

Work in Progress: Remote Instruction of Circuitry in a Multidisciplinary Introduction to Engineering First-year Course

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Abstract

This paper is focused on a course redesign transitioning from a hardware-based course into a course taught remotely. The J. B. Speed School of Engineering (SSoE) at the University of Louisville (UofL) has a two-course sequence that all first-year SSoE students are required to complete. This two-course sequence is designed to introduce incoming students to the profession and fundamentals of engineering. The first course is titled *Engineering Methods, Tools, & Practice I* (ENGR 110), and primarily focuses on introduction to and practice with fundamental engineering skills. The second course, *Engineering Methods, Tools, & Practice II* (ENGR 111) is typically a makerspace-based course primarily focused on application and integration of the fundamentals learned in ENGR 110. Included amongst numerous skills institutionally identified as “fundamental” were programming and basic circuitry. Therefore, all disciplines of SSoE engineering students are exposed to the basics of circuitry and programming through ENGR 111 pedagogy.

Due to the COVID-19 pandemic, this makerspace course is to be taught remotely in the spring semester of 2021. The instructional team felt that there were too many shared tools and teams were too close together to safely continue the course in a makerspace environment. This remote teaching has posed the instructional team some unique challenges due to the hands-on nature of the ENGR 111 course. Students are typically in face-to-face teams of 3 or 4 students and each group is given an Arduino, breadboard, and circuit components. The given assignments start out with basic circuitry and Arduino programming, followed by utilizing an Arduino to communicate with created circuits. The assignments are designed to help the first-year students gain comfort in circuitry and programming.

The instructional team has decided to use Tinkercad, which is a free online collection of software tools provided by Autodesk. Many people are only aware of Tinkercad as a 3D modeling programming, however in 2017 Autodesk merged its “123D Circuits” into Tinkercad [1] [2]. This makes Tinkercad an ideal platform to use for circuitry and Arduino programming.

The paper will further describe the design of the assignments, instructional team expectations from the students, the environment in which the students are using Tinkercad, as well as looking at expected course outcomes using the platform. This topic is a work in progress as data for evidence-based analyses will not be fully procured until after publication.

1. Introduction

The J. B. Speed School of Engineering (SSoE) at the University of Louisville (UofL) has a two-course sequence that all first-year SSoE students are required to complete. The sequence of courses are *Engineering Methods, Tools, & Practice I* (ENGR 110), and *Engineering Methods, Tools, & Practice II* (ENGR 111). The ENGR 110 course is focused on introducing first-year students to the profession and fundamentals of engineering. The second course, *Engineering Methods, Tools, and Practice II* (ENGR 111), is normally a makerspace-based course primarily

focused on application and integration of the fundamentals learned in ENGR 110. Skills that were identified as fundamental to all majors were basic programming and circuitry. Fundamentals of programming are introduced to the students in the ENGR 110 course using Python as the programming language. ENGR 111 follows with students applying their developed knowledge of programming, now integrated with circuitry.

The decision was conscientiously made to expose students to more than one type of programming environment over the two-course sequence. This decision was made to help the students realize that fundamental programming concepts remain unchained, i.e. a *for* loop works identically in all environments regardless of the syntax. Accordingly, ENGR 111 uses Arduinos (and associated programming language) to further the first-year students programming curriculum. The Arduino Uno was the chosen microcontroller since the platform is excellent for teaching basic circuitry and programming, such as having easily accessible digital and analog input/output ports.

ENGR 111 uses a scaffolded set of lessons to introduce circuitry, programming an Arduino, and interfacing between an Arduino and circuits. These lessons start with basic circuits using breadboards, basic components, and wires. Programming the Arduino is the next set of lessons, and these lessons focus on basic programming concepts and how to interact with the Arduino. Finally, there is a series of lessons that help the students create circuit(s) and program(s) that interact with each other.

