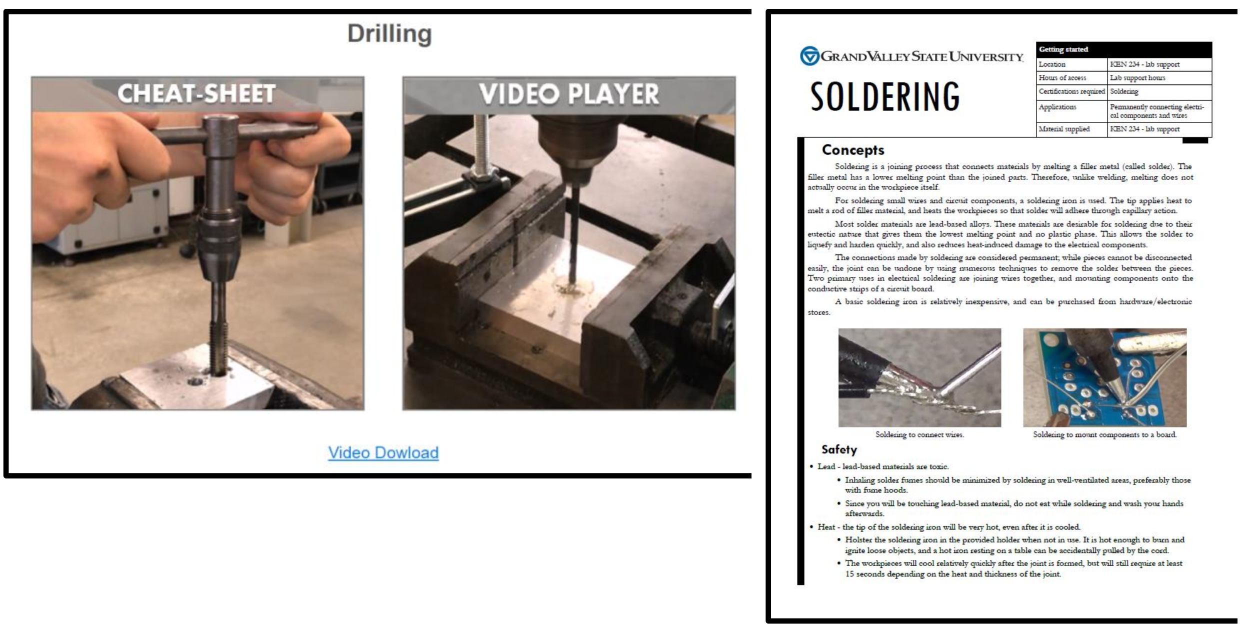
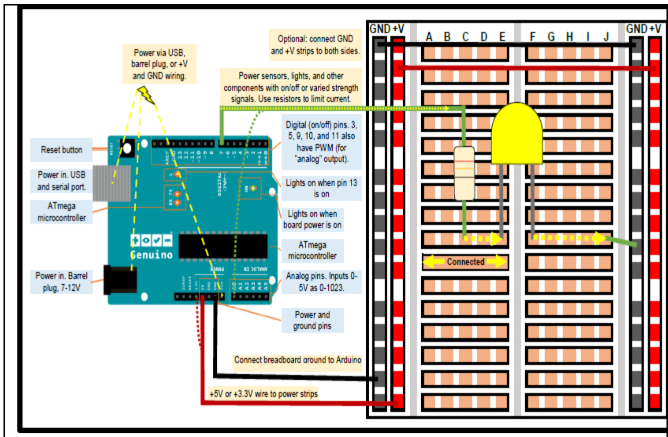


Figure 2. (a) Topical Thumbnails arrangement (b) Typical Cheat Sheet Content

The bottom of the main page is used by students who seek specific functional knowledge for their project. The student navigates through a tree of subject areas to converge on the desired information. For example, a student may wonder what options are available for making smooth edges on their plastic part. From a list of process categories, they select sanding and grinding. Each available resource at GVSU for that process is listed, and a brief description accompanies each resource. Of the available options, they also see that a deburring tool can work with plastic and will be the easiest solution. For these types of inquiries, watching a comprehensive video may not be the best solution. Other content such as process descriptions, schematics, and tables were developed to assist with general project-related student questions. Examples of these types of available content are shown in Figure 3.



