Designy: An Online Multimedia Platform for Supporting Prototyping in Residential Product Design Education

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Abstract
In residential product design courses projects are a key mechanism for motivating, applying, and consolidating broader teachings about design process and methods. Students are provided with opportunities to learn by prototyping, yet in many programs, there is little instruction on prototyping. As part of a continuous improvement approach for three different product design courses in Mechanical Engineering at MIT, an effort was made to better teach and support student prototyping using online technology. The result of the initiative was the development of an online multimedia resource hosting platform called Designy.

In order to support a variety of situations in which students might seek additional prototyping support during project work, resources were designed to utilize a combination of photo and video formats. Annotated images are used to introduce technical language, comprehensive narrated videos are used to show prototyping equipment operation, and short looping animations are used to show detailed steps of prototyping techniques. Providing students with multiple media formats allowed them to choose which resources best suited their support needs.

This platform was tested in two product design courses: 2.00b Toy Product Design, an introductory product design course taken mostly by freshman, and 2.744 Product Design, a skills-focused course taken mostly by graduate students. In 2.00b, students complete project work with significant staff supervision, whereas most of the project work in 2.744 is unsupervised. For this reason, testing in these courses provided an opportunity to evaluate the platform in course settings with different supervision models.

Usage data showed that around half of the students in each course exhibited activity on the platform, with a core group of 24 students (27% of the student population) in 2.00b and 28 students (35% of the student population) in 2.744 contributing most of the platform activity. To characterize student use of the platform, use case descriptions were collected from students during interview sessions with both 2.744 students (n = 10) and 2.00b students (n = 9). Students cited using the platform to support planning prototypes, for preparing to work in the shop space, for exploring the landscape of available tools and techniques afforded through access to the workshop, and to directly support the execution of prototypes in the workshop. Course staff members had activity on the platform comparable to student activity, and used Designy to prepare for advising students on project work and as a source of multimedia resources for preparing lecture materials. Overall, providing the platform to students removed typical
roadblocks to prototyping work, such as limited access to staff and difficulty operationalizing prototyping techniques learned through other means. Although some students prefer support of prototyping efforts through face-to-face interactions, Designy was found to contribute to student feelings of increased confidence and comfort while in the workshop, allowing students to work more efficiently and progress their project work further than if they did not have access to the platform.

Thesis Supervisor: David R. Wallace
Title: Professor of Mechanical Engineering
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Introduction

Mechanical engineering curricula at the university level are increasingly centered on design because designing reflects common professional engineering practice. As Atman et. al. states, "For engineers, designing integrates engineering knowledge, skill, and vision in the pursuit of innovations to solve problems and enable modern life" [1]. A design course early in the curriculum can help situate the rest of a mechanical engineering student's coursework in the context of designing. These cornerstone courses have been shown to enhance interest in engineering and improve motivation in later engineering courses [2]. In the later stages of a student's academic career, a design course can provide the chance to practice the skills and knowledge a student has gained through previous coursework, integrating those concepts together through project work that simulates a real-world context [3].

Product design is a discipline within mechanical engineering that is concerned with the creation of consumer products typically meant for sale. User-centric product design offers students a chance to learn about applying their science and engineering knowledge to solve meaningful problems for real people. From this point of view, product design in Mechanical Engineering at MIT is taught as a blend of traditional mechanical engineering and industrial design. Within professional design practice, prototyping is a core activity. Designers use prototypes for learning, communication, exploring subsystem integration, and as milestones for development [4]. Physical prototyping involves using physical materials to learn in an effort to progress a product concept towards becoming a commercial product.

Projects in product design courses give students the opportunity to learn how to utilize prototyping as part of designing. Physical prototyping provides students with a variety of learning opportunities where students can draw on concepts from their mechanical engineering course work, including mechanics, materials, manufacturing, and more. Prototyping as part of project work allows for students to emulate work done by practicing product designers. The
more real project work is—the more it reflects professional engineering design practice—the more motivating these experiences are to students [1].

Creating an environment where students can practice authentic product design project work requires providing a great deal of support. Without support, students can struggle to succeed in project work meant to resemble the work of design professionals, as they are still learning about what engineering practice entails. In large residential design courses, it can be challenging to address the needs of a large population of students who are all conducting project work at the same time. To increase the likelihood of students having successful project outcomes, support should be provided within the learning environment in many ways. Students can be instructed about prototyping techniques in lecture sessions through demonstrations from professionals. Activities can provide opportunities for students to practice prototyping techniques themselves. To fill in any gaps between instruction and techniques needed for project work, students support can come from lab staff members dedicated to working alongside students. However, each of these support channels has challenges with supporting student prototyping, and students can still struggle to execute high quality prototypes as part of their project work.

This research investigates providing additional support of student prototyping efforts through the use of a multimedia hosting platform developed with the context of three MIT product design courses in mind. In the three courses—taught through the teaching and research lab the MIT CADlab—educators have an attitude of continuous improvement, striving to improve the course experience each year. This thesis documents the design, implementation, and evaluation of Designy, a new instructional multimedia hosting platform, and the custom multimedia resources developed for it. The home page and an example content page from Designy are shown in Figure 1.
Section 1: Design and Implementation is a collection of chapters that together capture the process by which the Designy platform was created and describes the implementation of the platform that was tested as part of the evaluation presented in Section 2.

Chapter 1: CADlab-developed Product Design Courses provides the context necessary to situate the Designy platform in the environment it is intended to operate in. This chapter also discusses the preexisting multimedia environment that was a factor in making Designy development possible.

Chapter 2: Supporting Prototyping Work presents an analysis of student problems with conducting prototyping activities in CADlab-developed courses and explores ways in which an online platform might be used to support student prototyping. A description of
anticipated use cases for the platform and list of attributes that situate the platform in the context of CADlab-developed courses are presented.

Chapter 3: Designy Implementation captures how the platform was implemented for testing in two product design courses in the Spring Semester 2018. The layout of the website, the types of multimedia resources hosted on it, and how the platform was integrated into course experiences are described.

Section 2: Evaluation is a collection of chapters that describe how Designy was evaluated during testing in 2.00b Toy Product Design and 2.744 Product Design.

Chapter 4: Methodology outlines the questions and data collection methods used to evaluate Designy. The methodology for two research tasks, quantifying platform activity and characterizing use, is presented.

Chapter 5: Analysis and Discussion presents the data collections and discusses the results in the context of both courses. A summary of results provides the basis for the evaluation of the platform.

Chapter 6: Conclusions and Future Work provides a summary of the evaluation of the Designy platform and outlines potential future work involving the use of Designy in research and teaching endeavors.
Related Work

Engineering practice is heavily supported through the use of digital technology, so it is natural to extend that support to engineering education. There are many examples of research about online technology being incorporated into the learning environments created by engineering educators [5]. Sorting through literature on technology use in engineering education can be complex due to a wide breadth of applications and evaluation methods.

In engineering education, it is less common to see studies centering around technology use in project-based courses, whereas studies in mechanics [6], dynamics and controls [7], or manufacturing [8] are more common. Sometimes technology use is explored as a replacement for physical aspects of learning environments [9]. The use of virtual environments has been explored as a replacement to providing students with physical products in product dissection activities [10]. Reasons for exploring the use of virtual environments for dissection activities include decreasing costs, space limitations, and time costs associated with preparation of instructional materials [11]. On a more positive, improvement-oriented note, virtual dissections could also provide students with learning opportunities that would not otherwise be possible in a classroom setting, such as the ability to dissect a windmill [12].

Even in design education research, investigation in the use of online technologies tends to focus on facilitating the learning of computer-based design topics. Use of online multimedia in mechanical engineering courses has been studied through the use of recorded lecture videos for teaching students about CAD [13]. In engineering graphics, use of online multimedia was shown to provide rich feedback regarding resource utilization to instructors [14]. In an effort to make resources about sustainable design available to a wide audience, multimedia resources were developed to teach online users about sustainable design principles, FEA analysis, and building design analysis techniques [15].

Recently, use of online multimedia in engineering education classrooms has been studied more extensively—with research on flipped classrooms becoming more popular. Flipped classroom
research typically involves the use of recorded lecture videos assigned as homework to free up more time in class for activity, but these activities more commonly involve team problem solving instead of additional hands-on instruction [6] [16]. Flipped classroom studies have also been done in design education settings, but once again this exploration focused on CAD instruction, freeing up class time for students to practice CAD under the supervision of instructors or teaching assistants [17]. In the past, flipped-classroom-style investigations of prototyping content took place in a CADlab-developed product design course, even before the term flipped classroom was popularized, but more recent examples of multimedia use in design courses do not typically focus on prototyping[18] [19].

Online technology has been researched for use in project-based and problem-based learning in engineering contexts, but these explorations do not always include a physical element [20] [21]. Use of online technology to facilitate team communication and collaboration has been studied through the use of wikis as tools for working on design reports [22] and through communication technology used to support geographically distributed student design teams [23]. In industry, use of online multimedia through video instruction with interleaved formative assessments has been shown to work better than recorded lecture slide delivery for supporting software training in large scale engineering project work [24].

Outside of research contexts, multimedia for supporting physical project work like prototyping is prevalent. A short search on a video platform like YouTube will provide dozens of videos on operation of various prototyping equipment. The website Instructibles provides expert and novice users alike tutorials on aspects of physical prototyping and craft work, and has even begun to branch out into more professionally developed multimedia resources in the form of online classes [25]. There are websites in design education contexts developed to provide students with multimedia resources to support prototyping [26]. In research contexts, examples of studies of multimedia use as part of supporting prototyping are harder to find. One study included prototyping as part of a flipped classroom experiment for teaching engineering design, but the coverage of prototyping was textbook-style and prototyping-focused classroom exercises were devoid of physical hands-on activity [27]. Another research project involved the development of
a web-based tool that was used to explore supporting physical prototyping work through providing an online form of process documentation [28].

In the online education world, the popular online format of MOOCs (massively open online courses) combines elements of multimedia instruction with online-enabled communication tools and occasionally interactive modules. In general, MOOCs have the ability to reach a wide audience, connecting to many users who otherwise might not have access to the educational opportunities provided on these platforms. The effectiveness of the MOOC format continues to be discussed, as the format can have a very different educational purpose from traditional residential education at the university level [29]. Two examples of MOOCs about product design, one from Coursera [30] and another from MIT and Harvard’s edX [31], cover prototyping, but mostly focus on the use of prototypes in a design process. These courses do not contain an extensive coverage of prototyping technique, mainly focusing on paper and cardboard prototyping techniques. The educational multimedia platform Lynda, which is not technically a MOOC but does focus on multimedia instruction, includes some resources on prototyping but tends to focus on exposure instead of operationalizable technique instruction [32]. Ultimately, these online courses are limited in their ability to deliver prototyping instruction due the limited access to prototyping equipment of their target audiences. One advantage of a residential university education is access to prototyping equipment that professionals would use. The Designy platform is intended to support the prototyping work of residential students, as opposed to being a standalone course for the general population, in order to explore multimedia instruction at the intersection of residential and online education.

Research of prototyping in an educational context tends to focus on the use of prototyping as part of design learning, with a focus on describing features of prototyping activities that contribute to student learning [33] [34]. Studies comparing design novices and design experts are common in design research in order to identify areas where design pedagogy can be enhanced [35] [36]. This type of research has been extended to prototyping education in the form of studying novice perceptions and uses of prototypes as part of conducting design activities, which can identify student misconceptions about prototyping [37] [38]. Recently, research about
prototyping in educational contexts has also been done in the form of evaluating makerspaces [39] [40].

There is a gap in research about use of multimedia to support physical prototyping. This gap could exist for several reasons. One factor could be that engineering design in many engineering programs is covered in a textbook-style format due to resource limitations. Another possibility is that multimedia resources may not be shared beyond an engineering program at a particular university. The research presented in this thesis investigates utilizing the affordances of an online multimedia platform to improve upon teaching prototyping techniques to engineering students. In this way, this work explores the combination of physical project work with digital support to better aid students as they practice design work. By providing an example for how multimedia resources can fit into the context of design education, future educators may be inspired to explore online multimedia in their own learning environments.
SECTION 1

DESIGN AND IMPLEMENTATION
Chapter 1

CADlab-developed Product Design Courses

Designy is a platform created to operate in the specific context of residential product design courses, as opposed to creating a separate standalone course or a tool specifically for research. Although the current implementation of the platform could be used in a variety of situations to support design education in and out of coursework, the main intended application of the platform is to support student prototyping efforts in MIT product design courses. The main goal of this section is to describe the learning environment of CADlab-developed product design courses in order to give context for the design decisions made during the development of the Designy platform.

First, the learning opportunities offered to students as part of a CADlab-developed course are outlined, followed by a description of how prototyping instruction is provided in these learning opportunities. Next, specifics about the course population, learning goals, project scope, and existing prototyping support offered to students in the three CADlab-developed courses—2.009 Product Engineering Processes [41], 2.00b Toy Product Design [42], and 2.744 Product Design [43]—are provided. A series of common principles that are present in each course experience are described in the following section to give context to certain details about the implementation of the Designy platform. At the conclusion of this chapter, examples of how online multimedia was used in CADlab-developed courses prior to Designy are given.

1.1 Learning Opportunities

For mechanical engineers, learning product design includes learning about design process strategies which aid designers in conceiving innovative ideas, evaluating and choosing between different product opportunities, and exploring design ideas through conducting user research.
The three CADlab-developed product design courses have projects centered around students creating physical prototypes as part of advancing product ideas.

Teaching and learning in a CADlab-developed course are not easily summarized by a list of topics and lectures. It is more helpful to think of a CADlab-developed course as providing students with a series of learning opportunities while motivating students to want to take advantage of those learning opportunities. Some experiences, such as lectures, involve the entire student population, whereas other experiences are optional and students can choose which opportunities to take advantage of. Students also have agency in choosing which aspects of their project work to focus on. For these reasons, students can choose different pathways through a CADlab-developed product design course. Thinking about the variety of learning experiences that happen course-wide reveals how complex the learning environment in a product design course can be. In order to better understand the learning environment of a product design course, it will be helpful to illustrate a few key learning opportunities provided to students.

1.1.1 Lectures and Extra Tutorials

The lecture experience in CADlab-developed courses is the main way content about product design is delivered to students. Although there is traditional content delivery supported by projected slides, this type of teaching does not usually dominate lecture time. Many lectures contain elements of theatrical performance, including skits or presentations supported by physical set pieces. Other lectures include activities where students practice design skills in a lecture hall, either alongside teammates or independently. Examples of learning experience in lecture sessions are provided in Figures 1-1 and 1-2. Some lecture sessions include trips to a lab space to utilize the equipment or to host demonstrations. Lecture time is often assigned to creating learning experiences centered on whichever way students are going to best learn the intended product design content, often with the aim of capitalizing on having a large group of students in the same room. The diverse range of learning experiences provided in lecture sessions center around motivating students to learn deeply and apply what they have learned to their project work. Lecture sessions build excitement for product design topics and are designed to foster a sense of joy in learning.
Figure 1-1: Lectures are learning experiences that capitalize on having many students in the same room.
Figure 1-2: Lecture sessions in CADlab-developed courses also contain elements of theatrical performance (above left: a theme reveal in 2.009 in which students learn about the theme for the course) and learning activities (above right, students in 2.00b practice sketching techniques. Bottom: students in 2.744 explore sketch modeling for carnival games).

Similar to lectures, CADlab-developed courses also have optional learning opportunities outside of lecture time provided through extra tutorials. These tutorials cover content that is difficult to fit into regular lecture time. These tutorials might be useful only to a certain subset of the student population or might require the use of a facility other than a lecture hall. Students are not required to go to extra tutorials, so students normally only attend tutorials they are interested in. Some extra tutorials provide students with a chance to practice hands-on skills, whereas other
tutorials may be about communication, teamwork, or design process strategies. Extra tutorials are often taught by course guests with a particular area of expertise. An example extra tutorial session is shown in Figure 1-3.

Figure 1-3: Students in 2.00b learn about soft goods prototyping through learning sewing in an extra tutorial.