Although the ENGR 111 structure is the antithesis of a remote pedagogical setting, course administrators decided to redesign the ENGR 111 experience as a remote delivery due to the reality of the Covid-19 pandemic. Remote delivery has been institutionally defined as a course that meets online, and synchronously. The use of the makerspace was not feasible due to the close-proximity nature of numerous hands-on activities for as many as 96 students per class, and the provision of multiple shared tools amongst six different classes. Therefore, the remote designation challenged instructors in retaining a heavy focus on teamwork, in addition to the active learning environment of the conventional course iteration. The following sections provide further detail in these efforts for ENGR 111 curriculum specific to programming and circuitry.

2. Technology

Several technology requirements were identified as essential and practical in meeting the aforementioned objectives in course redesign. These included a computer, access to the internet, Microsoft (MS) Teams, and a Tinkercad [3] account. The instructors acknowledged practicality in these requirements because:

1. all SSoE students are required to have a Tablet PC,
2. all UofL students have access to the Microsoft suite of applications including MS Teams,
3. Tinkercad allows free accounts.

For the internet connection requirement, students have the option of free access across a very large area of campus property, and the instructors were confident that any student living off campus had internet access.

2.1. Additional Tinkercad Details

The entire Tinkercad site includes powerful simulation software for a variety of purposes, such as 3D modeling and Arduino programming. Autodesk defines Tinkercad as a free online collection of software tools that help people all over the world think, create, and make [3]. However, the scope of this paper will focus solely on the electronic circuit environment. This circuit environment allows for design, programming, and simulation.

Tinkercad has a simulation workspace (Figure 1) and a component library that is based on existing Arduino kits. This allows for the creation of a variety of circuits that range from simple to complex. In most respects, Tinkercad operates identically to a breadboard circuit.

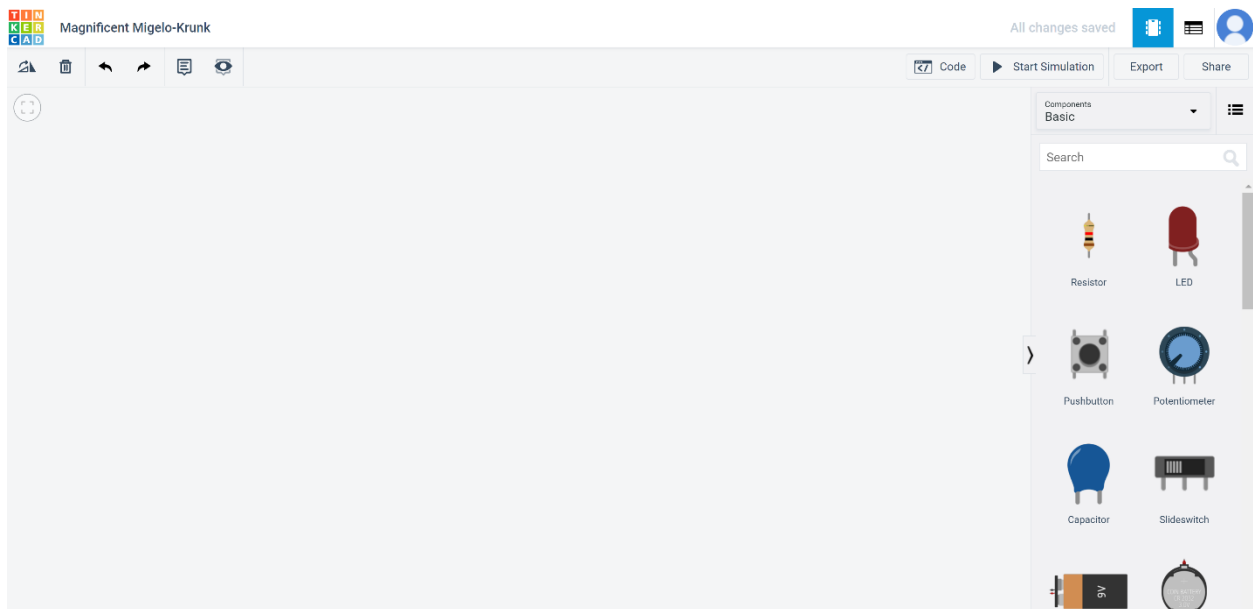


Figure 1: Workspace in a new Tinkercad simulation.

