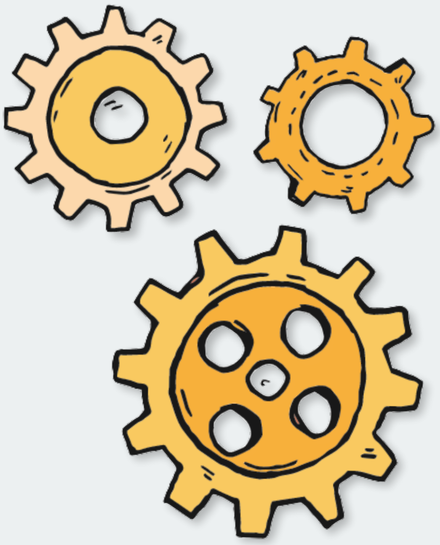
Dec 18, 2020

Interaction Lab For Middle Schoolers

10-week after-school STEAM education camp



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Educational Goals, Instruction, and Assessment, Fall 2020

Individual Project

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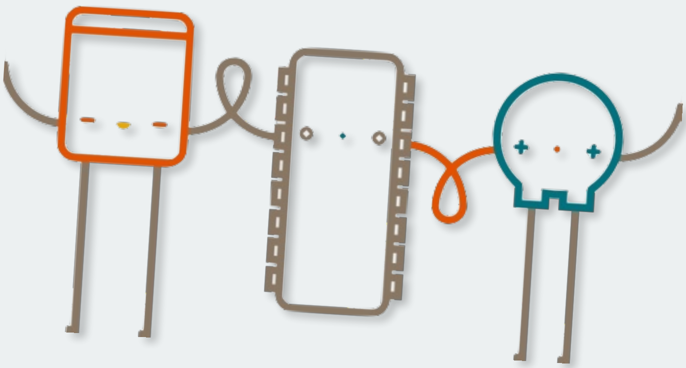
TINKERCAD



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1. Project Topic Description

This project intended to design an after-school camp for middle school students, with a focus of introductory electrical engineering knowledge and interactive design. The subject is highly related to **STEAM** Education especially **Engineering Education**, the **FabLab** program which was first set up by MIT Media Lab, and the concept of **maker** and **DIY**.

1.1 Educational Design Focus

1.1.1 Learning Challenges

> **Why Hands-on Practices does not Enhance Learning?**
>
> In a summer camp for 8-12 years old kids I assisted this year, the topic is also about interactive design with engineering knowledge. The summer camp last for 4 weeks, 3 lessons each week, each lesson last for 2 hours approximately, 24 in-person hours in total. Every lesson the instructors would first do some direct lecturing of electrical engineering related topics, and then encourage children to do some drawing and structural design hand work with cardboard in the rest of the class. At the end of the camp, we hold a "Hackathon", in which we provided different scenarios and asked students to utilize electrical control knowledge and make their own products with physical interaction in groups of four. However, few students successfully made use of electrical control, and most of them are only building physical structure with cardboard.

In this activity, although instructors make use of hands-on practice, and combine different instructional methods together in a course, the outcome is unsatisfactory. Why? This activity involves multiple disciplines, including basic knowledge from electrical engineering, mechanical engineering, computer science, interaction design and art design. One major challenge of learning and teaching is the "discipline integration" [1, p.411]. Teachers had trouble in designing instructions of "how to teach subject matter across disciplines'' [2, p.174]. The failure to implement reasonable "discipline integration" [1] leads to the ignorance of certain objects.

What's more, in this case, students demonstrated their skills to do handwork and drawing with cardboard and paper instead of their ability to integrate electrical control, which is the problems that [3] have documented, "learning may occur, but it is not the primary objective" [3, p.73]. This is a consequence of bad "discipline integration", and also a consequence of the misalignment of assessments and instructional approaches and goals.

Another main challenge is the lack of "effective assessment" [1, p.174]. Maker activities are more complicated to be assessed due to its subjective characteristics. Quizzes and exams may not be effective ways to evaluate students. To build a valid scoring rubric is challenging. Other learning challenges such as lack of "access to resources" or "lack of collaboration among colleagues" are also notable [2, p.174].