1.1.2 Projects

Project work is a key component in a CADlab-developed product design courses because projects are a large source of learning opportunities. Each product design course has a project where the main final deliverable is a product prototype. Projects in design courses provide students with opportunities to practice the design process strategies they are learning in lectures, to integrate knowledge from engineering science and math courses from other parts of the curriculum, to create a context for learning about teamwork, to give students practice with presenting their work, and to allow students a chance to practice craft skills through the fabrication of prototypes. Helping support student project work is the main goal of the research project presented in this thesis.

In CADlab-developed product design courses, students have considerable ownership over their project work. While each final project deliverable involves creating a prototype for some aspect of a product experience, in each course students choose the product opportunity to pursue. We have found that giving students control over their project directions provides additional motivation to execute high quality project work, and course staff are carefully guided to support
project work without taking ownership away from students. Allowing students to choose the direction of project work adds complexity to supporting student prototyping, as the potential space of techniques students might be interested in utilizing becomes larger with greater variety in projects.

Students work on project teams ranging in size from 5 to 20 students depending on the course and the learning goals. Students begin design projects by brainstorming many product ideas, which are identified opportunities where a physical product can be used to address certain user needs combined with early thoughts about what the physical implementation of the product would be. Student ideation work can be seen in Figure 1-4.

Figure 1-4: Students in 2.009 (left) and 2.00b (right) discuss potential product ideas in the beginning stages of their project work.

In each stage of project work after initial ideation, students conduct a series of design activities to learn about their product ideas, growing their body of knowledge about a few different project directions being explored in parallel. As students learn more about a particular project direction, they eliminate ideas until they have selected the one product concept they will present as their final project deliverable. Prototyping is one activity designers use to gather information about a potential product concept.
As part of a larger design process, prototyping represents a way that a designer can learn by using physical materials to explore a question. These questions can vary based on the stage of a design process. Early stage prototypes might explore core functionality or details about user experience, as shown for the toy product idea in Figure 1-5. Later stage prototypes, such as the detailed technical prototypes in Figure 1-6, might explore how product subsystems should be integrated.
to optimize performance. Physical prototypes are not used in all design activities, but their versatility as learning tools can make them useful to designers in a variety of situations, such as conducting user research by taking a prototype to a prospective target user.

In each CADlab-developed course, prototypes are constructed by the students at a variety of levels of fidelity depending on the design question to be explored. Early stage prototypes, often referred to as sketch models, utilize a variety of rapid prototyping techniques using simple materials to explore significant questions with low time and cost investment. As prototypes reach higher and higher fidelity, students use more detailed design and fabrication techniques. Students create CAD models and utilize digital fabrication techniques alongside more traditional techniques such as machining, and woodworking. The full space of techniques that might be relevant to students as part of their project work is large. Some of these techniques are explicitly addressed as part of the content delivered to students through lectures, where as other techniques are expected to come from interactions between students and staff members.

1.1.3 Presentations

Each CADlab-developed design course has student presentations that are typically associated with course milestones. Student presentations are most commonly held in lecture halls which seat the entire course population at once, although there are a variety of design presentation formats where students present their work. During milestone presentations, students present design representations that explain their progress with regard to project work. These representations could be posters, CAD models, or prototypes at various fidelities. Two examples of students using different fidelity prototypes as part of student presentations are shown in Figure 1-7.
Students use prototypes as part of their presentations in 2.744. These prototypes may be early exploratory prototypes (left) or higher fidelity experience prototypes (right).

Some presentations may focus on students discussing their work by projecting slides showing multimedia content about the operation or design of their prototypes, whereas other presentations may focus on discussions with course staff while the staff can directly interact with student prototypes, as show in Figure 1-8.

In many of these cases, students have the opportunity to learn from the work of their peers. Presentations are also an opportunity for course staff to evaluate and contribute to student teams.
that are not under their direct guidance. Final presentations for the courses vary in terms of scale, audience, and presentation style, but all of the final presentations for a course serve two key purposes. One is to motivate students, as they will want to present their best work to the design experts and MIT community members who attend the presentations. The second is to act as a celebration of student accomplishments throughout the term.

1.2 Prototyping Instruction

It is important that student project work resemble the work of practicing designers as much as possible. The opportunity to practice authentic work both motivates students to take learning experiences seriously and better prepares them for their future careers as engineers [1]. However, if students are expected to do real work, they are going to need support. In a large residential course setting, it can be difficult to address the needs of every individual student. In terms of prototyping, students can either be expected to figure out what prototyping knowledge they need on their own or the course staff need to explicitly teach students about prototyping techniques. In CADlab-developed courses, there is a significant effort to teach prototyping techniques to students.

If it is likely that students will be unfamiliar with a particular set of prototyping techniques and that set of techniques will be relevant to most students, prototyping instruction will be included in a lecture setting. In this way knowledge of prototyping techniques can be presented to the entire student population. If only certain students might be interested in certain prototyping content, then there might be instruction given to students through an extra tutorial setting.

The main ways students learn about prototyping techniques in CADlab-developed courses is through demonstrations, activities, and interactions with course staff. Demonstrations and activities are used in lecture and extra tutorial sessions to instruct groups of students in prototyping techniques. In demonstrations, an expert designer practices prototyping techniques while students watch. Sometimes the demonstration of prototyping techniques happens in a lecture hall while at other times in a workshop space.
Sketch modeling techniques—a set of techniques for quickly making low cost prototypes—are likely to be relevant to each student in a CADlab-developed product design course. It is also likely that students coming in to a product design course will not have experience with sketch modeling, which makes sketch modeling techniques a clear choice for teaching in a lecture session. Lecture time is dedicated to sketch modeling demonstrations in each CADlab-developed
design course. Example photos of sketch modeling demonstrations in two courses are shown in Figure 1-9. Demonstrations can also take place in a shop space, as seen in Figure 1-10.

Demos can be coupled with activities where students can try out prototyping techniques themselves. There are several advantages with including activities instead of presenting demos alone. One main advantage is that students can explore deeper nuances associated with application of prototyping techniques through trying these techniques themselves. Several examples of students participating in prototyping activities are presented in Figure 1-11.

Figure 1-11: Activities are included as part of prototyping instruction to give students hands-on experience with tools and techniques.

If students do not come into a design course with knowledge of prototyping techniques relevant to their projects, and those techniques are not covered in lectures or extra tutorials, then course
staff are responsible for supporting student prototyping efforts. Utilizing course staff for supporting project work represents a flexible way to help students with a variety of project needs. Students working directly with staff members can be seen in Figure 1-12.

Figure 1-12: Course staff assist students where other methods of prototyping instruction can fall short.

Course staff can assist students in several ways. Course staff members might have the expertise needed to help students directly, but if they do not, they likely can connect students to another staff member who can better assist them. When the course has access to them, dedicated technical staff like those who work in the Pappalardo Lab can be a great source of prototyping support. Lab instructors, mentors, TAs, and the course instructors also have experience with prototyping techniques. Ultimately, for those techniques not explicitly addressed in lectures and extra tutorials, usually a member of the course staff can help fill in the gaps.
1.3 Course Overviews

Each CADlab-developed course is tailored to fit the needs of students at different points in a mechanical engineering program. An overview of the different courses is summarized in Table 1-1.

Table 1-1: Course details are compared between 2.009, 2.744, and 2.00b.

<table>
<thead>
<tr>
<th></th>
<th>2.009</th>
<th>2.00b</th>
<th>2.744</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Population</td>
<td>150</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Student Year</td>
<td>seniors</td>
<td>freshman</td>
<td>graduate students</td>
</tr>
<tr>
<td>Course Staff Members</td>
<td>71</td>
<td>49</td>
<td>3</td>
</tr>
<tr>
<td>Staff Types</td>
<td>instructors + mentors</td>
<td>instructors + mentors</td>
<td>core team only</td>
</tr>
<tr>
<td>Project Scope</td>
<td>alpha prototype</td>
<td>toy product prototype</td>
<td>experience design + detail prototype</td>
</tr>
<tr>
<td>Workspaces</td>
<td>Pappalardo Lab, Product Design Lab</td>
<td>Product Design Lab</td>
<td>Product Design Lab</td>
</tr>
</tbody>
</table>

1.3.1 2.009 Product Engineering Processes

2.009 (pronounced “two-double-oh-nine”) is the largest of the three CADlab-developed product design courses with a course population of typically around 150 students. The majority of students are mechanical engineering undergraduate seniors. The course is also open to students from other majors who want to participate in the course and contribute to a large team project. Students enter 2.009 with different levels of prototyping experience, ranging from highly experienced mechanical engineering students with a significant amount of previous prototyping-focused coursework to students with little to no prototyping experience previous to 2.009.
Student teams in 2.009 consist of around 18 students. The final, fully functional prototype deliverable is a high-fidelity alpha prototype, which is similar to a production-quality product in operation, appearance, and material choices. An example of a final prototype deliverable from 2.009, a temperature detecting bracelet for firefighters, can be seen in Figure 1-13.

![FireSense, a bracelet for detecting doorknob temperatures to inform firefighters in action, is an example of a 2.009 final prototype deliverable.](image)

Students in 2.009 receive significant support from a large group of course staff members. During weekly three-hour lab sessions, student teams work in a machine shop lab setting under the supervision of the lab staff. Design prototyping work in 2.009 mainly happens in the Pappalardo Lab, an engineering workshop equipped with machines capable of both light and heavy machining. The Pappalardo Lab is run by a director and five technical instructors who work with the students. Students have access to the Product Design Lab (PDL) as a satellite workspace for work outside of business hours. The PDL has no dedicated technical staff and is mainly operated by teaching assistants.

Working directly alongside the students in lab sessions is a team of lab instructors, typically industry or academic professionals who are product design experts. Lab instructors are primarily responsible for guiding their team through different design process stages of project work,
keeping students on track for success and helping them avoid common pitfalls. There are also team mentors who can be practicing designers or design-focused graduate students. Mentors also provide support to the students, typically through their particular area of expertise. Each team of students has two lab instructors and around four or five mentors. At the center of the course staff is the core teaching team that consists of the course instructor and several TAs. This core teaching team is responsible for creating lecture experiences and generally overseeing the entire course. The core teaching team will also support student prototyping efforts.

1.3.2 2.00b Toy Product Design

"Two-double-oh-bee" follows a very similar course model to 2.009 but is adapted for a different population of students. A typical course population for 2.00b is approximately 80 freshmen. Most of these students have not yet declared a major of study and are interested in exploring mechanical engineering, so they often take the course as a way to inform their decision about which major to choose. Most incoming students have a low level of experience with prototyping techniques.

Student project teams in 2.00b are typically 5 students working together to complete a toy prototype. Final toy prototypes should function like and appear like production-ready toy products, but typically have significantly less complexity than a typical alpha prototype from 2.009. An example is provided in Figure 1-14. The scope of the class is appropriately tailored for teams of 5 students with potentially little to no project experience, but with a similar commitment to quality work as in 2.009.
Figure 1-14: Magnitude X, a tabletop game that vibrates to add difficulty to a block building task, is a final prototype deliverable from 2.00b students.

Figure 1-15: Students in 2.00b working in the Product Design Lab, or PDL, under the supervision of course lab instructors and mentors, seen wearing lab coats.

A large amount of student support comes from the course staff through prototyping instruction and lab supervision. Many of the learning experiences in 2.00b are prescriptive, carefully walking
students through practicing prototyping skills. 2.00b teams have one three-hour lab session per week in the Product Design Lab. During these lab sessions, each team in 2.00b is guided by a lab instructor who is either a design professional or a graduate student studying mechanical engineering with an interest in design. There are also one or two mentors, usually undergraduate upperclassmen, assigned to a team. Mentors are typically Toy Product Design alumni or undergrad students looking for more product design experience. Lab instructors and mentors can be seen supervising students in Figure 1-15. A core team of course instructors and teaching assistants has a similar role as in 2.009 in that they are involved in both creating lecture experiences and supporting student project work.

1.3.3 2.744 Product Design

Finally, "two-seven-four-four" is a graduate-level course, although some undergraduates take the class as well. Students in the course are primarily mechanical engineering students, but it is also common for students from a variety of business-focused graduate programs to take the course. In terms of incoming experience with prototyping, some students come into the course with a high level of experience from undergraduate mechanical engineering courses, whereas others come in with less experience. Some graduate students entering 2.744 are coming from backgrounds outside of engineering and may have no incoming prototyping experience at all.

Project teams in 2.744 are self-selected groups of around 6 students. This is in contrast to 2.009 and 2.00b teams, which are carefully crafted by the teaching staff. Balancing skillsets and interests within project teams is an area where the course staff in 2.744 relies on the maturity of the students. The project brief in 2.744 changes each year based the industry partner for the course. For several years, the course has worked with the company Five Wits to produce interactive experiences, with the latest implementation of the course charging students with developing aspects of "escape rooms," interactive room-sized puzzles designed for entertainment. Final prototypes in 2.744 do not always represent an entire product. Often the prototyping component of the course is scoped so that students resolve a single component of the whole experience to a high level of fidelity, considering the entire experience but executing a prototype that only
encompasses one key aspect of this experience. Examples of 2.744 experience prototypes are provided in Figure 1-16.

![Image of student teams in 2.744 with their final deliverables, a light up puzzle (left) and a tilting platform laser game (right), each designed to be a part of larger escape room experience.]

Lecture sessions include activities where students practice sketching, digital rendering, sketch modeling, and design details such as color and form, but 2.744 does not have supervised lab sessions. The support level for project work in 2.744 is much lower than in 2.00b or 2.009. Students are expected to organize and complete project work on their own. The only shop space provided to 2.744 students is the PDL, which is also shared with the 2.00b class that is run subsequently during spring semesters. However, since the class is made up of graduate students, students in 2.744 will typically have access to additional shop spaces either through research labs or public shop spaces on campus. The core team of the course instructor and two or three teaching assistants is responsible for the entire operation of the course, including lecture experiences, course activities, and supporting project work.

1.4 Principles of a CADlab-developed Course

Each CADlab-developed course differs in a variety of ways, but there are a few principles that guide how all of the courses operate. These principles, while not hard and fast rules, are part of
what make CADlab-developed courses a special experience for students. These principles have
had an influence on the design and implementation of the Designy platform.

1.4.1 Set an Example of Good Design

In project work, students are expected to exhibit a high level of quality in their craftsmanship and
design. Prototypes from these courses sometimes represent the highest fidelity project work
students complete in the mechanical engineering curriculum at MIT. In order to create an
environment where high-quality work happens, course staff in CADlab-developed courses have
to hold themselves to a high standard when creating course learning experiences. Any aspect of a
course experience, whether it is a physical prop, multimedia to be shown in lecture, or part of the
lab space, should be an example of high quality work. Conversely, if an aspect of a course is
poorly executed, students may take that as an invitation to execute poor quality work themselves.
For this reason, course staff in CADlab-developed courses strive to keep a high level of quality in
all aspects of a course experience.
1.4.2 Work Can be Fun

Figure 1-17: Fun is a key part of the course atmosphere of CADlab-developed courses. Shown here are students having fun in the 2.009 build challenge (top), during an electronics prototyping extra tutorial session in 2.00b (bottom, left) and during a presentation session in 2.744 (bottom, right).

Another theme in CADlab-developed courses is the idea that hard, valuable, meaningful work and fun are not mutually exclusive experiences. Often times, fun can make hard work more manageable, more interesting, and result in a better learning experience. Creating fun learning experiences can also keep staff members engaged as well! Fun finds its way into course experiences in a variety of ways, as exhibited in Figure 1-17. Overall, fun and humor are used to foster a sense of community in CADlab-developed courses that can be a key aspect in making students feel comfortable interacting with course staff and with each other while they work.
1.4.3 Continuous Improvement

Each year feedback is solicited from the course staff and from students to identify areas of future improvement. In this way, CADlab-developed courses are constantly changing and evolving each year. Not all changes to a course end up realizing their intended improvements, as it is difficult to predict all of the factors that affect learning experiences in as complex a setting as a project-based course, but an attitude to try to improve is present in the CADlab course staff. The research project presented in this work is an example of trying to improve the student experience as part of continuous improvement.

1.5 Online Multimedia Environment

Digital multimedia and online technology continue to be incorporated into CADlab-developed course experiences in new ways as part of continuous improvement efforts. In order to better understand the use of multimedia and online technology in CADlab-developed courses, a few relevant examples are presented here.