Tinkercad has an intuitive environment for adding and customizing components. Nodes in the prototyping area of the breadboard highlight green when moused over. Clicking on components (such as a resistor) brings up a customization box where the properties of the components can be adjusted and modified (Figure 2).

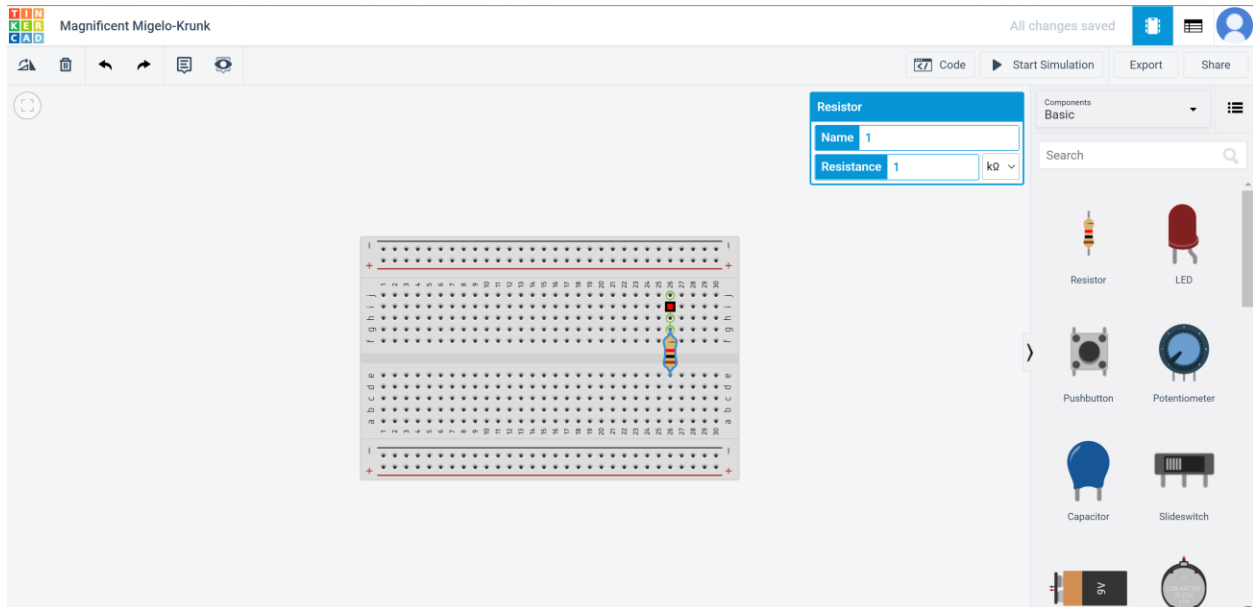


Figure 2: Changing properties of components in Tinkercad.

Another important detail beyond the circuit's functionality is the accuracy of the simulation itself. One important aspect of circuitry for engineering is the ability to measure the system, and the built-in multimeter (Figure 3) does so just as effectively as the physical device. The built-in multimeter also will not be damaged or have a fuse blown if used incorrectly. Additionally, circuits in Tinkercad can be named, saved, and shared.

