

A Web-based supplement to support Mechanical Engineering student's introduction to design and prototyping in a shop environment.

by

Alexandra Taylor

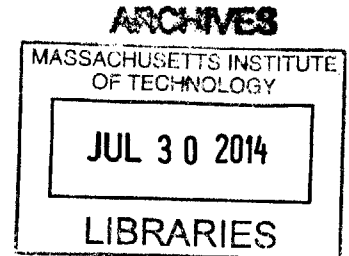
Submitted to the
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Abstract

The first step out of the lecture hall and into the machine shop is an eye opening period for engineering students. This exciting yet sometime intimidating experience happens for undergraduate mechanical engineers in 2.007 at MIT, Manufacturing and Design I. This experience holds an essential place in the curriculum as a class to build familiarity using the machine shop and creating self-confidence in the young students as engineers. As friendly and open as the mentors are, communication gaps are still found when students nod their heads, too embarrassed to ask another question in this completely foreign environment. Therefore, an interactive learning tool was developed to supplement 2.007 curriculum and provide another confidence building resource. The website design was chosen to give students a learning outlet in the comfort of their typical study space. Using this medium also allowed the opportunity to learn website design including, but not limited to, setting up a server, and coding html and php. With time, this project could be expanded to cover the majority of resources available in the Pappalardo Lab.

Thesis Supervisor: David Wallace
Title: Professor of Mechanical Engineering

Acknowledgements

I would like to thank Professor Wallace, for his unwavering support throughout this entire project. After helping me through the initial brainstorming process, he guided me through the semester with patience and sought to know me as an individual as he continued to engage me with positive feedback. I would also like to thank Eric Lau and the MIT Student Information Processing Board for their help when I felt lost in the world of computer science. And lastly, I would like to express my appreciation for my fellow mechanical engineering classmates that tested the site and provided insightful feedback.

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Introduction

Teaching methods and educational environments are continuously evolving fields, attempting to reach out to each and every student's needs. Gaps in direct student-professor communication become most apparent when the students are introduced to a lab environment and are either too shy or too stubborn to ask for guidance. The goal of this thesis was to provide an additional learning tool to help expose entry level mechanical engineers to available resources during their first semester in the shop. More specifically it was designed to supplement the MIT class 2.007, Design and Manufacturing 1, held in the Pappalardo Lab. This interactive web based interface was designed to broaden not only the student's shop vocabulary but an understanding of the tools and machining options available. Engaging students with multiple formats of informational games will help students familiarize and test themselves with basic design knowledge required to excel in the shop. Figure 1 & 2 are two example quiz formats.

Drills & Taps

Drill Size Major Dia.	Tap Size Major Dia.	Tap Size Pitch Dia.	Tap Size Pitch Dia.		Tap Size Pitch Dia.	Tap Size Pitch Dia.	Tap Size Pitch Dia.	Tap Size Pitch Dia.	Tap Size Pitch Dia.	Drill Size Major Dia.	
			Tap Size Pitch Dia.	Tap Size Pitch Dia.						Drill Size Major Dia.	Drill Size Major Dia.
1	1.315	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270
2	2.540	2.484	2.484	2.484	2.484	2.484	2.484	2.484	2.484	2.484	2.484
3	3.810	3.754	3.754	3.754	3.754	3.754	3.754	3.754	3.754	3.754	3.754
4	5.080	5.024	5.024	5.024	5.024	5.024	5.024	5.024	5.024	5.024	5.024
5	6.350	6.294	6.294	6.294	6.294	6.294	6.294	6.294	6.294	6.294	6.294
6	7.620	7.564	7.564	7.564	7.564	7.564	7.564	7.564	7.564	7.564	7.564
7	8.910	8.854	8.854	8.854	8.854	8.854	8.854	8.854	8.854	8.854	8.854
8	10.160	10.104	10.104	10.104	10.104	10.104	10.104	10.104	10.104	10.104	10.104
9	11.430	11.374	11.374	11.374	11.374	11.374	11.374	11.374	11.374	11.374	11.374
10	12.700	12.644	12.644	12.644	12.644	12.644	12.644	12.644	12.644	12.644	12.644
11	13.970	13.914	13.914	13.914	13.914	13.914	13.914	13.914	13.914	13.914	13.914
12	15.240	15.184	15.184	15.184	15.184	15.184	15.184	15.184	15.184	15.184	15.184

Rank the following from largest to smallest diameter.