1.5.1 Multimedia for Community Building

Each CADlab-developed course has a custom website used to support various aspects of the course. The home page of each course website has a section for photos of students. On the 2.009 webpage, a scrolling reel of photos, seen at the bottom of Figure 1-18, shows students participating in learning activities, working on their projects, and becoming closer team members.
Throughout the term, course TAs take photos and videos of students participating in various learning opportunities, including lectures, tutorials, project work, and presentations. This media is then used in a variety of ways. Photos find their way into lecture slides to review key points from past learning experiences. For the final presentations in each course, media collected throughout the term is used as part of the celebration-focused aspects of the final presentations. Of course, no community building activity would be complete without proper social media content. Many CADlab-developed courses have accounts, managed by the TA team, on popular social media platforms like Facebook, Instagram, Twitter, and Snapchat. The TA team uses these social media platforms to post content about students working together, behind-the-scenes
media, and generally fun stuff. The multimedia captured throughout the term represents a key part of what makes each semester a special experience for the students.

1.5.2 Documentation of Student Work

In a CADlab-developed design course the semester is marked by milestones where students are tasked with presenting their work to both their peers and the course staff. Student presentations are often filmed. In 2.009, these video recordings, along with photos of student prototypes, form the basis for a review system where documentation of student work is provided for course staff members to review online and leave written feedback to the students.

The multimedia documentation from the milestone reviews and final presentations for 2.009 are also used outside of the review systems. In 2.009, this media is collected on the 2.009 Course Gallery, a collection of all of the multimedia documentation of student projects [44]. This includes multimedia created by the students, such as presentations slides, videos, photos, and diagrams. By browsing the gallery, students can review the project work of past students in order to prepare for upcoming milestone reviews themselves.

By curating some examples of exemplary work from past years, instructors can give students concrete examples of what high quality work looks like, encouraging improvement in student projects year over year. In 2.00b and 2.744, students can view video documentation of past final presentations on a Vimeo playlist. Through video documentation, students in the current course connect with students of the past.

1.5.3 Directly Supporting Student Learning

Course websites are also used as learning management sites. The home page of each website shows relevant course information that is updated regularly to reflect the current status of the course. Here students can find the relevant assignments, information about upcoming milestones, and links to interesting content related to what is being covered in lectures and labs that week.
There are examples of video resources on design instruction, including content on sketch modeling techniques, that were used to support student project work prior to the creation of Designy. Screenshots of frames from these video resources are presented in Figure 1-19. Use of multimedia to deliver prototyping content to students in a CADlab-developed course dates back to 1997 [18] [19]. In 2007, a series of video tutorials were made available to students via the 2.009 Course Website.

Overall, content for supporting student prototyping efforts is limited on course websites. Only a few resources are provided to students, and many of these resources were dated and needed updating. Through existing multimedia-related efforts, CADlab course staff have built up an extensive stock of media production equipment including cameras, microphones, lighting, and more. A natural extension of this media production environment was to more deeply explore the use of multimedia to deliver design content to students. The existing multimedia environment, coupled with the additional need to further support student prototyping efforts, provided the context for creating the Designy platform.
Chapter 2

Supporting Student Prototyping

The design process for Designy included a broad conceptual exploration of what an online platform could provide to students in design courses. While this conceptual exploration included a broader look at supporting several aspects of student project work, a decision was made to focus on supporting student prototyping. Web prototypes created during the early design phases for Designy created a context for discussions with students about the difficulties associated with project work CADlab-developed courses. A more detailed discussion of the design process that resulted in the Designy platform is provided in Appendix A: Design Process.

Discussion with students about use of the online media to support student prototyping efforts, coupled with the author’s teaching experience working directly alongside student teams, provides the basis for the analysis presented in this chapter. This chapter begins with a summary of identified problems with prototyping instruction in CADlab-developed courses. Next, reasons for why an online platform is a good fit for a supporting prototyping are presented, followed by an analysis of existing online multimedia solutions and why they may not be ideal for students in CADlab-developed courses.

A series of Anticipated Use Cases were outlined based on how students in CADlab-developed courses might utilize a new platform for supporting prototyping. Information about the context of CADlab-developed product design courses was also analyzed to form a series of design attributes, referred to here as Designy Attributes, which together with the Anticipated Use Cases inform the design of the fully realized Designy platform. The Anticipated Use Cases and Designy Attributes are outlined in this chapter, and how they factor in to the implementation of the Designy platform is discussed in Chapter 5: Designy Implementation.
2.1 Problems with Prototyping

2.1.1 Learning about Prototyping in Lectures and Extra Tutorials

Prototyping instruction in lectures and extra tutorials provides students with the knowledge they need to complete project work. Instruction in these settings is often provided through demonstrations and activities. However, certain features of demonstrations and activities are problematic for both students and instructors.

Live demonstrations can be a great way to learn about prototyping techniques, but sometimes demos are crowded and it can be difficult for students to see the action. There can be many steps and details to remember from a demo, and students can have trouble remembering these steps and then subsequently practicing demonstrated techniques in their project work. Through demos alone, students may struggle to operationalize the techniques they are learning to apply them to their project work. For instructors, providing demos to students comes along with a significant amount of preparation. Demonstrations can also take a significant amount of instruction time, limiting the number of demonstrations that can be provided to students.

Another way to teach prototyping techniques is through active learning during lecture or tutorial sessions, allowing students to more deeply explore techniques by trying them out themselves. Participating in structured learning activities where students are lead through prototyping techniques step-by-step can help students operationalize the techniques they may learn through demonstration. The main disadvantage of learning prototyping through activity is the time and cost associated with creating activities for students to learn from. Preparation and required instruction time are both increased greatly when providing students with an activity to learn from. In CADlab-developed courses, there is a preference for teaching through activity despite these costs, but the time and cost of activities still ultimately limits the amount of prototyping instruction that can be provided to students through activity.

Whether learning through activity or live demonstration, it can be hard for students to remember what they have learned and apply it to their project work. Prototyping techniques can
involve many steps that need to applied in a detail-oriented manner. Often times, providing students with a reference that highlights key points in prototyping techniques can help them apply what they have learned to their own work.

2.1.2 Student Feelings of Intimidation

Even if students remember what they have learned in demonstrations or activities, they still may feel intimidated by the shop equipment. The hesitation students might feel toward using shop equipment is a reasonable one, as shop equipment can be dangerous if used improperly. Students may also be self-conscious about potentially misusing equipment and being reprimanded, or they may be afraid of embarrassment about the craftsmanship of their work. In some higher-level design courses, this issue can be exacerbated by expectations that students should be coming into product design courses with experience using fabrication equipment.

To help cover instances where prototyping instruction cannot be provided in lectures or extra tutorials, course staff are assigned to help students with their prototyping work. However, there are also challenges associated with student interactions with course staff members. Help from course staff relies on students being open to interacting with staff members that are there to help them with their work. One potential roadblock for students is that they can be hesitant to reveal that they need assistance. This hesitance can come from worrying about their course grades, a feeling of embarrassment, or potential feelings of intimidation towards the course staff despite the staff’s best efforts to appear friendly and approachable. Staff need to be aware of when students might be hiding the fact that they need additional help, but ultimately if a student is not open to receiving help, it will be difficult to address their needs.

Of course, not all students experience feelings of intimidation in a shop space. Some students enter CADlab-developed courses with complete comfort in utilizing shop equipment and interacting with course staff. Other students have indicated a feeling of pressure to perform, particularly in 2.009, resulting in a hesitance to attempt prototyping activities for fear of failure. These students occasionally default to others students who step up to take ownership of prototyping activities.
While trying to understand the underlying impetuses of student intimidation can be complex and difficult, it is clear to see that there are shortcomings with relying on students to ask for help with prototyping activities. It is possible that better preparing students for prototyping work may help them feel more prepared for conversations with staff members, less intimidated by shop equipment, and more receptive to getting help from course staff members.

2.1.3 Understanding the Prototyping Landscape

Another identified issue with student prototyping is that students can struggle to understand all of the tools available to them for prototyping work. Even if they can identify different options for fabrication methods, choosing between those options can be difficult for a student to do. Understanding the landscape of available tools is particularly difficult because the landscape seems to change each year, as workspaces evolve to include new tools and new materials. Course staff can help students navigate the landscape of potential fabrication methods and equipment to use, but even course staff familiarity of the available prototyping equipment can be limited, as many staff members may be unfamiliar with the full set of tools available to the students. This problem is coupled with the fact that students also do not always have access to the course staff when they have questions about prototyping-related issues.

2.2 Online Multimedia for Prototyping

2.2.1 Affordances of an Online Platform

An online media platform can potentially help address some issues students have with prototyping efforts. One advantage of an online platform is that students have access to the platform at any time. What this means for students is that they have the platform as a resource when the course staff might otherwise be unavailable.

Another benefit of utilizing an online media platform is that the platform can be optimized for scalability, with the potential to expand to cover more content in a way that expanding face-to-face prototyping instruction cannot. Course time cannot expand to cover the large space of
possible prototyping techniques that students might find relevant to their project work, but an online platform, through development efforts that can span multiple semesters, can expand to cover content that would otherwise be left for students to seek out on their own. Online content could be used to cover niche topics that would not fit lecture instruction. These factors make delivering prototyping content a good fit for an online platform.

In terms of multimedia delivery, there are some advantages to delivering prototyping-related content through photos and videos. Small details can be highlighted in a video or image through the use of detail shots and macro photography. In this way, media can be used to highlight small but important details that might be lost in a quick or crowded demonstration. Multimedia also allows students to revisit parts of a video over and over, going at their own pace to make sure they do not miss any relevant details.

2.2.2 Existing Multimedia Solutions

The vast Internet does already provide a broad range of exiting multimedia resources that students could use to support their prototyping efforts. Many examples of online tutorials exist on a variety of sites aimed at the designers, makers, and students of the world. In order to evaluate these existing multimedia solutions in terms of how they might benefit students, a few examples are provided. Two key resources students might use to support their project work are YouTube and Instructibles Classes.

YouTube has a huge pool of resources provided by the vast community of equipment producers, DIY enthusiasts, and professional modelmakers. The video tutorials that can be found on YouTube range from videos about using shop equipment to following professional prototypers around while they conduct design activities. One famous example of following a professional modelmaker includes the One Day Build series produced by Tested, shown in Figure 2-1, which follows former Mythbuster Adam Savage around while he conducts relatively short prototyping and modelmaking activities [45].

Following along while Savage narrates his thought process as he demonstrates techniques in his shop space provides viewers with an opportunity to learn what an expert designer is thinking. These videos also expose viewers to demonstrations of prototyping techniques. While One Day Builds are an example of high-quality, useful content students could use to learn about prototyping, these resources are optimized for entertainment instead of instruction. While there are additional examples of high-quality prototyping-centric entertainment that can provide students with inspiration and knowledge to become better prototypers, many YouTube resources can lack the quality needed to support design education.

Instructibles offers a series of tutorials uploaded by their community that walk their users step-by-step through DIY-style activities and projects. Recently Instructibles has branched out to more professionally produced content provided through Instructibles Classes [25]. Many of these tutorials are about the use of shop equipment that design students might use through project work in design classes.
After the first pass raise the blade up in increments until you cut through the wood, or you reach the maximum height of your blade. For most 10" saws this will be around 3" maximum height.

When you’ve reached the maximum blade height, keep the fence and featherboard where they are and just flip the wood over and align the cut channel with the blade. Repeat the same process of starting with a shallow up and raise the blade after each successive cut.

Figure 2-2: An example of multimedia use in an Instructibles Class covering table saw use.

Multimedia tutorials on Instructibles Classes rely heavily on the use of images and text, but can also contain short looping animations and videos. Overall, Instructibles classes provide users with reasonable quality tutorials across a variety of content.

Although there are existing multimedia resources that could be used to support student prototyping in product design courses, there are many reasons why these resources do not represent an ideal solution for students in a product design course. One big issue with existing resources is that the users of online tutorials are rarely using the same equipment students will be using in their project work. Having resources that align with the exact equipment students have access to makes those resources more relevant and increases the likelihood that students will be able to extend what they have learned to their project work.
Another issue with existing resources is that they are rarely presented in the context of product design prototyping. Online tutorials can be overly thorough if they are meant for people who need to maintain shop equipment, for example. Many online tutorials are aimed at DIY enthusiasts, and while there is overlapping content, the requirements for making a design prototype typically vary in terms of quality of appearance or operation when compared to a DIY project.

Finally, finding relevant online tutorials in the sea of available resources can be overwhelming. It can take long stretches of repeated internet searching for students to sort through material to find a resource relevant to their project work. The time and effort it takes to dig up relevant resources can cause students to be reluctant to search for additional information on their own. A custom online platform could contain both custom multimedia produced for design students and curated resources from the broader internet. By providing students with relevant resources, they will be more likely to utilize additional support. Making high quality resources easily accessible to students could even help motivate students to seek deeper knowledge beyond what is provided by a course through prototyping instruction.

2.3 Anticipated Use Cases

Insights about student prototyping work came from teaching experience, working alongside student teams, and some preliminary research activities discussed in Appendix A: Design Process. Identifying the problems students have cited with prototyping work in product design courses was an important step towards creating a potential solution through the use of a custom online multimedia platform. The series of Anticipated Use Cases that were outlined in an effort to explore how the platform might be used by students to support their prototyping efforts is presented in Table 2-1.
Table 2-1: Anticipated Use Cases were outlined to connect student problems with prototyping to potential solutions using an online platform.

<table>
<thead>
<tr>
<th>Anticipated Use Case</th>
<th>Student Problem</th>
<th>Potential Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Students have a hard time understanding the landscape of available prototyping tools and techniques.</td>
<td>Present information about fabrication options and design guidelines for students to use when planning prototype execution.</td>
</tr>
<tr>
<td>Preparing</td>
<td>Students may feel uncomfortable prototyping due to feelings of unfamiliarity or intimidation of the equipment or staff.</td>
<td>Provide students with resources they can use before coming to work in a shop space.</td>
</tr>
<tr>
<td>Exploring</td>
<td>Staff members have a varied level of understanding of prototyping tools and techniques available to students.</td>
<td>Provide students with comprehensive documentation of the tools and resources for them to explore out of curiosity.</td>
</tr>
<tr>
<td>Executing</td>
<td>Students find it hard to remember and operationalize what they learn in live prototyping demonstrations and activities.</td>
<td>Provide students with references to follow while executing prototypes.</td>
</tr>
</tbody>
</table>

2.3.1 Planning

Students come up with ideas for what a prototype should be based on the questions they want to answer in order to progress their product concept. They may need support in planning the execution of their prototype. During this process, the online platform could provide students with resources documenting the landscape of possible tools and techniques they may want to consider for the creation of their prototypes. This could aid students in choosing which fabrication methods to utilize during the creation of their prototypes or may aid by providing design guidelines for designing prototypes meant to be fabricated utilizing a particular technique.
2.3.2 Preparing

Whether or not students have plans to fabricate a specific prototype, they know at some point they will need to work in the shop space to create prototypes. Some students may want to use the platform to prepare themselves for working in the lab, becoming familiar with the operation of machines and the details of performing prototyping techniques without a specific task in mind. In this way the platform could be used to help prepare students more generally for working in the shop space.

2.3.3 Exploring

Students may simply be curious about the prototyping capabilities afforded by the shop space. They may want to know more about the equipment and tools they have been exposed to in demonstrations, or may be interested in finding out more about all of the available tools and supplies they have access to. The platform should capitalize on this natural curiosity, exposing students to a wide breadth of information without making them feel overwhelmed.

2.3.4 Executing

It can be hard to remember the steps a student might have learned about in a lecture demo, a course activity, or through interactions with a course staff member. The platform could provide students with a reference while working directly with shop equipment to execute their prototypes. If course staff are not present or are not able to help students in the shop, students can use the references on the platform to progress with their prototyping work.
For reference, the Anticipated Use Cases are compared in Figure 2-3. The Anticipated Use Cases of Planning and Executing both outline ways in which students might use Designy while trying to address a specific question about a prototyping task they are trying to complete, whereas during Preparing or Exploring, students are becoming informed in a more general way. Executing is the only use case where students would need to utilize the platform while in the shop space, whereas the other use cases can happen inside or outside of the shop.