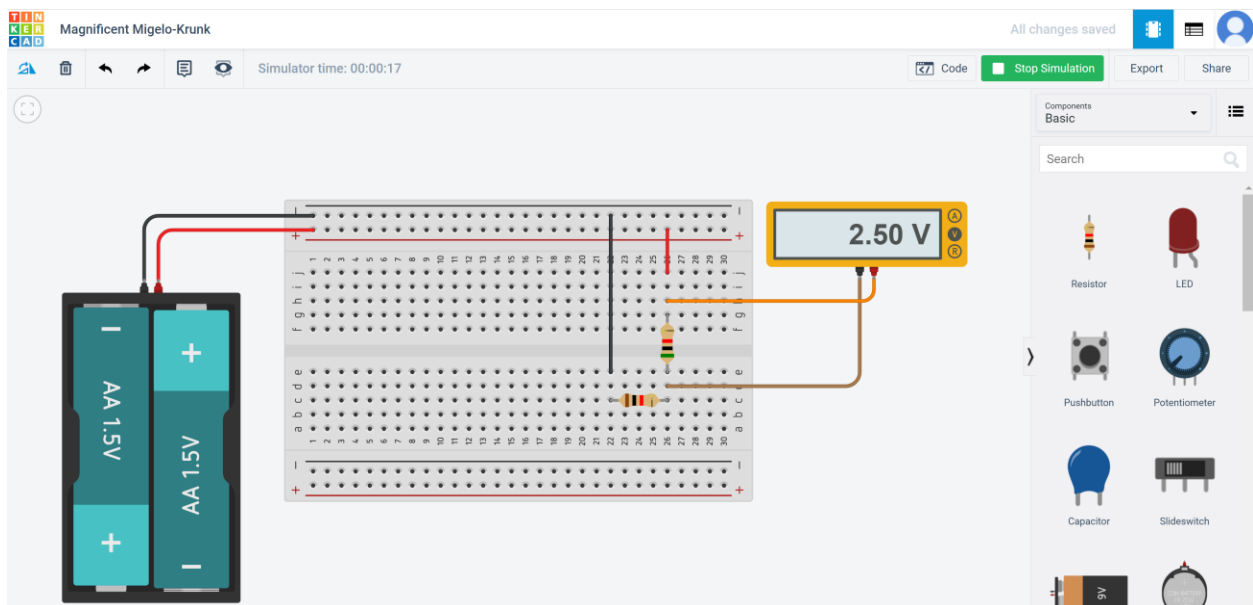


Figure 3: Using the multimeter in Tinkercad.

3. Assignment Descriptions

The Tinkercad environment was employed in ENGR 111 for two course meetings in Spring 2021 for the purposes of circuitry instruction: “Laboratory Preparation” and “Introduction to Circuitry”. Both classes were taught in previous iterations of the course utilizing physical circuitry components. However, in the transition from typical to remote instruction, these labs continued to include the same circuit-building activities. Regardless of iteration, these classes were both performed by students in groups of 3-4.

The “Laboratory Preparation” class’s primary purpose is to introduce the materials in the course, such as Arduino and circuitry components. However, this class also allows students to explore the purpose of these components through circuit construction. In this class, students build four pushbutton circuits with light-emitting diodes (LEDs) as given in an Arduino Projects book [4]. These circuits are shown in Figure 4.