File #1 Tap Drill Major Diameter Close Fit

Largest:

Smallest:

What drill number should be used to prepare ABS for a #40 tap?

Drill Number:

Which screw has a larger diameter?

Ø 5/16 x 1/2-24 or 1/2 inch long

How many threads does a 1" long 1/4-20 screw have?

Threads Count:

As the drill number increases, the diameter of the bit

Decreases () Increases () I don't know.


Figure 1: Drill & Tap Chart Quiz Layout


Please name each fastener from the word bank below.


Word Bank


Washer Weld Nut Dowel Pin Solder Bolt
 Cotter Pin E-Clip Rivet Clamp Retaining Ring


*Words can be used more than once
































Word Bank

Washer Weld Nut Dowel Pin Solder Bolt
 Cotter Pin E-Clip Rivet Clamp Retaining Ring

*Words can be used more than once

Figure 2: Fastener Quiz Layout

Goal

There are as many different learning styles as there are students. With that said, there are no ideal learning environments/formats that work well for all students. The best way to reach every student's needs is to design and offer multiple learning opportunities. The idea of this interactive learning tool is to help familiarize 2.007 students to the resources available in the Pappalardo lab. 2.007, or Manufacturing and Design I (1), is made up of entry level students ranging from previous hobby shop users, to those who have never stepped into a machine shop. These mechanical engineering sophomores are exposed to the material in lecture or by explanation in lab, and the goal here is to repeat this exposure with another source, hoping to broaden their visions and get them to the point where confident enough, or even curious enough to seek out an e-clip, pick up a Dremel tool, figure out how to use a lathe and gain ultimate familiarity by actually using the full range of resources available in lab. As the

first mechanical engineering lab class at MIT, 2.007 should be an eye opening learning experience, not an environment to rely on a previously defined comfort zone. The staff of the Pappalardo lab is a great resource and it is good to hear that students utilize their help. This project provides another opportunity for students to engage in a self-led learning activity.

Learning process for coding the online resource

This project started with two things in mind, it was going to be an educational tool and it was going to be directed towards the mechanical engineering community. From there, the brainstorming began. After a few weeks of thought and experimenting with different ideas, the focus was narrowed down to an online interactive resource aimed towards 2.007 students during their first academic lab experience. Familiar with the class content and structure after taking 2.007 sophomore year, the catch was starting with no html or other web design background.

Learning to code started from the basics Code Academy (2) presented the material in a way that fit my personal learning style. I flourished with the interactive format, going back and forth between instructions, examples and coding opportunities on the same page. It provided optional hints and instant feedback with a preview of the page created with each color coded line of code. This learning approach was more time consuming than just reading through text, but it led to understanding the significance of each character. In this environment I learned how to handle pictures, links, forms, organization of files and basic CSS.

The next leap was becoming familiar with Bootstrap, premade CSS pages with references to ease the design of buttons, forms and alignment keys. Even knowing the basic structure of html, I took many lines of code for granted. Using code without a full understanding led to some bad coding habits that had to be fixed later in the project.

Coding version one started at this point. This is where web pages started to come together. The initial topics included edges, tools and fasteners, all with drop down menus, screws which included nuts, screw heads and screw types with a word bank and a drill and tap page which mixed multiple choice and fill in the blank. To connect it all together a home page was added and navigation buttons including a home and a submit button were added to each page. Once these front pages were set up, the question was, where should the submit button lead?

This is when php (hypertext preprocessor) was discovered (3). Php became the logic behind responding to user input, and the way to provide user specific feedback. With the php code mixed right in with the standard html code, the second learning curve converged much faster. Without Code Academy to serve as a guide, php was learned seeing examples, altering the code and then noting the effect. This was a great point of understanding. Experimenting with different form types and input values, I was forced to step back and understand the original Bootstrap code, simplify it, and take out a lot of redundancies. To implement this new addition, a local server had to be installed. This was a learning process in itself.