2.4 Designy Attributes

In addition to outlining several potential use cases of the Designy platform, it was also useful to outline several attributes the platform would likely need in order to be properly situated within the context of a CADlab-developed course. These attributes come from an analysis of the context in which the platform would be used, CADlab-developed product design courses, as well as from discussions with students. Without exhibiting the attributes outlined here, it was the opinion of the author that the platform would not be heavily utilized by students.

2.4.1 Flexible

The platform was intended to be used in a variety of use cases. In addition, students with different levels of incoming experience might be interested in using the platform, so it must also support a variety of users. Often times, when designing any product to be used in multiple ways,
tradeoffs must be made that can reduce the overall effectiveness of the product. For this reason, the platform needed to be carefully designed to be flexible enough to handle multiple use cases with a single implementation.

### 2.4.2 Exemplary of Good Design

In a CADlab-developed course, any teaching tool needs to set an example of good design in the minds of the students. The implementation of the website itself, as well as any media resources hosted on the platform would all have to be an example to the students of what good web and multimedia design should look like. This is important because students often develop multimedia themselves to document and present their work. If the platform does not set a strong example of quality work, it could act as an invitation for students to conduct poor quality work themselves.

### 2.4.3 Fun

Throughout each CADlab-developed course there is an effort by the course staff to show students that they can have fun while working hard. This element of fun in a course should follow through into the Designy platform and the media contained within it. By being fun to use, not only are students hopefully delighted and inspired to continue using the website, but the platform itself would seem more like an integrated part of a course that is fun to take. Therefore, if the platform is fun, it will fit better into the overall course experience.

### 2.4.4 Usable

Creating a usable website is a good idea for any web development project or any teaching tool, but this design attribute has specific implications for being part of a project-based product design course. Students in project-based courses are very busy, dealing with the task of completing project work while managing the wide array of learning opportunities presented to them. In order to have a chance at helping students with their project work, the website must be careful to not create confusion or else risk students giving up on use of the platform entirely. The platform would need to prove its utility before even being used by students, and then provide a simple and
rewarding experience during use. In other words, use of the platform would need to be fast, simple, and clear to actually be utilized by students.

2.4.5 Present

If students are not aware of the platform, they certainly will not be active users. Multiple communication channels would need to be used to make sure student awareness of the platform is high.
Chapter 3

Designy Implementation

Designy takes inspiration from aspects of many existing platforms for online learning, taking ideas from these websites and modifying them to fit the goal of supporting student prototyping in CADlab-developed courses. Online course hosting platforms like Coursera or edX utilize multimedia, primarily in the form of narrated videos, to deliver content to users. Originally, Designy was planned to primarily be comprised of video content, which was explored in previous work, but eventually it was decided that video alone would not best suit student needs [46]. Examples of multiple multimedia formats used in Instructibles Classes and manuals documenting the operation and maintenance of Formlabs 3D printers are notable instances of inspiration for multimedia resources on Designy [25] [47].

Although the Designy platform will continue to evolve and change as it is used in future design courses, the implementation of the platform as it was used in Spring 2018 is documented in this chapter. Student use of Designy in 2.00b Toy Product Design and 2.744 Product Design during that semester provides the setting for evaluating Designy in Section 2. A detailed description of the web platform and the multimedia resources it hosts are presented here. A technical description of how the platform works is provided in Appendix B: Website Documentation.

3.1 Web Layout

To begin explaining the implementation of the Designy platform, it will be useful to walkthrough a typical user experience. The platform is currently not open for public use, and is only accessible to users with a username and password provided by the author. Students are given usernames and passwords that are easy to remember. No critical information about students is stored on the website, so passwords can be simple and shared to make it easier for students to log on.
After students log in, they are presented with the **media library** page, seen in Figure 3-1. On this page, all of the multimedia resources a student has access to are presented to the student. The **recently viewed** section can be found at the top of the page, which shows the most recent four online resources the student has visited. Below the recently viewed page, resources available to the student are presented in a tile layout, with a series of **topics** organized under a given **category**. Topic tiles contain a photo that helps students quickly identify what the tutorial is about. The use of photos helps students find resources when they may not know the name of a particular piece of equipment or technique. The flat organizational structure of the website was
chosen in contrast to a more linear format, which is a common format for online courses. This structure allows for students to utilize any resource hosted on the platform at any point in a design process, which is important because design processes among student teams can vary greatly depending on specific details of the project. Upon clicking on a panel, a student is taken from the media library page to a **content page**, as shown in Figure 3-2.
Bandsaw

A Versatile Cutting Tool

Bandsaws are useful to prototypers for their versatility. They can be used to cut a wide variety of materials with little setup time. Different specialized blades can be put in a machine to depend on the job to be done.

For freeform shapes, typically all you have to do is adjust the blade guard and start the machine up. For straight cuts, we have a machine with an adjustable fence for pushing your workpiece up against.

Operating a Bandsaw

Figure 3-2a: The top portion of an example content page about using one of the bandsaws located in the PDL. The beginning sections show basic operation and outline use of the tool in a design prototyping context.
In the PDL, the Rikon machines have a thinner blade with more teeth (12tpi) or teeth per inch. Having more teeth on a blade leads to a slower, more controlled cut. This blade can handle a wider variety of materials, including plastic and metal. Having a thinner blade means you can cut tighter curves. Since the cut is less aggressive, this blade leads to a nicer finish.

The other type of blade used in the PDL is a thicker blade made for cutting wood. Larger teeth with more space in between them allow for more material to be removed, resulting in a faster, more aggressive cut with a slightly rougher finish. The wider blade makes it harder to cut tight curves, but it's better for straight cuts because this blade has a tendency to drift while cutting. Although this blade can handle a variety of materials, we tend to use it mostly for wood.

Figure 3-2b: The remaining sections of the bandsaw content page, highlighting important features of the tool and providing helpful operation tips.

A content page hosts a variety of helpful media resources on a single web page. Multimedia resources can be about how to operate a piece of equipment, how to perform a collection of techniques, or can present a series of tips. Each content page is broken down into sections. Most
content pages start with an overview section at the top of the page, showing students quickly how the equipment or techniques fit into creating design prototypes. As a student progresses down a content page, they are presented with more detailed information about the tool or technique. Through careful organization of multimedia resources, a single content page can provide useful information to both inexperienced students looking for a starting point and experienced students looking for more detailed information. When browsing a content page, there is a navigation menu on the left side of the screen that remains on the screen as the student scrolls through the page. This menu has helpful links to the different sections on that particular content page, which helps the student browse that content page if they want to skip to different sections, and also has links to other resources that are in the same category as the topic the student is browsing.

3.2 Media Elements

Each section of a content page is made up of related digital media elements created from photographs, videos, and vector graphics. An outline of the media elements found on Designy is presented here.

3.2.1 Photo-based Media Elements

![Images](image.png)

Figure 3-3: Images, both with and without a backdrop
The most prevalent media element on the website are **images** (Figure 3-3). Images are made by editing digital photos and are used both with and without backgrounds to highlight particular tools, materials, and details about certain operations. Images are used in combination with text to provide descriptions about important fabrication details. Most of the images used in multimedia resources are created in the PDL and office studio, but images are also pulled from the Internet if sufficient quality images are found.

![Image of equipment]

*Figure 3-4: Annotated Images*

In order to better explain specific elements of a photograph, an **annotated image** (Figure 3-4) is produced to make certain terminology known to students. Annotated images can be used to outline different parts of a piece of equipment or to highlight details on an existing prototype.
Physical props are photographed to create prop graphics (Figure 3-5), which show specific details about a prototyping technique using the same physical materials that students might be using in a design prototype.

Multiple images and graphics are strung together in order to create workflow graphics (Figure 3-6). These graphics quickly show the major steps that need to be performed to operate a piece of equipment or to perform a technique. In this way, workflow graphics quickly outline fabrication steps, helping students quickly gauge how to properly prepare for a fabrication method.
The use of **interactive web graphics** (Figure 3-7) as a media element was also explored. Currently, only one interactive web graphic exists on Designy, because these graphics require a significant time investment and can behave differently on mobile devices.

### 3.2.2 Video-based Media Elements
Narrated videos (Figure 3-8) are videos that include both audio and visual elements and are typically filmed demonstrations. Most often, narrated videos are used to show the operation of a particular piece of equipment. Narrated videos often include all of the details needed for the basic operation of a piece of equipment, providing students with a “one-stop shop” to be able to quickly get started using a tool or technique. Chapter markers are used to make searching easier and to make video organization clearer. Of all of the media elements, narrated videos take the longest time to produce.
An animation (Figure 3-9) on the Designy platform is a short, auto-playing, looping video. These media elements can have annotations inserted into the video as well. Animations are normally used in place of photographs where additional detail is provided by showing how an action plays out over time. Multiple animations together are used to form Cheat Sheet sections (Figure 3-10), where various steps of an operation are listed with animations side-by-side with paragraphs of text. In this way, animations can be used though Cheat Sheets to provide references students can work along with.
Now it's time to hop on Illustrator! We have a dedicated computer by the machine that has the Roland CutStudio plug-in installed. Make sure that Model is set to GX-24. Also, make sure to go to the panel options and check the Connection menu. If the USB option is blank, then the machine will not properly connect.

The CutStudio plug-in has many options to help you set up your job. One of the more helpful ones is Move to Origin which takes your artwork and moves it to the bottom left corner of the sheet so that you don't waste any plastic. In this example, the plug-in is set to Output All Lines and we can see the updated preview window. You can also choose to output selected lines, or lines on a particular layer. Explore the plug-in to find some more useful features! When you are ready to cut, press the Output the Paths button.

Figure 3-10: An excerpt from a Cheat Sheet section showing students how to operate the Vinyl Cutter. The still images in this figure are animated on the live vinyl cutter content page.
3.3 List of Resources

In total, Designy includes 28 multimedia resources organized in 6 different categories. These topics contain a total of 67 unique media elements. A shorter resource might only contain 2 or 3 media elements, whereas longer resources can contain upwards of 15. These media elements are constructed of thousands of pictures and video clips recorded during the development of Designy. The Bandsaw multimedia resources, which represents a typical Designy resource in terms of level of detail, involved shooting 19 photos and 69 video clips that were then used to construct the 15 media elements on that content page. The section headings and media element count of each topic is listed in Figure 3-11.
3D Printing

3D Printing Overview
- Intro
- Choosing a printer
- Integrating hardware
- Visual models
- Design tips
  media elements: 9

Up Plus 2
- Overview
- Workflow
- Post-processing
  media elements: 5

Prusa
- Overview
- Workflow
- Post-processing
  media elements: 4

Dimension
- Overview
- Workflow
- Post-processing
  media elements: 5

Objet Alaris
- Overview
- Workflow
- Post-processing
  media elements: 7

Digital Fabrication

Digital Sheets Overview
- Digital sheet machines
  media elements: 5

Laser Cutter
- Laser beams
- Operation
- Parameters
- Materials
- Vector cutting
- How to vector cut
- Raster cutting
- How to raster cut
- Makeercase
- Gear generator
- Tips
  media elements: 12

Vinyl Cutter
- Overview
- Stickers and masks
- Label Cutouts
- Operation video
- Sticker workflow
- Stickers cheat sheet
- Label workflow
- Labels cheat sheet
  media elements: 18

Carvey
- Overview
- Example projects
- 2D Carving workflow
- 2D Carving cheat sheet
  media elements: 10
Shaper
overview
example projects
workflow
operation
cheat sheet
media elements: 10

Handheld Tools

Power Drill
overview
media elements: 2

Impact Driver
overview
operation
media elements: 3

Jigsaw
overview
media elements: 2

Hand Router
overview
media elements: 2

Dremel
overview
media elements: 2

Sanding
overview
orbit sander overview
detail sander overview
media elements: 3

Figure 3-11: Each category and topic on the Designy platform, with the associated section headings and a count of media elements in that resource.
3.4 Course Integration

If students are expected to use an optional learning resource in a design course, that resource needs to have a strong presence in the course or students will forget about it. When the platform was ready to be used by students, an email was sent to them with their login information. It was assumed that only a limited number of students would log on to the platform from an email alone. Students in design courses tend to be very busy, and even if something like the Designy platform will benefit them, they will not take the time to use something that requires their time if they do not see the value of its use.

3.4.1 Creating Awareness of the Platform

Throughout the semester, efforts were made to integrate the platform into both 2.00b and 2.744 to get students to understand the value of the platform. Students were never required to log in, as the platform is designed to be an extra resource to help students who may need it. No assignments required the use of the Designy platform and there was no tie between usage of the platform and grading. Even though requiring students to log on to the platform would expose them to the potential benefits it could provide, making something a requirement without justification could be interpreted as wasting a student’s time and potentially discourage future use of the platform.

Figure 3-12: A demonstration of the Designy platform was given to 2.744 students to raise awareness of the platform. A similar demonstration was given to 2.00b students and staff members.
In addition to email updates, students received demos of the Designy platform in order to give them a better understanding of what the purpose of the platform was. Photos from an example demo in 2.744 are provided in Figure 3-12. Students in 2.00b and 2.744 were given a live demonstration of using the website to clear up any potential issues regarding logging on to the site and navigating it. Similar demos were given to the course staff so that staff members also understood the platform and could refer to it when guiding students during project work whenever appropriate.

### 3.4.2 Physical-Digital Connection

There were also ties between the physical lab space—the PDL—and the Designy platform through the use of QR codes. Equipment and tools in the shop that had associated online resources were marked with a sticker containing a scannable QR code that would take a mobile device user directly to the Designy page associated with that piece of equipment. An example QR code is shown in Figure 3-13.

![QR Code Example](image)

**Figure 3-13:** QR codes were attached to shop equipment that had associated Designy tutorials. These codes could be scanned using a mobile device to help students quickly navigate to the relevant Designy page on the phones and subsequently their laptops.

If students then wanted to view the resource on a laptop computer instead, they could visit Designy on their laptops and navigate to the Recently Viewed section of the media library to view
the content page they were just browsing on their mobile device. Even if students were not interested in using their mobile devices to scan QR codes, the physical sticker would still act as a visual indicator, letting students know that there were associated Designy resources. Use of QR codes was covered in the lecture demos about Designy.

Besides performing the lecture demos, the author was also part of the course staff for each CADlab-developed course run during Spring Semester 2018, with the primary responsibility of helping students with project work in the PDL lab space. By being both the developer of the Designy platform and an instructor helping design students, the author could recommend Designy multimedia resources when appropriate. However, the platform is designed for use in specific situations, one of which is when students do not have access to a course staff member. There were no instances were a student was seeking help via a face-to-face interaction and the platform was recommended instead of directly helping students with prototyping work.

3.5 Supporting Student Prototyping with Designy

The Anticipated Use Cases and Designy Attributes presented in the previous chapter were used to inform the design of the platform. A few highlights about how these factors affected the implementation of the Designy platform are shown in Tables 4-1 and 4-2. A summary of the media elements used to create the content pages is presented in Table 3-3.
<table>
<thead>
<tr>
<th>Anticipated Use Case</th>
<th>Design Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>overview sections quickly express how tools and techniques can contribute to prototypes, aiding students in choosing between fabrication methods. Design guidelines are presented in multimedia resources regarding how prototypes should be designed to accommodate particular fabrication methods.</td>
</tr>
<tr>
<td>Preparing</td>
<td>Detailed information is provided on the exact tools students will be using in the shop space, directly preparing them for working in the shop.</td>
</tr>
<tr>
<td>Exploring</td>
<td>The media library page is designed with attractive thumbnail photos in a tile layout to capitalize on student curiosity. Multimedia resources are organized on the media library page in a flat structure to present students with a broad array of resources at once.</td>
</tr>
<tr>
<td>Executing</td>
<td>Narrated videos and cheat sheets provide students with a reference to follow alongside when conducting prototyping activities. QR codes provide direct access to relevant resources when in the shop space.</td>
</tr>
<tr>
<td><strong>Designy Attribute</strong></td>
<td><strong>Design Features</strong></td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------------</td>
</tr>
</tbody>
</table>
| Flexible              | content pages provide multiple media elements, sometimes with redundant content, to support use in different prototyping situations.  
the website can be displayed on a variety of screen sizes.  
both basic and detailed information is provided to accommodate students with both low and high prototyping experience. |
| Exemplary of Good Design | attention to detail in graphic design creates a clean aesthetic.  
media elements are produced with high technical quality. |
| Fun                   | whenever possible, humor is added to media elements to delight student users and to better fit into the context of a fun course. |
| Usable                | website layout is flat to make navigation easy.  
media resources are designed to be concise, direct, and clear.  
photo thumbnails are provided so students can quickly find what they are looking for, even if they do not know the name of the equipment or tool. |
| Present               | awareness was increased through course demos, email, and slack communication. |
Table 3-3: A Summary of Multimedia Elements and their intended applications.