Scale: Best (black) → Worst (white)

Materials			Yield Strength*, psi	Relative Cost	Machinability	Weldability	Impact Resistance	Wear Resistance	Chem. Resistance	Flat: Block	Flat: Plate	Flat: Sheet	Extrude: Strip	Extrude: Angle	Extrude: Round bar	Extrude: Rectangular bar	Extrude: Rectangular tube	Extrude: Round tube	Filament
Metal	Aluminum	AA 6061 (multipurpose)	35K							•	•	•	•	•	•	•	•	•	
		AA 2024 (high strength)	37K							•	•		•	•	•	•			
	Steel	AISI 1010 (low carbon steel)	30K							•	•	•	•	•	•	•	•	•	
		AISI 4140 (alloy steel)	60K							•	•		•	•	•	•			
		O1 (tool steel)	50K							•	•	•			•	•			
		304 Stainless	25K			X				•	•	•	•	•	•	•	•	•	
	Brass	360 (free machining brass)	15K							•	•		•		•	•			
	Bronze	High-strength 630	50K		X	X									•				
Plastic		ABS	5K							•	•	•	•		•	•			•
		PLA	5K																•
		Acetal	6K							•	•	•	•		•	•			
		Nylon 6-6	10K							•	•	•	•		•	•			
		PVC	6K															•	
Wood		Lumber	7K										•			•			
		Plywood	2K								•	•	•						
		MDF (med. density fiberboard)	2K							•	•	•							

*McMaster minimum values. Wood values from Matweb.
X = technically feasible but not acheivable with GVSU resources

Figure 3. (a) Schematic developed for introductory Arduino prototyping (b) Comparison table developed for common engineering materials

For a typical resource or process, the Maker Module video content describes scientific theory, operational instructions, and safety advice. Engineering laboratory staff develop the content of the videos, catered to the perceived needs of students for that process. In all Maker Modules videos there is a host, a graduate student who is familiar with the processes. The intended advantages of using a graduate assistant to host the videos are:

1. Increased engagement for viewers when the host is visible
2. Viewer perception of a singular instructor for all Maker Modules content
3. Higher relatability with undergraduate or graduate level audiences
4. Increased confidence for first-time learners from seeing a fellow student safely and comfortably demonstrating the process

Each video is roughly eight to twenty minutes long and the learning material presented in each video is concise. For many of these processes, an in-person certification can last up to an hour. This difference is explained partially by the use of fast-forward and skipping through repeated steps in the videos to reduce the time spent. Complicated machine processes require multiple videos to comprehensively cover the content. For the manual lathe process, the video content is separated into an overview video that discusses the safety and fundamentals of all lathe operations and a demonstration video that shows the video host using the turning process to create a waterproof container. Screenshots from the manual lathe process video series are shown in Figure 4.

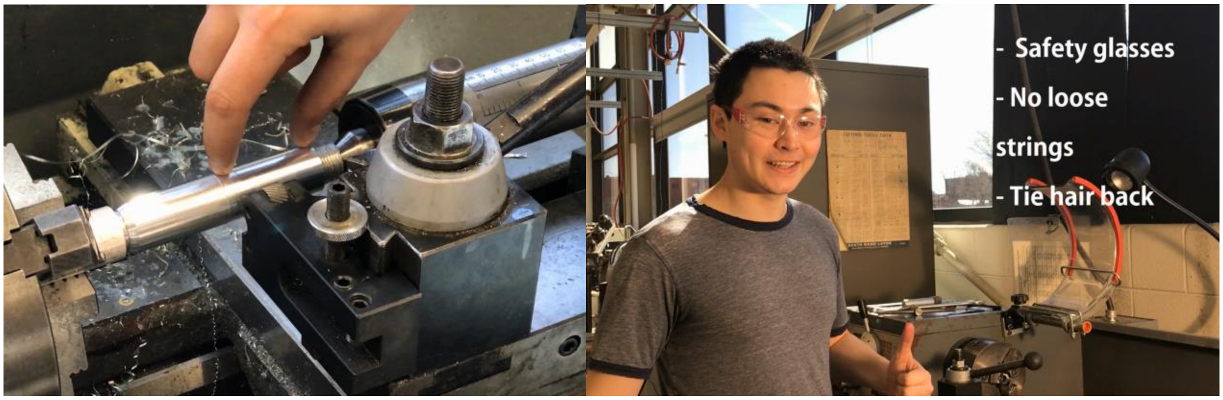


Figure 4: Screenshots from a three-part manual lathe instructional video series.

Conclusions

The learning effectiveness of Maker Modules has not yet been formally evaluated. Currently, the videos have been shared with students, staff, and faculty by request. The creation of a "CNC lathe" maker-module video allowed graduate students to successfully operate the CNC lathe where no opportunities to learn the machine were previously offered. In the hands-on laboratory component of the manufacturing processes course, overview videos for welding and manual lathe operations were shown to upperclassmen prior to in-person demonstration. Through March 2019 to April 2019, groups of volunteer students will undergo the hands-on machine certification process with and without reviewing supplemental e-learning materials beforehand. The results of a post-certification knowledge test will be compared to determine the effects of the e-learning materials. To ensure that this learning is effective at various levels of experience, this will be tested for two different types of students: underclassmen who are trying to become qualified to safely work in a machine shop, and upperclassmen or graduate students who need to learn an advanced machine process for a project-related class. Ideally, offering e-learning materials should increase overall scores. To level the playing field between students, the e-learning materials should also greatly improve the knowledge of the lowest scoring students.

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