Starting with multiple choice, the php code was applied to different form types through a process of defining values, interpreting user input, comparing it to the correct

answer and displaying feedback accordingly. Default values were given to avoid visible error messages on the user interface when a question was left unanswered and radio buttons were used instead of check boxes to insure only one answer was selected per question. The next format to tackle was the fill in the blank that I coupled with the nut and screw pages. These blanks presented a problem of their own. Not as black and white as the radio button, these areas had to deal with the variability of user answers. To reduce ambiguity, a word bank was provided and the php code was designed to account for any combination of capitalization. It would accept an answer as long as the name was spelled correctly. There were multiple ways that a text box could be used, including but not limited to ranking items, and fill in the blank with and without a word bank. To avoid ambiguity, questions were worded carefully and the response length was limited to help users realize if they were on the wrong track. Later to improve upon the word banks, drop down menus were also explored.

Initial Implementation

The most straight forward quizzes, covered hand held and machine shop tools all found in Pappalardo. These tool quizzes were broken into two very similar formats, both using radio buttons. The first page (shown in figure 3), Tool 1, displayed a tool name and two pictures of tools below that the user could choose to match with the tool name with the radio buttons below. Tool 2 (shown in figure 4) took a slightly different approach, displaying one picture of a tool and asking the user to name it by selecting one of the labeled radio buttons below. Both pages had 7 questions and returned feedback with the submit button below.

The solution pages were simple and held the same layout as the question webpages. Each picture or set of pictures was labeled with Correct! This is a “name of tool” or Nope. This is a “name of tool” in green or red respectively. In addition, the Tool 1 solutions boxed the correct picture for comprehension at a quick glance. An example of both can be seen in the figure 3 and 4 below.

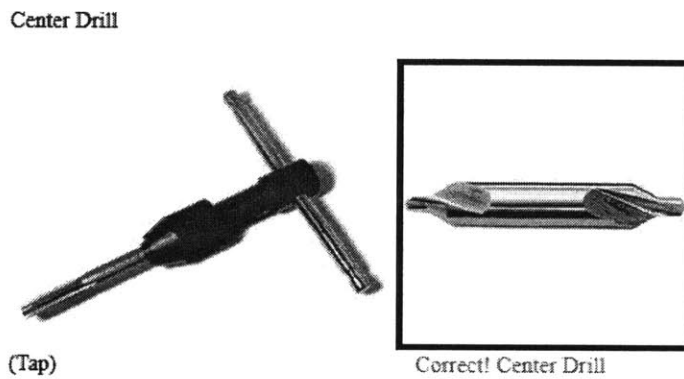


Figure 3: Tool 1 Solution Example

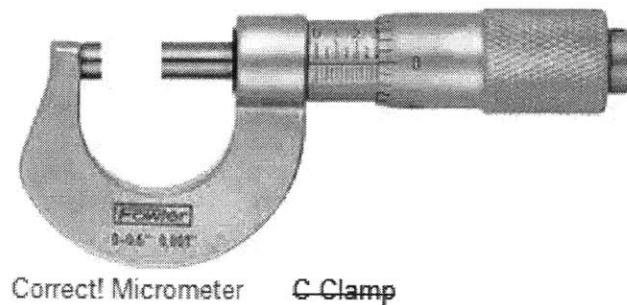


Figure 4: Tool 2 Solution Example

Screw types, screw heads and nuts were initially all grouped together in one category, but were separated early on to preserve a quick and friendly quiz feel. On the first screw webpage, users were asked to name six pictures of standard screws from a word bank above (shown in figure 2). The nuts were handled in a similar fashion except without a provided word bank. The screw heads followed with a standard multiple

choice selections ranging from flat heads to socket caps. The solutions to all three pages had the same layout as the quiz pages, with the correct answer highlighted in green if the question was answered correctly and a correction from the original input answer highlighted in red if the question was answer incorrectly. The drill and tap page was a section of its own. Each multiple choice and text box question referenced the complete drill chart on the top of the page. All answers could be found within the chart, but a previous understanding was found to be quite useful.

The first thing that became apparent was the difficulty level of the topics. The initial idea was to have quizzes of varying difficulty, but have them all relevant to the 2.007 lab experience. The quizzes that were assumed to be the most difficult were that, and more. The screw and nut quizzes stumped even the senior mechanical engineering students that tested the tool, word bank or not, while the multiple choice under the screw heads landed closer to a guessing game than deductive reasoning. Although the topics were interesting, the common denominator was that the topics were not known by students even after they had completed 2.007, nor were they particularly relevant.