<table>
<thead>
<tr>
<th>Photography-Based</th>
<th>Video-Based</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>images</strong></td>
<td><strong>narrated videos</strong></td>
</tr>
<tr>
<td>help students identify tools and materials available to them</td>
<td>show comprehensive operation steps along with an audio voiceover to highlight key information and explain process steps in detail</td>
</tr>
<tr>
<td><strong>annotated images</strong></td>
<td><strong>animations</strong></td>
</tr>
<tr>
<td>highlight key details using text callouts</td>
<td>illustrate key techniques using short, focused videos to reduce ambiguity as compared to images</td>
</tr>
<tr>
<td>introduce students to technical language</td>
<td>use annotations to provide additional information</td>
</tr>
<tr>
<td><strong>prop photos</strong></td>
<td><strong>cheat sheets</strong></td>
</tr>
<tr>
<td>show prototyping outcomes with materials students may be using in their prototypes</td>
<td>combine animations and text to provide a detailed reference students can use while working on prototypes</td>
</tr>
<tr>
<td><strong>workflow graphics</strong></td>
<td></td>
</tr>
<tr>
<td>provide a process outline to inform student prototyping decisions</td>
<td></td>
</tr>
<tr>
<td>list necessary materials, supplies, and files to students before they begin the process</td>
<td></td>
</tr>
</tbody>
</table>
SECTION 2

EVALUATION
Chapter 4

Methodology

Designy was tested in two product design courses in Spring Semester 2018: 2.00b Toy Product Design and 2.744 Product Design. Testing with the two student populations of 2.00b and 2.744 provided an opportunity to test with a broad variety of students. 2.00b students tend to enter the course with little previous prototyping experience and learn in an environment with significant support and supervision. 2.744 students vary widely in terms of incoming prototyping experience, receive less project support, and prototype under practically no supervision.

Students were given access to the platform a few weeks into the Spring Semester, around the time when they started prototyping exercises. As the semester progressed, multimedia resources were added to the platform, expanding the utility of the platform. This chapter outlines questions that guided the investigation of the platform as well as the collection of data that contributed to the evaluation of the platform.

4.1 Questions

4.1.1 Testing in a Real Context
Designy is a platform designed to operate within a specific context. The research project created around identifying student problems with prototyping, creating a potential solution through the additional support provided by an online platform, and the subsequent testing of that platform in a real learning context takes inspiration from design-based research and action research [1].

4.1.2 Questions about Designy
The Designy platform was released to students after a brief demonstration of how to use it and what types of media resources students would find there. Use of the Designy platform by students was always voluntary. The only students to use the platform were those who thought it
might be beneficial to their project work or those who were simply curious about it. One overarching question situates the rest of the evaluation of the platform: did students even use the platform? If students did not take advantage of the platform, it would be impossible to evaluate it. The evaluation of Designy begins with quantifying activity on the platform in order to better understand if students found the time to use it.

If students did utilize the platform, then we can ask a series of deeper questions regarding how students used the platform. For students who do end up using the platform, how did use of the platform affect their prototyping experiences? What value did the platform provide to them, if any? How did the platform fit into their design processes? Did less experienced students find the platform more valuable? What about students with a high level of incoming experience? What are reasons why students did not use the platform? Ultimately, the path to beginning to understand the answers to these questions leads to the research task of characterizing student use of Designy.

4.2 Data Collection

Multiple sources of data were collected to explore questions about the use of the platform, including quantitative web usage data and qualitative data collected through interviews with students from 2.00b and 2.744.

4.2.1 Web Usage Data: Tracking Clicks

The Designy platform collects usage data tied to the usernames of students. Activity was documented by recording each click a student made, documenting each visit to the media library page and each content page a student loaded in their browser. Clicks are tracked with an associated timecode, showing the date and time a student visited a page. Figure 4-1 shows an example of click data values collected on the platform.
Figure 4-1: The Designy platform keeps track of the page visits, or clicks, associated with each username. Here, the usernames have been removed.

Click data can be used to identify which resource pages were used by which students. However, there are limitations that come along with click data. Clicks alone do not specify how thoroughly a student used a particular resource, so it is difficult to tell if a student visited a page in curiosity or to answer a specific question that they had.

4.2.2 QR Code Tracking

QR codes were placed on equipment, tools, and in material storage areas that had associated Designy content pages. Students could scan the QR codes to be taken to the relevant page on their mobile device or to send that resource to their laptop computers. The service used to generate QR codes from website links also keeps track of the number of scans a QR code has [48]. In this way it is possible to see if QR codes are being scanned and which codes receive more scans. However, there is no way to tie a scan to a particular user on the Designy platform, so only the quantity of scans can be determined.

4.2.3 Interview Data

The quantitative data, used primarily to track usage of the web platform and the media resources within it, can only really provide information about activity on the platform. Tracking information alone cannot tell the story of why a student is using the platform. In order to get a
more thorough picture of how the platform was used, student interviews were conducted with
students from both 2.00b Toy Design and 2.744 Product Design.

Overall, 19 students participated in interviews, coming from both 2.00b (n = 9) and from 2.744
(n = 10). Of these interviews, 7 of them were 1 hour in length and the other 12 were 30-minute
sessions. Students were recruited through email or volunteered to be interviewed while
responding to a course survey. A total of 51 students were asked if they wanted to participate in
an interview session, with 3 students that initially agreed for an interview session dropping out.
Overall, the pool of interview subjects represents a broad variety of students in terms of incoming
experience. Details about the interview subject population are discussed in the next chapter.

All of the interview subjects were interviewed by the author. Although the author had teaching
responsibilities in both courses, there were no grading responsibilities and all interview subjects
acknowledged that participating in an interview session would have no effect on their grades. As
part of their design work, students in both courses are coached on giving and receiving valuable
feedback, and no hesitance to provide critical feedback on the Designy platform was detected.

The interview protocol for all interview subjects included discussing with students about how the
platform fit into their design processes. Students cited the situations in which they used the
platform, which the author then interpreted in the context of the Anticipated Use Cases for the
Designy platform, allowing for documentation of Realized Use Cases. One important note is that
students were not presented with a description of Anticipated Use Cases, as that could potentially
bias them to cite uses that did not match their actual use. The author was responsible for
interpreting cited use cases and sorting them into which Anticipated Use Cases they might
match. For those students who did not use the platform, their reasons for choosing not to were
documented.

Each interview session also included a discussion about incoming prototyping experience.
Through a brief discussion of prior experiences with prototyping, a judgement was made by the
author regarding incoming experience level and students were placed into high, medium, and
low incoming experience bins. Each student was also asked about their use of the Designy platform in order to determine “significance of use”. A student was characterized as using the platform in a significant way if that use contributed to their learning of prototyping or to furthering their project work. This allowed for determining which students had used the platform in a meaningful way, as opposed to students who may have signed on to the platform and clicked on a few pages without using the platform to contribute to their learning.

Students in longer interview sessions were also asked about any usability issues with the platform and were provided with a laptop computer to use during the interview while discussing the Designy website alongside the author. Students were then asked about their media element preferences.
Chapter 5

Analysis and Discussion

Results of the efforts to quantify activity and characterize use of the Designy platform are presented here. Additional interview notes are provided from student conversations about multimedia preferences and content requests. A broader discussion of the results is presented at the end of the chapter.

5.1 Quantifying Activity

5.1.1 Student Activity

In 2.00b Toy Product Design there was a total of 316 unique student page visits, or clicks, during the semester, compared to 367 total student clicks in 2.744. Table 5-1 presents the proportion of active students on the platform, defined as students that have logged on at least once. In 2.00b, 49% of the student population were active users, or 43 students. In 2.744 there was a similar number of active students, with 51% of the course population showing activity, or 42 students in that course.

Table 5-1: Overall student activity on Designy during Spring 2018.

<table>
<thead>
<tr>
<th></th>
<th>2.00b</th>
<th>2.744</th>
</tr>
</thead>
<tbody>
<tr>
<td>clicks</td>
<td>316</td>
<td>367</td>
</tr>
<tr>
<td>student population</td>
<td>88</td>
<td>82</td>
</tr>
<tr>
<td>active students</td>
<td>49%</td>
<td>51%</td>
</tr>
</tbody>
</table>
Designy Activity in 2.00b

Figure 5-1: Activity per student in 2.00b ranked from highest to lowest.

Designy Activity in 2.744

Figure 5-2: Activity per student in 2.744 ranked from highest to lowest. The student activity rank graph has a similar shape to the 2.00b graph.
Table 5-2: Differences in student population and supervision model across 2.00b and 2.744.

<table>
<thead>
<tr>
<th></th>
<th>2.00b</th>
<th>2.744</th>
</tr>
</thead>
<tbody>
<tr>
<td>student year</td>
<td>freshman</td>
<td>graduates</td>
</tr>
<tr>
<td>course staff members</td>
<td>49</td>
<td>3</td>
</tr>
<tr>
<td>supervision level</td>
<td>high</td>
<td>low</td>
</tr>
</tbody>
</table>

Figure 5-1 shows the number of clicks attributed to each student in 2.00b ranked from highest to lowest activity. Although 43 students showed some activity on the platform, the graph of student activity shows that a smaller set of students contributed most of the activity. The long tail trailing off to the right of the graph indicates that there was a large group of students contributing only a few clicks each. In Figure 5-2, we can see a similar trend in activity distribution for 2.744. The similarity in the shape of the graphs between 2.00b and 2.744 is surprising considering that the two courses have students in different academic years (freshman and graduate) and the supervision level for the courses is also dramatically different, as highlighted in Table 5-2. We can see slightly more activity in the top half ranked students in 2.744 versus 2.00b. If we sort students into bins, where high activity is defined as 10 or more clicks, low activity is defined by less than 3 clicks, with medium activity in between, we can begin to define a core group of users in terms of activity.
Student Activity Levels in 2.00b

Figure 5-3: Student activity in 2.00b can be grouped by high, medium, and low use activity levels.

Student Activity Levels in 2.744

Figure 5-4: Student activity in 2.744 grouped by activity level.
Table 5-3: Activity level groups in 2.00b and 2.744. The core activity group is formed by adding the high and medium activity level groups.

<table>
<thead>
<tr>
<th>activity level</th>
<th>2.00b students</th>
<th>2.744 students</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>medium</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>low</td>
<td>19</td>
<td>13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>core activity group</th>
<th>2.00b</th>
<th>2.744</th>
</tr>
</thead>
<tbody>
<tr>
<td>high + medium students</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>course population</td>
<td>27%</td>
<td>35%</td>
</tr>
</tbody>
</table>

In Figure 5-4, we can see that there were more students in the medium activity level group in 2.744 versus 2.00b, shown in Figure 5-3. Student activity level groups are presented in Table 5-3. Adding the high and medium activity level groups together shows a core activity group of 24 students in 2.00b and 29 students in 2.744. In general, activity on the Designy platform in these courses is modest, with half of the class active on the platform and around a quarter of each class contributing most of the activity. Student activity on the platform can not be characterized as extensive, but was significant.

5.1.2 Staff Activity

Course staff in each course also contributed to activity on the platform. Table 5-4 shows course staff members in 2.00b contributed 284 clicks, whereas course staff members in 2.744 contributed 58 clicks. Course staff in 2.00b include the core teaching team of TAs and lecturers, lab instructors, and mentors, whereas in 2.744 there is only the core teaching team of the course instructor and TAs. To further investigate staff activity, staff activity rankings are presented alongside students’ activity rankings in Figures 6-5 and 6-6.

Table 5-4: Overall staff activity on Designy in Spring 2018
<table>
<thead>
<tr>
<th></th>
<th>2.00b</th>
<th>2.744</th>
</tr>
</thead>
<tbody>
<tr>
<td>clicks</td>
<td>284</td>
<td>58</td>
</tr>
<tr>
<td>staff population</td>
<td>49</td>
<td>3</td>
</tr>
<tr>
<td>active staff</td>
<td>40%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Staff and Student Activity in 2.00b**

- **course staff**
- **students**

Figure 5-5: Course staff members activity in 2.00b as compared to student activity.
Staff and Student Activity in 2.744

Figure 5-6: Course staff members activity in 2.744 as compared to student activity.

If we include staff member clicks and compare them to student page visits it is clear to see that course staff use is comparable in many cases to student use. Note that there is an overlap between course staff members in 2.00b who are also 2.744 students. These students were counted as 2.744 students in the data analysis, and not as 2.00b staff members.
5.1.3 Team Activity

**2.00b Staff and Student Activity by Team**

- course staff
- students

![Graph showing activity breakdown by team for 2.00b](image)

Figure 5-7: Student and staff activity broken down by 2.00b team.

**2.744 Student Activity by Team**

![Graph showing activity breakdown by team for 2.744](image)

Figure 5-8: Student and staff activity broken down by 2.744 team.
Student and staff activity are broken down by team in Figure 5-7 and Figure 5-8. There was student activity from each team in the course, but the amount of activity varied significantly by team. There does not appear to be any correlation between staff and student use on a particular team. In 2.744, each team had student activity with some teams showing more activity than others.

Several team factors could be contributing to team-by-team variance in activity. Students could be using the platform together or a lab instructor could be encouraging a team to use Designy. Team dynamics could also be a contributing factor to an absence of activity, as strong team members could be assisting their teammates in ways that could reduce a student's need to use the platform.
5.1.4 Multimedia Resources Activity

It is possible to track the amount of activity each resource on Designy experiences. Table 5-5 shows which resources were visited more often by students in 2.00b and 2.744.

Table 5-5: Student activity broken down by category

<table>
<thead>
<tr>
<th>Resource Category</th>
<th>2.00b</th>
<th>2.744</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchtop Tools</td>
<td>16</td>
<td>26</td>
<td>42</td>
</tr>
<tr>
<td>Handheld Tools</td>
<td>23</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Sketch Modeling</td>
<td>15</td>
<td>18</td>
<td>33</td>
</tr>
<tr>
<td>Shop Tips</td>
<td>27</td>
<td>16</td>
<td>43</td>
</tr>
<tr>
<td>3D Printing</td>
<td>54</td>
<td>36</td>
<td>90</td>
</tr>
<tr>
<td>Digital Fabrication</td>
<td>46</td>
<td>71</td>
<td>117</td>
</tr>
</tbody>
</table>

The 3D Printing and Digital Fabrication categories saw the highest activity. This could be due to student interest in those areas or a consequence of less time in lecture activities and extra tutorials devoted to these topics. Another possibility is that many students want to utilize 3D printing and digital fabrication tools in their projects, but lab instructor and TA knowledge of these tools is spread out amongst course staff members, so detailed help using these tools is harder to find. Use of a digital fabrication tools often requires remembering a detailed set of steps, so students may appreciate having a resource to reference. Projects in 2.00b are at a scale where 3D printing is more appropriate, which could have contributed to higher 2.00b activity in that category. Digital fabrication tool use was more common in 2.744, where students typically construct larger prototypes. Many students in 2.00b have access to course staff members to assist with using digital fabrication tools, whereas higher activity in that category for 2.744 students could be contributed to less available staff assistance when students wanted to use those tools.
All of the other categories have less activity than 3D Printing or Digital Fabrication, but have similar activity to each other, including the Shop Tools and Tips category, which was added late in the semester. The higher activity level of the Shop Tips category in 2.00b is due to higher activity on resources about locally sourcing project parts. The Handheld Tools category was visited almost exclusively by 2.00b students. These instances of higher 2.00b use in suggests that the higher general engineering experience of the students in 2.744 may be the cause for the lower observed use of those online resources by 2.744 students. Each student in 2.00b received explicit training using benchtop tools, as these tools play a major role in many prototyping activities. Students in 2.744 only received an optional training session in these tools during a time when not all students could attend, which could be a factor in higher 2.744 activity in the Benchtop Tools category. In summary, the different supervision models and project scopes in 2.00b and 2.744 may be significant factors in differences in activity across the two courses.