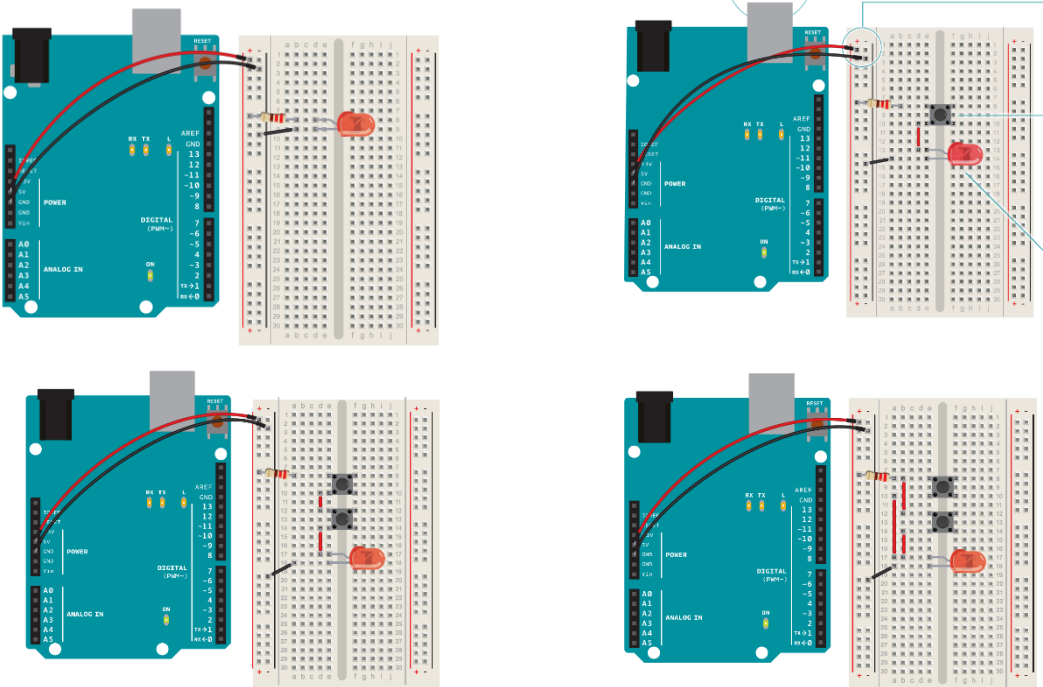


Figure 4: Pushbutton/LED circuits for "Laboratory Preparation" class.

The “Introduction to Circuitry” class has students constructing two basic circuits: a resistor circuit and a LED circuit (see Figure 5). Once built, students use a multimeter to discern common circuit principles through Ohm’s Law.

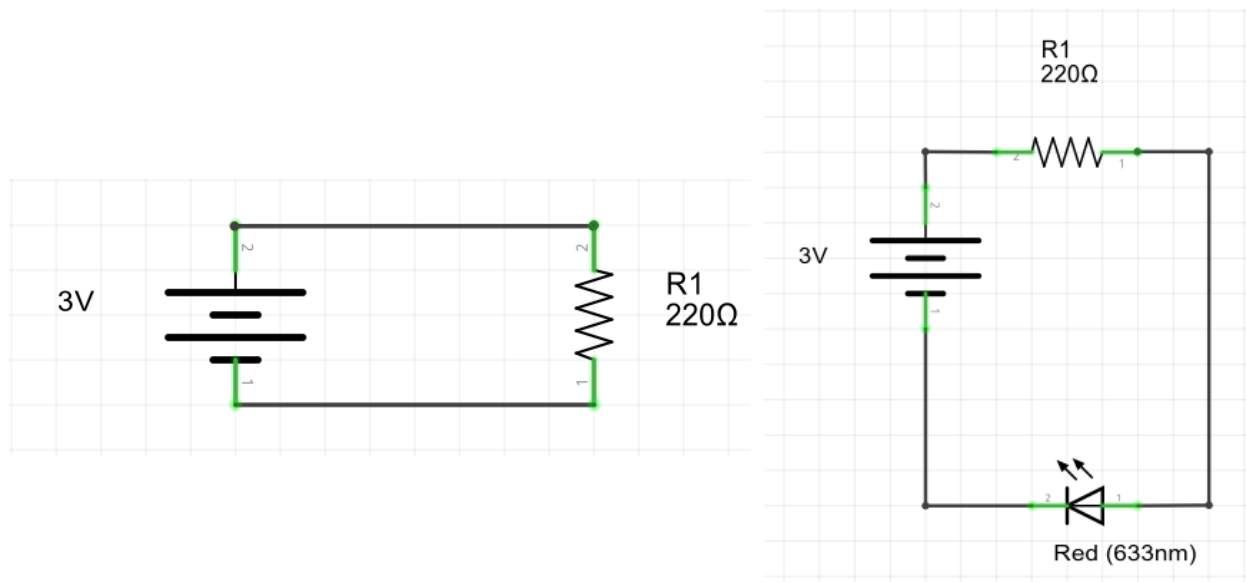


Figure 5: Basic circuits for "Introduction to Circuitry" class.