Feedback

In order to get an understanding of the students that this project would be serving, the body language and the verbal feedback of the students while exploring the website was just as important as their written responses. Glancing over the shoulders of students taking the quizzes or even just sitting in the same room, it was interesting to see how seriously students approached it. I found it amazing how much thought was

placed into each quiz and how much their pride was dependent upon their performance, keeping in mind that the final outcome had no tangible consequences. There was no final score to be calculated or comparisons to be made, just competitiveness within one's self and a sense of accomplishment.

It was evident from the beginning that no design was going to be deemed perfect. As one student suggested a pop up hint that appeared after two minutes "stuck" on a page, another vocalized that she wouldn't like that at all. She didn't like the idea that the computer recognized that she was struggling. She did, however, state that she would use a hint button and actually suggested it in the written feedback.

Final Implementation

The first round of student testing resulted in many alterations in format and content. First in line was offering a quiz on fasteners, an alternative and hopefully more applicable topic to replace the screw and nut quizzes. The top line of the fastener quiz can be found below in figure 5.

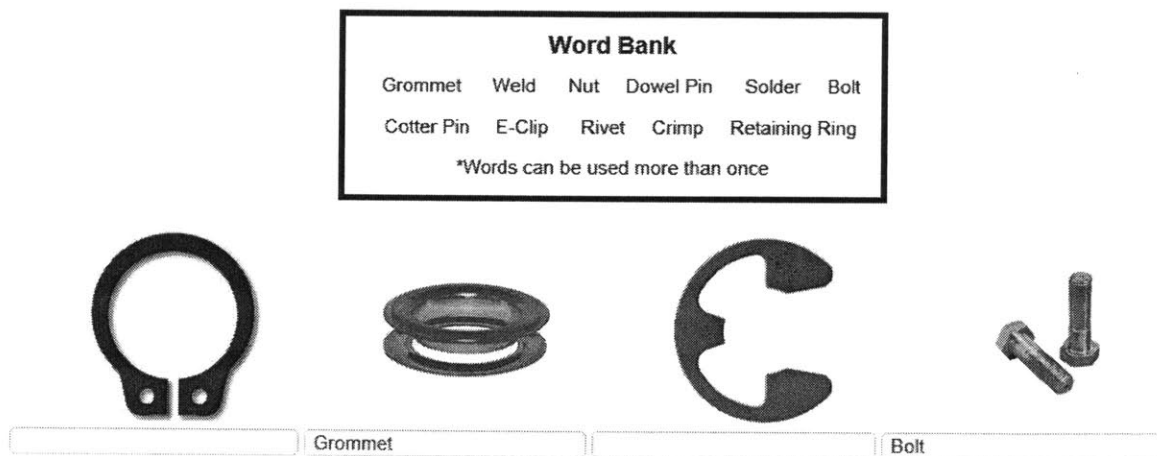


Figure 5: Fasteners with Word Bank

Additionally, users liked the idea of crossing off terms as they went, a feature not offered with the original word bank. To replace the traditional word bank, individual drop down menus were assigned to each tool to select the correct term. Believing that this layout would help students to focus on each individual question without becoming overwhelmed, the decision was made to present 12 tools on a single page. This allowed users to compare pictures on a larger scale and promoted the use of deductive reasoning. The first line of the tool quiz with drop down menus can be seen below in figure 6.



Figure 6: Tools with Drop Down Menu

Another key complaint was the default options used for multiple choice selections. Originally, the first radio button was checked by default. This caused some to lose track of the last question answered and confused some, believing that the quiz did not reset after the previous user. To fix this problem an additional button labeled 'I don't know' was added and selected as the default option. The figure 7 below shows an example of the final multiple choice layout.



Figure 7: Multiple Choice Redesign

The original drill and tap quiz had caused some problems as well. Since the drill chart itself took up the majority of the screen, to complete the drill quiz, users had to scroll up and down to read the questions, refer to the chart and check the question again. This process extended the frustrations of many and caused comments that even with only 7 questions the quiz was too long. To address this concern, the densely filled chart was cropped to only include screw sizes zero through twelve and two questions were removed. The remaining questions were inspected individually and carefully rephrased to be more clearly connected to the drill chart above.