5.1.5 Activity Timing

Timecodes recorded as part of click tracking can be used to show how student activity varies over time. Figure 5-9 shows timing activity data for 2.00b and 2.744 along with course milestones and Designy updates.
Figure 5-9: Activity varied throughout the semester, with pockets of activity grouped around lectures demos of Designy. Most of the Designy activity happened towards the ends of the semester.
Designy was first released to students in 2.00b on March 8th, and a pocket of course activity can be seen as students sign on. 2.744 students did not have access to the course at this time, but some 2.744 students are staff members in 2.00b, so activity can be seen by those students before Designy is released in 2.744. This initial batch of content has multimedia resources on benchtop tools and sketch modeling with sheet materials. Sketch modeling with foams was added shortly after, as course milestones which required sketch modeling were approaching in both courses. A small amount of activity can be seen on March 21 when the foam resources were added and students were notified on through email and on Slack, a messaging app used by students and staff in both courses. The platform experienced low activity through the 2.00b Sketch Modeling Review, in which students are expected to present prototypes created using sketch modeling techniques. Timing data suggests that the Designy platform was not used by 2.00b students to prepare for the sketch model review. Information about the Designy platform was only communicated to students through digital communication until April 4th.

On April 3rd, 2.744 students were given access to Designy through email and received a demonstration of the platform in lecture that day. The platform had recently been updated to include brief information about 3D printers and digital fabrication tools. 2.744 activity was high during the launch of the platform and continued through to the 2.744 Concept Review, the first milestone in 2.744 with a prototype as a deliverable. Activity in 2.00b remains low through the 2.00b Mockup Review. It is plausible that leading up to this milestone students in 2.00b were receiving adequate help from the course staff.

A large update to Designy took place on April 25 (late in the term at a peak final prototyping time), and a demonstration of the updated platform was given in 2.00b and 2.744 lectures. This update included more detailed information on all of the digital fabrication and 3D printing tools, in addition to the Shop Tips category. After this update activity on the platform increased significantly. This increase could be due to several factors. The Designy platform was recently updated to include resources that align with tools that engineering students tend to be interested in: 3D printers and CNC tools. Project-work increased towards the end of the semester and became the central focus of both courses leading up to the final presentations. Expected
prototype fidelity also increased in a way that makes digital fabrication and 3D printing prototyping methods more appropriate for prototyping activities later in the semester. All of these factors likely contribute to the high activity seen throughout the end of the courses.

Designy activity continued after the courses ended. Throughout the following summer, a small subset of students continued to use the platform. In the two-month time period following the conclusion of the courses, 14 students and 3 staff members had shown activity on Designy.

5.1.6 QR Code Scans

The service used to generate the QR codes also keeps track of the number of times each code is scanned. Total QR code scans are presented in Table 5-6.

Table 5-6: Total QR code scans for each category.

<table>
<thead>
<tr>
<th>QR Scans</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchtop Tools</td>
<td>26</td>
</tr>
<tr>
<td>Sketch Modeling</td>
<td>6</td>
</tr>
<tr>
<td>Shop Tips</td>
<td>2</td>
</tr>
<tr>
<td>3D Printing</td>
<td>7</td>
</tr>
<tr>
<td>Digital Fabrication</td>
<td>14</td>
</tr>
<tr>
<td>Handheld Tools</td>
<td>2</td>
</tr>
</tbody>
</table>

QR codes were used sparingly by students. Benchtop tools show the highest number of scans. Resource activity for these tools was higher for 2,744 students, so it is possible that those students accessed Designy through scanning QR codes. Benchtop tool QR codes are the most visible in the shop, so it is also possible that these tools were scanned out of novelty. When asked, none of the interviewed students cited QR codes as having a significant impact on their use of the platform, with many of them never scanning a single code.
The author suspects that having the QR codes as visual indicators, reminding the students that there are digital resources to support their project work, is a valuable addition to the shop space. In the future, it would be interesting to see the effect of increased use of signage and posters in the shop space, effectively creating a digitally augmented shop.

5.2 Characterizing Use of Designy

Click tracking can provide insights as to how the platform is being used, but does not provide insights into the deeper questions of why students are using the platform. To begin answering those questions, data from conversations with students need to be analyzed. Through these discussions, Realized Use Cases can be cataloged and then characterized using the Anticipated Use Cases that the platform was designed around.

5.2.1 Interview Participants

To better understand the group of interviewed students, the beginning of each interview session was used to determine incoming experience levels and the significance of platform activity. Experience is evaluated relative to peers, so a high-incoming-experience 2.00b student might not be as experienced as a high-incoming-experience 2.744 student. Significance of platform activity was determined by asking students if platform activity represented meaningful use that supported their prototyping work in any way. Table 5-7 shows each interview subject, which course they were in at the time of the interview, their activity rank, activity level, activity significance, and their incoming experience level. Participants are sorted within each course by activity rank, except for those participants who did not have significant activity, who are placed at the bottom of each course list.
Table 5-7: Interview participants characterized by activity levels, activity significant, and incoming experience.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Activity Rank</th>
<th>Activity Level</th>
<th>Activity Significance</th>
<th>Incoming Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.00b</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>high</td>
<td>yes</td>
<td>medium</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>high</td>
<td>yes</td>
<td>high</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>high</td>
<td>yes</td>
<td>low</td>
</tr>
<tr>
<td>D</td>
<td>8</td>
<td>high</td>
<td>yes</td>
<td>medium</td>
</tr>
<tr>
<td>E</td>
<td>N/A</td>
<td>medium*</td>
<td>yes</td>
<td>medium</td>
</tr>
<tr>
<td>F</td>
<td>11</td>
<td>medium</td>
<td>yes</td>
<td>low</td>
</tr>
<tr>
<td>G</td>
<td>16</td>
<td>medium</td>
<td>yes</td>
<td>medium</td>
</tr>
<tr>
<td>H</td>
<td>3</td>
<td>high</td>
<td>no</td>
<td>low</td>
</tr>
<tr>
<td>I</td>
<td>9</td>
<td>high</td>
<td>no</td>
<td>low</td>
</tr>
<tr>
<td>2.744</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>1</td>
<td>high</td>
<td>yes</td>
<td>low</td>
</tr>
<tr>
<td>K</td>
<td>2</td>
<td>high</td>
<td>yes</td>
<td>high</td>
</tr>
<tr>
<td>L</td>
<td>4</td>
<td>high</td>
<td>yes</td>
<td>low</td>
</tr>
<tr>
<td>M</td>
<td>5</td>
<td>high</td>
<td>yes</td>
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</tr>
<tr>
<td>N</td>
<td>6</td>
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</tr>
<tr>
<td>O</td>
<td>8</td>
<td>high</td>
<td>yes</td>
<td>high</td>
</tr>
<tr>
<td>P</td>
<td>12</td>
<td>medium</td>
<td>yes</td>
<td>high</td>
</tr>
<tr>
<td>Q</td>
<td>13</td>
<td>medium</td>
<td>yes</td>
<td>low</td>
</tr>
<tr>
<td>R</td>
<td>N/A</td>
<td>none</td>
<td>no</td>
<td>low</td>
</tr>
<tr>
<td>S</td>
<td>31</td>
<td>low</td>
<td>no</td>
<td>low</td>
</tr>
</tbody>
</table>

Overall, the pool of interview subjects represents a diverse group of students that had a varied amount of activity on Designy and included students with both high and low incoming levels of prototyping experience. Student E does not have an activity rank. This was due to a tracking error on the Designy platform, which shows no activity associated with that student's username. Student E later revealed that he accessed the platform using his phone, indicating that there may be an issue with tracking mobile activity on Designy. The interview discussion suggested that student E used Designy to contribute to his learning and likely had a medium activity level.
Figure 5-10 shows the activity ranks of the interview participants, and identifies which students had activity on the platform but did not have significant use using a red bar. Student R does not appear in Figure 5-10 because he never logged on to Designy.

Students H, I and S, who had activity rankings 3 (2.00b), 9 (2.00b), and 31 (2.744), respectively, were determined to not have significant use of the platform. Each of these students expressed that they signed on to Designy out of curiosity, but the platform did not contribute to their project work or their learning. It is interesting to note that students H and I are in the high
activity user groups, further reinforcing the limitation of activity tracking in that it does not guarantee meaningful use of the platform.

5.2.2 Realized Use Cases

Generally, all of the use cases cited by students aligned with one of the four Anticipated Use Cases that were used to guide the design of the platform: Planning, Preparing, Exploring, and Executing. For reference, these four use cases are briefly outlined here:

**Planning** refers to when students have an idea for a design prototype but they have not decided how to execute that prototype. Students are considered to be using the platform for planning if they are using Designy to help decide between fabrication methods, deciding which fabrication steps they need to take, or figuring out design details based on how a prototype will be fabricated.

**Preparing** refers to when students do not have a specific task in mind but want to be generally prepared for working in the shop space. Students are considered to be using the platform to prepare if they are using the platform to become generally familiar with the shop space so that once they start working they are more informed.

**Exploring** refers to when students are using the platform out of curiosity about what is available to them in terms of tools and materials. Students are considered to be using the platform as exploring if they do not have a specific task to complete, but they want to have a more comprehensive understanding of the lab space.

**Executing** refers to when students are using the platform to perform a specific prototyping operation. Students are considered to be using the platform to execute if they are using Designy directly alongside operation of a shop tool or while performing a prototyping technique.
Table 5-8: Realized Use Cases cited by students in 2.00b and 2.744. Note that students H, I, R and S did not cite any use cases.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Activity Rank</th>
<th>Activity Level</th>
<th>Activity Significance</th>
<th>Incoming Experience</th>
<th>Planning</th>
<th>Preparing</th>
<th>Exploring</th>
<th>Executing</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.00b</td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>C</td>
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<td>D</td>
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<td>P</td>
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<td>low</td>
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<td></td>
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<td>R</td>
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<td>low</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>31</td>
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<td>no</td>
<td>low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Realized Use Cases cited by each interview participant is provided in Table 5-8. Students with high activity generally exhibited multiple use cases. Many students used the platform for only a single type of use case, often to address a particular question or roadblock they had about completing their design prototyping exercises. These use cases fall under Planning and Executing. Single use case types from students of 2.00b tend to be aligned with Planning, and 2.744 students tend to using the platform to support Executing. This suggests that 2.00b students are more likely to use the perform to complete the task “I need to figure out how to do this,” whereas 2.744 students are more likely to visit the platform to complete tasks such as “I need a reference while doing this.” In order to describe student use in more detail, examples of each type of use case are provided in Tables 6-9, 6-10, 6-11, and 6-12.
Table 5-9: Planning Use Cases

**Planning:** 9 students

<table>
<thead>
<tr>
<th>participant ID</th>
<th>student used Designy to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, E</td>
<td>figure out the feasibility of an idea</td>
</tr>
<tr>
<td>C, K</td>
<td>figure out how to break into fabrication steps</td>
</tr>
<tr>
<td>B, P</td>
<td>investigate or source materials</td>
</tr>
<tr>
<td>D, G, J</td>
<td>design CAD details and/or choose a 3D printer</td>
</tr>
</tbody>
</table>

Students A and E provide clear examples of using the platform as Planning. When they would have a variety of ideas about how to implement a prototype, they would use the Designy platform “to see if this is even possible.” During early stage sketch modeling prototyping, Student K cites using the platform in order to better understand what techniques are used in sketch modeling as part of breaking down the execution of a prototype into fabrication steps. As part of a team-based effort, Student C used the Designy platform along with her teammates in order to explore different fabrication methods for their prototype. In a later stage prototype, Student D spent significant time preparing a CAD model to be 3D printed, and used the Designy platform to incorporate guidelines about designing models for 3D printing.

Students D, G, and J used Designy to help choose which 3D printer to utilize. The high numbers associated with use the of 3D Printing resources suggests that this could be a popular use case for many students who were active on Designy. Instead of using the Designy platform to inform design details or their fabrication method, Students B and P used the platform to inform their material choices and to help locally source materials to use in their prototypes.

Planning proved to be one of the most popular use cases amongst students. To them, the Designy platform proved to be a useful source of information to utilize while designing their prototypes and figuring out how to make them a reality.
Table 5-10: Preparing Use Cases

**Preparing**: 4 students

<table>
<thead>
<tr>
<th>participant ID</th>
<th>student used Designy to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A J L</td>
<td>feel more or informed before shop work</td>
</tr>
<tr>
<td>J K</td>
<td>review safe operation of tools</td>
</tr>
</tbody>
</table>

Student J wanted to see the exact procedure for using shop tools in the PDL before coming in to work in the shop. By having a better understanding of these potentially dangerous tools, she felt more confident about being able to work in the shop space successfully. Student K was also concerned with safe use of the shop equipment in order to not hurt himself while operating potentially dangerous machines like a drill press. Student L cited Designy as a key factor in getting oriented in using the space for project work.

Only a few students cited Preparing as a use case for the platform. It was more common for students to cite use cases relating to a specific problem or road block they were having as part of their prototyping project work. However, to the students who did cite using the Designy platform for Preparing, being able to do so contributed to making the PDL a more comfortable place to work in. Student J cited the platform as a factor in “making the PDL feel like a friendly work space, definitely less intimidating than the Hobby Shop,” an alternative space that is occasionally used by students in 2.744.

Table 5-11: Exploring Use Cases

**Exploring**: 4 students

<table>
<thead>
<tr>
<th>participant ID</th>
<th>student used Designy to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A E K L</td>
<td>see what is possible, learn about all tools in the shop</td>
</tr>
</tbody>
</table>
About half of the students in each course signed on to the Designy platform at least once. Many of these students logged in due to being curious about what the platform was like. A few students stayed because they were curious about what the PDL shop space had to offer. Being curious while on the Designy platform is an easy way to rack up clicks, so many of the students with higher activity rankings cited Exploring as a use case.

Student A had the highest number of clicks of any student user. He viewed each resource at least once, returning to use those tutorials he would later need to answer specific questions. Another user, Student L, cited wanting to learn about all of the available tools in the PDL, using the platform to satisfy her curiosity as to what the PDL afforded in terms of prototyping possibilities. Student K went to the platform in order to investigate the use of a certain tool seen in a class demo, but then cited “once I had watched one video, I had to watch them all.” One hope during the design of the platform was that more users would cite a similar experience, logging on to Designy in order to answer one specific question and becoming more curious once presented with the array of media resources. However, exploration does take time, which is a precious commodity for students in project-based classes.

Table 5-12: Executing Use Cases

<table>
<thead>
<tr>
<th>Executing: 8 students</th>
<th>student used Designy to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>participant ID</td>
<td></td>
</tr>
<tr>
<td>A O</td>
<td>use the vinyl cutter</td>
</tr>
<tr>
<td>F J K L O N</td>
<td>use the laser cutter</td>
</tr>
<tr>
<td>F</td>
<td>perform finishing techniques</td>
</tr>
<tr>
<td>N Q</td>
<td>use the Shaper Origin</td>
</tr>
<tr>
<td>O N</td>
<td>reduce the fear of breaking a tool</td>
</tr>
<tr>
<td>O N</td>
<td>not have to wait to get help from a TA</td>
</tr>
</tbody>
</table>

Most of these Executing-related use cases occurred when students were using digital fabrication tools, which likely accounts for why those resources make up the category with the highest
activity. Students O and N were concerned that if they did not carefully operate a piece of expensive equipment, such as the laser cutter, then they might damage the machine. The fear of damaging equipment made them hesitant to use those tools to fabricate their prototypes. Student M was only interested in using the platform for becoming more comfortable with the laser cutter. These students used the Designy resources to make sure that they properly used the tools in ways that would reduce the chances of damaging the equipment.

In many cases, students prefer to get trained on a piece of shop equipment by a TA in order to learn proper and safe operation through face-to-face interaction and then use Designy as a reference during subsequent use. If students had simple questions after being trained, instead of “bothering a TA” the students would use Designy to answer their questions. These instances occurred when a TA was either busy helping other students or not present in the shop space at all. The desire to not bother busy TAs was cited by Students A and O. Students O and N cited using Designy when TAs were not present in the shop when they were working either early or late hours instead of having to wait to receive help from the course staff when they next were present in the lab.