While the material of each lab is identical between years, one major difference provided by the change in platform is the efficiency of exposure. In a typical environment, students in a group stand around a table sharing one set of equipment (i.e. one breadboard, one set of components, one multimeter, etc). This means that during circuitry instruction, students must share a breadboard, which often leads to roughly half of each group watching rather than actually constructing the circuit. With Tinkercad, each student creates an account and can work on circuits in their own workspace simultaneously with other students in their group. While each student in this situation is constructing a unique circuit (they are not editing the same circuit at the same time), this allows each student to get the experience of building circuits.

After completing the assignments, students were required to demonstrate the functionality of their four circuits. In Spring 2021, for “Laboratory Preparation”, students were instructed to build all circuits themselves in Tinkercad while discussing with their teammates, mandating individual exposure. This specific instruction was highly recommended but not required for “Introduction to Circuitry”.

4. Comparison Results

As mentioned, these learning modules covered identical material in Spring 2020 and Spring 2021, with the only difference being in the circuit construction method. This allows for a comparison of student performance to see if any impact was made by the utilization of Tinkercad in place of physical circuitry.

Student groups were graded on each lab assignment out of five points, which were awarded based on demonstration of properly built circuits and reasonable data from circuit measurements. Table 1 below shows the average student grade on both assignments.

Table 1: Comparison of student performance in circuitry laboratory assignments.

Iteration	Instructional Mode	Number of Students (<i>n</i>)	“Laboratory Preparation” Average	“Introduction to Circuitry” Average
Spring 2020	Physical Circuitry	450	4.91	4.83
Spring 2021	Tinkercad Simulation	426	4.70	4.77

These results show that while the average scores dropped very slightly between 2020 and 2021, the difference between these scores for the sample sizes given is quite small. This indicates that for a complete change in platform, there is little impact on student performance.

It is noteworthy that while overall grades were not impacted greatly, student experience increased substantially. The use of Tinkercad significantly enhances the ability for each student to gain circuitry knowledge through practice. In a physical environment, some number of students are typically left out during circuit construction, as breadboards are not large and can only be worked on by 1-2 students at a time. Tinkercad avoids this issue by allowing students to build the same circuit simultaneously while asking teammates for help, improving the collaborative learning from the experience.

First-year students have thus far enjoyed the virtual environment. Comments from students to instructors have indicated that satisfaction in these classes have improved with the use of Tinkercad. Here are a few sample comments:

- “I have worked on physical circuits before in high school, and I liked this environment and feel like it was the same as for real.”
- “I learned more doing it myself with my teammates than relying on one person who is good at circuits to do it.”
- “I enjoyed designing my own circuits but working with my team to be sure I was doing it correctly.”
- “I enjoyed the circuits without being able to damage anything.”

5. Conclusion

The ENGR 111 course at the University of Louisville is typically a laboratory-based, hands-on course set in a makerspace setting. Due to the COVID-19 pandemic, the course was switched to a remote instruction mode course for the Spring 2021 semester. In order to maintain the inclusion of circuitry instruction in this remote setting, Tinkercad was utilized for circuit simulation.

Comparing the results of two circuitry lessons between Spring 2020 and Spring 2021 indicate that there is little impact on student performance with the use of Tinkercad. Beyond this, Tinkercad allows for increased student participation, as each student can construct their own circuits rather than having to share breadboards among the team. Student feedback regarding Tinkercad is overwhelmingly positive as well. This paper has been identified as a work in

progress because measures for obtaining quantitative and qualitative evidence-based data are currently being finalized amongst course administrators.

References

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