The solution pages were remodeled as well. The simplicity of the original solutions did not provide enough information to please the users. Right or wrong the students wanted to minimally see not only the correct answer but their answer and the other choice if applicable. In addition to these simple requests students asked to be provided with additional information including, but not necessarily limited to typical uses of the tool or hardware and a link to additional related resources such as Wikipedia (4). Through observation it was also found that users expected the solutions to be in the

same format as the completed quiz and were caught off guard every time the solution page was shifted or altered.

When asked what format they found most intriguing some students had a slight preference towards one or another, but most appreciated the variation. While positive feedback was given regarding the drop down menus, the topic of fasteners did not top the list. After providing this replacement, the drill and tap quiz was voted most useful followed closely by tools, with fasteners in a trailing third.

Results

Is this interactive tool useful for 2.007 students? This question was asked of sophomores through seniors alike and the answers varied, but they did have one thing in common. Responses across the board recognized that they relied on the Pappalardo staff for this information, and they never truly learned it for themselves. While a handful of students were content with this fact, others realized the benefit of knowing this information for themselves and thought this interactive web design could be a useful tool.

Looking Forward

Continuing the project from here, the first focus based on user feedback would be to implement more informative solution pages, in order to make each page more of a resource, than just a quiz. On the tool pages for example, each correct and corrected answer would be followed by an explanation of the tool's purpose and an example of it in use. The fastener page would be supplemented in a similar way, with advantages of

using that particular fastener and a picture of it in its typical use. The drill and tap chart already has some explanations under way, but it is a topic that seems to need additional assistance. Detailed instructions on how to use a drill chart including how to look up a specific screw based on diameter and thread count and when to utilize different drill sizes from a tap hole to a free fit should be available. In addition to drill chart specific instructions, a beginner's guide to interpreting screw sizes and thread callouts could also be beneficial. All three categories could also be supplemented with links to supplemental reading.

After the solution content is established, the focus should be directed towards formatting. The home page could be much more than just the current navigation page. The home page is an opportunity to welcome the user, give general instructions and most importantly an explanation of each quiz, allowing students to differentiate between quizzes based on need. Though seemingly self-explanatory, the quizzes themselves could also use detailed instructions to clear up any ambiguities that could arise. That would be followed by straightening up the remaining alignment issues so the page is represented in the same manner, regardless of the screen size.

Before adding additional topics, a behind the scenes clean up would be beneficial. This would include referencing the navigation bar to a central file so the site becomes more alteration friendly even as it grows in size. Once the current site is well oiled, additional quiz topics should be added to assist across the whole 2.007 experience. Topics suggested in feedback included, but were not limited to, safe ways to use tools and machines, proper use of measuring tools redesign tips for machining, materials, simple circuitry and electrical engineering affiliated hardware. When thinking

about additional quiz topics the Pappalardo shop staff should be consulted to get a sense of where they notice the largest gap in student knowledge. As much as the class evolves, so could this project, shifting with the curriculum or emphasis of a particular year.

Work Cited

- (1) <http://ocw.mit.edu/courses/mechanical-engineering/2-007-design-and-manufacturing-i-spring-2009/>
- (2) <http://www.codecademy.com/dashboard>
- (3) <http://www.php.net/>
- (4) <http://www.wikipedia.org/>

Appendices

User Feedback

Where did you become familiar with these topics?

Tools	Academic setting	Non-academic setting	I am not familiar
Fasteners	Academic setting	Non-academic setting	I am not familiar
Drill & Tap Chart	Academic setting	Non-academic setting	I am not familiar

Which topics would have assisted your learning experience in 2.007? (Circle all that apply)

Tools Fasteners Drill & Tap Chart

What other topics align with an intro level MechE lab experience?

Thoughts relating to content.

Each quiz was

Too Long About Right Too Short

Would you prefer feedback after each question or at the end of each page?

After each question End of page Depends on the Topic

Which quiz format did you find most appealing?

Which parts did you find easiest/most difficult to use?

Thoughts relating to format and navigation. Please note anything that stuck out to you.