5.2.3 Experience versus Use

One of the main populations of interest as users for the Designy platform are students with limited prototyping experience coming into a product design course. One assumption is that low-incoming-experience students would appreciate the platform more than high-incoming-experience students who may already feel confident in their prototyping abilities. Indeed, many of the Realized Use Cases show that low-incoming-experience students do use the Designy platform as a way to support their prototyping efforts. Students J and L are both students in 2.744 who are mechanical engineering graduate students coming from a science background in terms of their undergraduate training. Neither of these students had extensive hands-on prototyping experience coming in to the course. Both of these students saw significant value in using the platform to familiarize themselves with the workshop space and become more confident in their own abilities to use shop tools. Each student quickly identified themselves as someone who would benefit from use of the platform after seeing a demonstration of it in a class session.
However, not all low-incoming-experience interview participants cited using the platform to contribute to their learning, and some high-incoming-experience students used the platform extensively. Students A and E had some prototyping experience entering 2.00b. They are examples of students who had the extra capacity to spend time in the courses taking advantage of additional learning opportunities, with Designy providing an opportunity for them to learn more about prototyping. Three 2.744 students with a high level of incoming prototyping from their previous coursework or from industry—Students K, O, N—used the platform because they wanted to be certain they were using the specific tools in the PDL properly. In this way, experience from their prototyping history helped them form questions about operation of shop equipment, prompting them to utilize the Designy platform to ensure proper and safe tool operation.

Some low-incoming-experience students chose not to use the Designy platform. Their motivations for not using the platform are discussed in the next section, along with reasons cited by high-incoming-experience students who chose not to use Designy.

5.2.4 Reasons for Non-Use

Some students choose not to use the platform because they feel they do not need additional help with prototyping activities. This is the main reason behind the limited use seen by Students 7 and 19, who had taken courses with a focus on prototyping before taking 2.744. These students rely on their previous experience and their ability to figure things out on their own in order to complete prototyping activities.

Students H, I, R and S were all low-incoming-experience and low-platform-activity students. Each student cited a preference for face-to-face interactions with people over using the platform as support for prototyping work. Students H and I were 2.00b students who felt they had sufficient support from TAs and lab instructors. Student H had signed on and explored the platform initially, but did not return to the platform to get help with prototyping work. Student I strongly preferred talking to a course staff member while using her team’s prototypes as
discussion tools. In this way, the student could ask specific questions about troubleshooting prototyping issues in a way that was not possible with Designy, citing one reason for not utilizing the platform was that “you can’t show a prototype to a website and ask it questions.”

Student R never signed in to use the platform, despite having no prototyping experience before entering 2.744. Throughout the course, Student R expressed significant growth in terms of prototyping ability, which started in a demonstration session as part of 2.744. This 45-minute introductory session, conducted by the author as part of a TA responsibilities in the course, was provided to students in 2.744 who were unfamiliar with working in shop spaces. This did not involve use of the Designy platform, although students were told that they had access to the platform if they wanted to review anything from the introductory session. Student 15 cited this session as enough instruction to get started working in the PDL. As the term progressed, Student R cited working closely with experienced teammates in order to learn about prototyping techniques, later transitioning to working more and more independently.

Another 2.744 student, Student S, strongly preferred getting assistance from course staff, citing the importance of developing face-to-face relationships as a reason for shying away from use of the platform. In her words, “Why look it up online like a nerd?” Student S mentioned that since course staff would generally help in a face-to-face session within 2 days, that was fast enough for her to not need to utilize the Designy platform.

Interestingly, the dangerousness of equipment was cited both as a reason for use of the platform and for hesitance to use the platform. For use of more dangerous equipment, Student 5 would prefer to be instructed and supervised by a person instead of learning about operation of machine tools from an online platform and then operating the equipment unsupervised. This is in contrast to Students K, O, and N, who cited using the platform in order to ensure safe operation.

Finally, some students mentioned that using a laptop in a shop space is sometimes difficult due to the loud noise and the presence of dust. One student recommended a dedicated tablet in the
space for viewing the platform so that students would not have to take their own laptops out while working in the shop.

5.2.5 Use by Course Staff

In addition to use by the students, use by course staff members—particularly in 2.00b—contributed to a significant amount of activity on Designy. As student design needs came up, course staff members that were heavily involved in supporting student project work could then point students to resources on Designy. 2.00b and 2.744 course staff observed that certain digital fabrication tools saw significant increases in usage compared to past semesters due to the availability of multimedia resources about those tools on Designy.

Besides use by course staff members to directly support student project work, the platform was used in other ways outside of the workshop. While preparing lecture content, 2.00b lecturers would use the Designy platform as a source of media resources for lecture slides. The user of the platform with the highest activity, both students and staff included, was one of the lecturers for 2.00b.

5.2.6 Notes: Media Preferences, Designy Attributes, and Requests

While students had different preferences for multimedia elements, all eight of the students asked about media preferences expressed an appreciation for having the option to choose different media elements for different prototyping situations. None of these students expressed confusion about the fact that there was redundancy in the information provided by different media elements on the same content page.

Feedback regarding media element preferences was mixed. Narrated videos and animations were the top choices of most students. Students appreciated how thorough the narrated videos were, providing them with almost all the information they needed with one viewing. Chapter markers were cited as an important for searching and revisiting videos as needed. The animations in cheat sheets were usually used to support execution efforts after students watched the introductory video. Cheat sheets were commonly cited as the impetus for students returning to use the
platform as a reference. Students also cited the value added by animations over static images, reducing ambiguity as compared to having to follow along with static images in other online tutorials.

Workflow graphics received mixed reviews from students. While some students appreciated having the prototyping process outlined for them in a single graphic, other students preferred to learn about these steps from the narrated videos. Annotated images also received mixed reviews, with some students finding value in them whereas others preferred to learn similar information from elsewhere on the page. Text is cited most often as the least important media element on a content page, with most students preferring to skip reading unless absolutely necessary. Student 6 mentioned that she would only read the text if she was dealing with a dangerous tool, like a drill press. Despite the resistance towards reading text, some students noted that the highlighted text boxes were appreciated elements that they would always read.

The Designy Attributes—Flexible, Exemplary of Good Design, Fun, Usable, and Present—are a series of attributes that were considered during the design and implementation of the platform. These attributes were found to be important factors in student use of Designy. Data showing use of the platform by students with both high and low incoming prototyping experiences suggests that the platform was successful in meeting the needs of a variety of students in multiple situations, a goal associated with the attribute Flexible. In terms of Fun, some students cited humor in narrated videos as motivating continued use of the platform. Multiple students provided positive feedback regarding the graphic design of the website and the high visual quality of the multimedia resources, related to the attributes Exemplary of Good Design and Usable. Finally, in terms of Present, timing data shows that students were more likely to use the platform directly after a demonstration of the platform in a lecture session, suggesting that efforts to increase awareness of the platform were key to student utilization of the platform. However, during interview discussions, some low activity students described not really knowing what types of resources were on the platform and upon reviewing the Designy website mentioned that they may have found it useful if they had a better understanding of the assistance the platform could
provide. These discussions suggest that increased effort to improve awareness of the platform might increase activity on Designy.

When asked about additional content for the platform, many students did not have requests, but there were a few requests that were cited by multiple students. Four students were interested in seeing more techniques that expert designers use to save time, along the lines of “tricks of the trade.” These same students were also interested in guidance on troubleshooting issues encountered when prototyping. Some students wanted resources on molding and casting techniques, which were a significant part of their project. One student requested content on machine elements for mechanical design and resources about topics like “how to create linear motion.” Several students requested content covering basic electronics prototyping.

5.3 Discussion: People vs Platform

The goal of the Designy platform was never to reduce the amount of face-to-face interactions students have with staff members. In fact, evaluating the Designy platform further highlights the importance of interactions between course staff members and students. Instead, Designy was developed in order to provide additional support to students through harnessing the affordances provided by an online multimedia hosting platform. Understanding the context of supporting student prototyping through interactions with course staff members and through the online platform together helps to identify the value students experience through use of Designy.

5.3.1 People Can Consider a Broader Context

All of the students, regardless of Designy activity level, appreciated the support provided by the course staff in 2.00b or 2.744. In our view, this is a distinguishing aspect of residential education. Students appreciated having access to instructors, mentors, and TAs who could look at their prototypes and help them troubleshoot. When assisting students with prototyping work, the questions that students ask course staff members begins a discussion about the type of support that they might need. Students might ask a specific question about using a prototyping tool when that tool is actually inappropriate for their task. In these situations, Designy struggles to provide
students with the support that they need. For a student to extract the help they need from the web platform, they would need more time than if they interact directly with an experienced staff member. In some cases, course staff can quickly identify the exact level of support a student might need.

Students can foster important relationships through interactions with course staff members, and these relationships can lead to guidance in a student’s career outside of the context of a single course. Course staff members can take into account complex social factors such as team dynamics. Generally speaking, course staff members can consider a broad context in order to provide students with the support that they need.

5.3.2 Designy Makes More Possible

Despite the limitations of a web platform as compared to a person, students still found support through utilization of Designy. Through Planning- and Exploring-type use cases, students can gain a better understanding of the landscape of the prototyping tools and techniques available to them. This can help students design better prototypes and remove roadblocks where a student does not know how to fabricate a prototype. Use of Designy while Executing prototypes helps operationalize prototyping techniques a student might have learned in a demonstration or prototyping activity. With a clear reference that students can use alongside operation of prototyping equipment, students feel less afraid of damaging equipment or hurting themselves. Students have cited Preparing-type use cases that contributed to increased feelings of comfort and confidence while working in the shop. In many cases, students have cited how having both access to course staff and the Designy platform allows them to pick the support channel they prefer in a given situation where need additional support. When students do not have access to course staff members, support from Designy takes the place of having no support at all.

Designy removes roadblocks students may encounter when trying to perform prototyping activities. This allows prototyping activities to become more approachable to students, ultimately allowing them to get more prototyping work done as part of their projects. Without access to the support provided by Designy, students could still receive support through other channels.
provided as part of the learning environment in a design course. However, in some circumstances, having access to Designy gives students the assistance they need to further their project work.
Conclusions and Future Work

Prototyping is a core activity for product designers and a key way that students learn about design. In product design courses, prototyping instruction through demonstration, activity, and through interactions with course staff members each provide students with support for their project work, but additional support through the use of online multimedia could help students progress further in their project work. As part of efforts of continuous improvement in CADlab-developed product design courses, the Designy platform was developed to explore the option of supporting student prototyping work using an online multimedia hosting platform. An analysis of existing student issues with prototyping instruction provided the basis for a series of Anticipated Use Cases which guided the structure of the platform and the types of multimedia resources hosted on it. On the Designy media library page, which serves as the home page for the website, students are presented with a tile grid system showing the various tools and prototyping techniques for which there are multimedia resources. A content page for a tool or technique uses media elements comprised of both photography and video resources to cover topics like basic operation of a prototyping tool and how that tool helps to create product design prototypes. Many content pages are also designed to provide a detailed step-by-step reference for students to use while working in a prototyping space.

Evaluation Summary

A total of 28 media resources were tested by giving students in two product design courses with a significant emphasis on creating design prototypes—2.00b Toy Design and 2.744 Product Design—access to Designy. These courses represent very different student populations and course supervision models. 2.00b is comprised mainly of freshman students with limited incoming prototyping experience. As such, there is a greater emphasis on prototyping supervision and staff support from the 49 course staff members. The 2.744 student population consists of graduate students with a mixed level of incoming prototyping experiences, with some students having more experience from their undergraduate curriculums and others coming in
from science or business backgrounds with less prototyping experience. Through an analysis of web platform usage data and interview data, insights were gained as to the value of the platform in supporting student prototyping. Around half of the students in 2.00b and 2.744 showed activity on Designy, with a core group of 24 students in 2.00b and 29 students in 2.744 contributing most of the activity. Activity was highest in the later parts of the semester when there were more multimedia resources released on the platform and student project work was the main focus of the courses. Both students with high and low levels of incoming prototyping experience had activity on the platform.

Characterizing student use revealed more about why students decided to utilize the platform and what value they found in using it. Designy has been used to successfully help students in executing their prototypes in the shop, as well as reducing apprehensions about damaging equipment or getting hurt. It has helped students get a better understanding of the landscape of available prototyping tools and techniques, leading to more informed decisions about fabrication techniques and design details. Finally, by helping student prepare for working in the PDL, Designy has contributed to making students feel more comfortable, more confident, and less intimidated while working in a shop environment.

In many situations students prefer face-to-face interactions. Students can ask questions, use prototypes as discussion tools, and get rich feedback from interacting directly with course staff. However, sometimes staff members are not available to students, and can be a source of intimidation themselves. By combining face-to-face interactions with the affordances provided by a multimedia hosting platform, a better experience can be presented to students. The cost of developing and maintaining a platform like Designy is high, but to be able to improve such an important aspect of the student experience in a product design course is worth it.
Future Work

Scaling Up

The main next step for Designy is continuing to scale up the number of multimedia resources and gathering more data about student use in future courses. There are currently plans to test the platform in the next 2.009 course. Not only would more fabrication techniques and more equipment operation tutorials be appreciated by students, but there are other directions to explore for developing media resources for supporting prototyping. Resources showing fabrication methods used to construct existing models could help students learn by example. Resources more explicitly dedicated to helping students choose between a variety of fabrication methods could help students make more informed decisions. The platform will continue to improve and evolve as more feedback is gathered on what aspects of prototyping students need the most help with.

Students have also requested continued access to Designy to support prototyping efforts outside of CADlab-developed product design courses. One student is interested in using the platform as part of a student-led group that supports extracurricular project work at MIT. Another student mentioned interest in using Designy for her UROP work, and has continued to exhibit Designy activity two months after the end of the semester in which Designy was evaluated. A professor at another university has also requested access to Designy to use as a reference for planning her own shop space. As time goes on, use of Designy outside of CADlab-developed courses may also be explored.

In terms of media development, expanding the course staff involved in the media production process could contribute to scaling up content coverage. Discussions with experienced prototypers who are part of the course staff for CADlab-developed courses would allow future media resources to capitalize on staff experience. Continued curation of existing online prototyping resources could allow future Designy resources to better capitalize on the work of
others, and connections to tool and material manufacturers could lead to partnerships in developing resources for students to use when prototyping.

**Activity Limitations**

Studying click tracking involved gathering information about activity on Designy, but whether or not this activity could be characterized as significant was determined though discussions with interview participants. In the future, if certain use patterns can be tied to significant use, analysis of click data alone may be able to give educators using the platform immediate feedback on whether or not students are using the platform in a meaningful way.

**Research to Improve Multimedia Resources**

During the Spring 2018 semester, an undergraduate researcher was responsible for testing Designy as an instruction tool for students interested in using the laser cutter [49]. In this study the researcher gathered rich feedback from students by directly observing students using Designy as a first training for using the laser cutter. After a supervised practice session where students had a chance to operate the machine themselves, the researcher interviewed students to gather feedback about the platform. This feedback was used to identify areas of improvement for the laser cutter resource and the platform as a whole. Additional detailed studies of student use of particular resources could help the platform continue to improve.

**Guiding Student Use of Prototypes as Part of Designing**

Designy could also be used to study aspects of supporting student project work outside of directly supporting prototyping efforts. An early stage exploration of how to best guide students through the process of assessing a product concept, navigating a question space, and choosing an appropriate modeling activity was conducted by another undergraduate researcher [50]. The insights gained in this exploration could be applied to the development of a web tool hosted on Designy that would utilize the platform not to support prototyping efforts directly, but rather to help students identify when prototyping is an appropriate learning activity. This tool could also
help students choose a type of prototype that will match the specific questions they might want to answer to progress their designs.

**Connecting Designy to Project Outcomes**

Use of Designy by students was characterized in order to better understand situations where students found the platform helpful as part of their prototyping efforts. Generally speaking, Designy was found to remove potential roadblocks that can stifle student prototyping work. A detailed study of how Designy contributes to improving project outcomes could give educators a better idea of how Designy might be contributing to overall design learning in a product design course.

A potential study could involve frequent research interviews with students as they use the platform as part of constructing prototypes throughout a semester. Uses of Designy could be tied to specific features in student projects. Researchers could also investigate if using Designy helps free up student time that can be used to improve other aspects of project work, such as user research. This type of study could also help identify if use of Designy has positive or negative effects on student creativity or on interactions with staff members. Student utilization of shop equipment could be documented to give a more comprehensive picture of how the student prototyping changes with the addition of a web platform.

**Designy for Studying Prototyping Instruction**

Designy could also be used for deeper investigation of multimedia learning in prototyping instruction. An experimental investigation comparing student’s ability to apply prototyping techniques learned through different forms of instruction—utilizing a Designy multimedia resource, a demonstration, or an activity—could provide insights that could help educators decide which mode of instruction to use in course settings. This type of research study could also investigate the use of supervised or unsupervised practice in addition to multimedia instruction. Alternatively, students could be given a choice of multiple options for prototyping instruction then their choices could be documented throughout a course.
Designy as a Teaching Tool

At a high level, what Designy represents to design educators is another possibility for creating learning opportunities for students. By keeping a sharp eye on identifying student problems and having an attitude towards continuous improvement, design educators may identify opportunities in which Designy could be used to support student learning through hosting multimedia content.


References


Appendix A

Design Process for the Online Platform

Designy began as an initial exploration of what a persistent online platform could offer in terms of supporting student learning. CADlab-developed design courses each have their own course website used to support the courses. The initial concept for Designy explored the idea of one website that could be used in multiple product design courses. This appendix chapter outlines how Designy evolved from a general exploration of online technology to support learning in product design courses into a multimedia hosting platform for supporting student prototyping.

A.1 Initial Concept Exploration

This research project was created after a previous exploration of teaching a design workshop through the use of online media [46]. The decision was made early in the project to support residential product design courses instead of creating a separate design education experience. The initial exploration of this concept is defined by exploring what affordances a persistent online platform could provide to enhance student learning in product design courses.

After an exploration of existing technology for creating online platforms, it was decided that a custom platform would be created in order to give the author complete freedom in tailoring the platform to specifically suit student needs. These factors lead to the development of a wireframe prototype for a persistent web platform to be used in multiple product design courses. Figure A-1 shows images of the wireframes from the initial concept exploration.
Figure A-1: An early wireframe mockup of the different features an online platform could have to support learning in product design courses.
The use of video resources to support prototyping is evident in the early conceptual wireframe for a persistent online platform, but many other features were also being considered during concept exploration. Online forums were considered to connect students to each other and to the course staff in order to document answers to common student questions. A section of the website would be devoted to providing students with a place to host media documenting their project work in a portfolio, and another web page would track their learning by keeping a tally of which multimedia resources students had viewed.

Multiple options for design content to deliver were being explored. Prototyping techniques were part of the initial set of content ideas. In addition, the platform could be used to deliver content about design processes, extending material presented in lectures. Media could be created showing how expert designers would behave in the same situations students find themselves in while conducting design project work. There was also a chance to enhance community engagement through the presentation of interesting media like behind-the-scenes style videos from creating course experiences or interviews with course staff members. Finally, hosting recordings of lecture and extra tutorial content for students to review was also being considered. Initially, the plan was to explore primarily video as a means of delivery.

Practical considerations, including limited resources and time, meant that all of the features of this initial concept exploration could not be explored. However, the initial exploration did help identify core web development skills, mainly related to developing database-backed websites, that would be necessary for creating a useful platform. The scope of the project was reduced to focus on a platform that would deliver multimedia content to students about product-design-related content.

Involvement in design courses each semester provided opportunities to develop and test web prototypes and to gather feedback from students regarding their course experiences. The timeframe for these explorations begins with Spring Semester 2017, in which 2.00b Toy Design was held, and continues through Fall Semester 2017 with testing in 2.009.
A.2 Spring 2017: Research in 2.00b

A.2.1 Transitioning Lab Spaces

2.00b Toy Design of Spring 2017 was the first time the shop space had transitioned from an old space to the current Product Design Lab. Access to the PDL was an important space for the development of multimedia resources about prototyping, as it meant access to shop equipment and materials. As part of a teaching assistantship and as work towards creating an online platform, much of the semester was spent on preparing the space for project work as the semester progressed.

A.2.2 The 2.00b Videos Page

In order to get some video resources in front of students to explore using multimedia to support product design education, a page was created on the course website to host recordings of lectures and extra tutorials. Although the main idea for the online platform was a separate website from the course website, creating a Videos page allowed for testing with students to begin right away, before a full platform was developed. Students were given access to the page to review lecture material or if they could not attend the lecture or tutorial session. A screenshot of the videos page can be seen in Figure A-2.
Figure A-2: A truncated sample of the 2.00b Videos page, used to host lecture videos and extra tutorial content as a way of testing multimedia with students in Toy Design.
The Videos page provided a backdrop for soliciting student feedback on use of the Internet in 2.00b and the potential for a separate platform to support student learning. Creation of this web page also involved an exploration of options for hosting online videos.

### A.2.3 Media Exploration

Work on the shop space continued as the semester progressed, and as the end of the semester approached, use of the PDL as a studio space to produce videos was explored. However, recording videos in the space proved to be difficult, as there were issues with audio quality and space limitations in the shop.

### A.2.4 Learning from Students in 2.00b

In order to better understand student use of the Internet to support product design learning in 2.00b more generally, a survey was given to the students and short interview sessions with students were held. 48 of 79 students (61%) completed the survey, which was given to students during the last lecture session of the course before the Final Playsentations. Five students were interviewed by the author, with sessions lasting around 30 minutes. These interviews were conducted in a casual setting, where students were asked about their experiences in 2.00b, use of the Internet to support their learning in the course, and the potential of an online platform to help them learn product design content. Survey and interview results that contributed to the design of the online platform are presented in Figure A-3.
On average this semester, how often did you visit the 2.00b course website?

48 responses

What type of device do you use most often to visit the 2.00b website?

48 responses

How many of the course videos on the Videos page of the 2.00b course website have you watched?

48 responses

Figure A-3: Selected results from a survey given to 2.00b students in Spring 2017.
One highlight from these survey questions is that students utilized the home page of the course website frequently, which makes sense as this was the main source of announcements for the course and was updated frequently to summarize important course information. However, one interesting note is that while laptop and desktop viewing of the course was most prevalent, a number of students viewed the course website primarily on a mobile device (10.4%). This proportion represents enough students to suggest that websites students are expected to use should be designed to support smaller screen sizes.

In terms of utilization of the Videos page, a large portion of the class was not aware that the page existed (22.9%). For the future platform, particular attention would need to be placed on student awareness of the platform. Through discussions with students it was determined that since many lectures involve activities, the experience of being in the lecture sessions was not really captured by viewing a lecture video. Students found that posted lecture slides were usually enough to review if they had to miss a lecture.

Two key points of feedback from student interviews are worth noting. The first is that when asked about what multimedia content would benefit students the most, the majority of suggestions centered around supporting project work. Students felt that lecture experiences and interactions with lab instructors were enough to learn what they needed to know about design process, but they could use more support in completing their projects. In addition, one student made a key observation about how the platform would need to fit into the course experience. She mentioned that if videos were created to be a part of the course experience in 2.00b, those videos must present the same elements of fun and excitement exhibited by the course for her to be likely to utilize those resources. In this way, feedback from students was beginning to shape the content and style of the future Designy platform.
A.3 Summer 2017: Preparations for the Fall

The summer after 2.00b 2017 was dedicated to advancing the development of the platform in a few different directions. A web implementation of the initial platform was under development, which was completed near the start of the Fall 2017 term. In conjunction with web development, additional work to address issues with media quality were also underway.

A.3.1 Addressing Media Quality Issues

Media quality is an important aspect of the online platform because the media produced must set a proper example for the students. Recording videos solely in the PDL proved difficult, as there were audio quality issues due to HVAC noise and the shared space was occasionally crowded. In order to combat these issues, a second space was developed in order to provide another setting for the creation of video resources. A short trip upstairs from the PDL space, part of an office room was converted into a combination storage space and studio over the course of the summer term. This office space allowed for the recording of clear audio while providing space for lighting equipment and an infrastructure for supporting multiple-camera filming.

A.3.2 Adjusting Platform Scope: Focus on Prototyping Content

In order to simplify content development, it was at this point in the design process that the decision was made to focus on prototyping content. The reasons why prototyping content is good fit for online multimedia delivery are discussed in Chapter 4: Supporting Student Prototyping. In terms of the design process for creating Designy, focusing on prototyping content allowed the platform to become more tractable, as now there was less of a need to develop media to support a broad array of student experiences.

A.4 Fall 2017: Research in 2.009

In Fall 2017 there was an opportunity to test, for the first time, an implementation of the online platform that was an independent website. It was during this semester that the platform was
branded as Designy. Although the web platform had progressed, media resources were not ready for students during Fall 2017, so the platform was once again tested with recorded lecture and extra tutorial videos. This was not the intended application of the Designy platform, but the platform needed to be tested to ensure robust use in the future. A screenshot of Designy as tested in 2.009 is provided in Figure A-4.
Figure A-4: Designy was tested in 2.009 during Fall 2017 by hosting recorded lecture and extra tutorial videos.
A.4.1 Multimedia Development

While web platform development had progressed, multimedia development progressed slowly. Technical quality of video resources had improved, but developing video resources that would be useful to students in a variety of situations proved to be difficult. With a shift to focusing on design prototyping, coupled with initial multimedia experiment in the PDL and office studio, a change in media delivery format was considered. Explorations to shift away from only video as a delivery format began. A decision was made to allow for multiple media formats to make up multimedia resources on the platform, including images, graphics, and short looping animations. Throughout the term, an exploration of how to create useful media resources using multiple media formats was conducted.

A.4.2 Research in 2.009

In addition to testing the early platform, there was also a chance to learn from the 2.009 2017 student population about issues in the course revolving around prototyping. After the completion of the course, during the time leading up to the Spring 2018 semester, 8 students were interviewed to provide reflections on their experiences in 2.009 and the potential benefit of an online prototyping platform. These casual interview sessions lasted from 60 to 90 minutes. Based on interviews with students, coupled with observations made by the author as part of the course staff in 2.009, an analysis of problems students had with learning and practicing prototyping techniques was performed. Information collected from students was used to inform the current implementation of Designy, as described in Chapter 4: Supporting Student Prototyping.

A.5 Design Process Summary

A.5.1 Preparing for Spring 2018

Throughout the year, web prototypes were constructed which provided a backdrop for research activities in two design courses, 2.00b and 2.009. After testing in 2.009, the core web platform that would be used for Designy was working reliably. In terms of multimedia development, a decision was made that the platform could better support prototyping efforts through the use of
multiple media delivery formats instead of primarily focusing on video. Both the PDL and the office studio were ready for use for developing media content. All of the pieces were in place for developing the fully realized Designy platform, but exactly how to use multimedia resources to support student prototyping was not yet clear. The details of exactly how the platform would support student prototyping were not yet worked out. Those details are explored in Chapter 4: Supporting Student Prototyping.
Appendix B

Website Documentation

A description of how Designy works is presented here for those curious about the technical implementation of the platform.

B.1 Under the Hood

B.1.1 Web Structure: Backend

The platform is designed to be used by multiple courses, but each CADlab-developed course has different student populations. This means that different students may need to be presented with different media resources throughout the semester, as certain resources might be more or less relevant to different groups of students. Also, the organization of the media resources need to be flexible enough to change throughout the semester, bringing relevant material to the top of the page. In order to track student usage to more deeply understand how the website is being used, students need to have accounts with associated usernames. Finally, in order to expand as content is developed, updating the media library page needs to be fast and easy. It was determined that the website needed to be database-driven. Thus, creating the platform would require both backend and frontend development.

Backend development for the Designy platform was mainly concerned with the creation of a database-driven website. A database, much like a spreadsheet, is used to store information on a website’s server. This is how information is stored even if a website user logs out and closes the website on their personal browser. For the Designy platform, the lists of usernames, categories, and topics are all stored in the database of the website.

The Designy platform is created using the Django framework, which is based on the coding language Python. Django is meant to simplify the development of database-driven websites by
providing a series of functions and structures that help the web designer create website features without having to learn how to directly manipulate the database. In short, learning the Django framework provides enough shortcuts that a novice web developer would then be able to create a database-driven website without extensive web development training. That is not to say that Django is designed only for novices, but the documentation of the framework is extensive enough, and the community is supportive enough, that it is a smart choice for novice users.

A database-driven website needs to be hosted on a server, just like any other website. However, additional functionality is needed for the server to be configured to support a framework like Django. The service Heroku was chosen to host Designy. It was determined that although there would be a cost associated with using Heroku, the development environment had better documentation, customer support would be better, and the service would be more robust than other potential hosting solutions.

Information stored in the database can be used to create the web pages that are presented to the user. This is how the media library page of Designy is constructed. A template file in Django describes how the web page should be constructed by reading the information from the database. Stored in the database are all of the categories—such as Benchtop Tools, Sketch Modeling, 3D Printing—and all of the topics—such as Bandsaw, Drill Press, Sheet Materials—that make up the media library. If an additional topic is added, the template will automatically update the media library page, requiring no additionally editing of website code. Topics listed in the built in administration tools provided by Django are presented in Figure B-1.
By adjusting resource ordering in the database, the organization of the media library page can be reordered automatically. The topics displayed are also connected to the course listings attached to student usernames. In this way, certain resources on the platform can be restricted to being viewed only by students in certain courses. In the future, this feature could also be used to host media intended for specialized audiences, such as training resources for TAs that should not be viewed by students.
By using the database to build the media library page, the process for uploading media is simplified for the media developer. The content pages are customized for each topic, so these pages cannot be constructed by reading data from the database. In order to keep full flexibility in the design of the content pages, each content page has its own template file, akin to creating a custom HTML page for that resource. This ensures that each content page does not have to follow a prescribed format, allowing for each content page to host whichever multimedia elements help convey the topic best.

Because this platform was developed as part of a research project, there is a need to track student usage of the platform. This is done through the use of middleware, or code that is run when the user’s browser requests information on the server. Middleware is supported by the Django framework. The Designy platform is set up to record each click made by the user in the database. This is done by altering code made freely available for general use [51]. This code needed to be adjusted by the author to work with the Designy platform. A full understanding of the middleware code was never obtained by the author, and upon reflection, it is surprising that it actually works. An additional page on the website was created to be able to access, review, and explore usage data from a browser, but is only accessible upon logging in to Designy as an administrator.

**B.1.2 Web Structure: Front End**

The frontend of a website organizes how information is presented to the user through the browser. This is where graphic design comes into play, which is important for a website to be used to display high-quality media resources. If the content on the website is not neatly organized, it can become confusing. Overall, a clean aesthetic was chosen to not distract from the media itself.

One guideline for the frontend design of the website was that the content had to be viewable on a variety of screens. In order to help with the presentation multimedia elements on smaller screens, the Bootstrap framework was chosen to aid in web design. The Bootstrap framework ties the underlying structure of a website to a responsive grid system, in which assets on a website can
automatically resize as the viewing window of the browser changes. If the developer of a website uses Bootstrap, then the same website can be displayed on a laptop and a mobile device, with the size and layout of the assets automatically adjusting so that they are optimized for viewing on that device.

Besides helping support different screen sizes, committing to a specific grid system can also help streamline the frontend development of a website. During the development of the content pages on Designy, a series of consistent layout structures were chosen. This meant that as development continued, there would be a design precedent and consistency maintained between the way certain media types were presented. Not only did this allow for more visual consistency on the website, but it also allowed for protocols to be developed regarding the use of particular multimedia elements. As a bonus, shortcuts could be made in the form of code snippets to streamline the development of content pages by capitalizing on the similarity of new pages to previously developed pages.

B.2 Multimedia Hosting

Heroku’s servers are not optimized for serving media content to users’ browsers. This presents a problem for a multimedia-heavy website like Designy. Two services are used to combat this problem. The first service is Wistia, a video hosting service similar to YouTube or Vimeo that was chosen early in development when the platform was going to be solely video-based. Wistia allows for chapter markers to be placed in videos for improved organization. Additionally, Wistia takes care of optimizing a video for streaming by automatically encoding uploaded videos.

Despite its advantages for longer videos, Wistia was not an appropriate solution for the short, auto-playing, looping videos that make up animations. In order to serve these files, Amazon Cloud Services was chosen. This service allows users to upload files and then link to the uploaded files on their own websites. Then, when the content is requested by a user, it is served from one of Amazon’s servers that is optimized for delivering content quickly to user’s browser.