This after-school camp will mainly focus on balancing the integration of disciplines, which includes designing goals with priority based on learners' profiles, designing instruction and assessments that aligned with goals, and designing active instructional approaches (**Big Ideas: Align Assessments and Instructions with Goals**).

1.1.2 Goals

The course is specifically designed for students from Grade 6-8. The course will cover knowledge of fundamental electrical control, using Arduino IDE and assorted controller and sensors kits, and basic interactive design principles. By the end of the class, students will be able to create their own circuits with LED, servos, motors, sensors, and control them by writing organized logical codes making use of variables, built-in objects, conditional logic, iterative logic, customized functions. Moreover, students will also be able to apply the interactive design principles to their own products. Students are required to display and give thorough description of their projects, including final outcome and building process.

Combining the learning goals and standards from International Technology and Education Engineering Association [4] and FabLab's Fab Academy [5], we could synthesize the learning goals as follows.

Students will:

1) Analyze real-life problems with the power of human- centered design with the help from instructors, and refine the interactive system designed for a specific domain and context.
2) Think of "creative solutions that work best by demonstrating careful selection of

resources to generate the best outcomes".

3) "Rapid-prototype by planning and executing" their proposed solutions using electrical control, digital fabrication and design thinking.

Student will develop and enhance their ability to:

4) Social responsibilities by engaging in solving social problems.
5) Compare and evaluate the design of creative solutions.

Community Norms:

6) Collaborative working
7) Oral communication formally and informally
8) Respect for distinctive opinions and critique
9) Reflection on own design and making improvement

1.1.3 Why is it Important

With the rise of DIY and Maker Movement, Maker activities have spread its influence to non- professionals without age limit [3, p.70]. Moreno and other researchers presented that "middle school years are a crucial time for cultivating students' interest in and preparedness for future STEM careers" [6, p.890]. Next Generation Science Standards (NGSS) [7] has emphasized the importance of integrating engineering education in middle school years [6, p.889] since it is always being neglected compared with Science and Math education. The emphasis of Engineering education in middle school can not only develop interests and affect students' future career decisions, but also give students positive impact on academic learning, since the transition from elementary school to middle school often comes with the change of school culture and intensified course difficulties, which will cause negative impact for students [6, p.890]. This interactive maker programs could provide the ignored engineering education and focus more on the application of basic EE knowledge and design principles, and further develop students' learning interests by making projects. It encourages and provides approaches for students to design products for solving real-life difficulties or social problems by themselves, which enhance students' social responsibilities.

1.1.4 Maximize the Continuity

The maker activities that designing interactive products and devices have the inner characteristics of problem- solving. By leading students thinking about their own difficulties and inconvenience in daily life, and also by providing students with social problems or current social events, instructors could raise examples of using interactive technologies to solve the problems, in order to tap students' motivation in learning. Instructors would also have close communication with learners weekly, discussing the solutions to the provided scenarios together. Moreover, because this activity is designed as an after-school camp, instructors won't give letter grades or official grades for the assessments and the final performances. Instead, instructors will provide targeted feedback referring the scoring rubrics with explicit description on students' strengths and things could be improved.

1.2 Initial Resources Available

1.2.1 Personal Experiences

I hold a bachelor degree in interactive media arts, in which we apply physical computing to design products or art projects. I also have intern experiences in different STEAM education companies as a teaching assistant and a tutor for students from Grade 6-12.

1.2.2 Consultants

Rodolfo Cossovich, instructor from NYU Shanghai with specialty in physical computing. "Cossovich has co-founded several projects with focus on Open Source Hardware both for robotics, education and electrical vehicles." [8]

Jundi Wang, course director of technology courses at Mengfu Education Technology Co., Ltd. Mengfu is a STEAM education company that provide students project-based courses in engineering and computer science.

Minchuan Zhou, a full-time tutor teaching mechanical engineering and structural design related knowledge. Structural design is a pre-requisite for taking interaction lab.

1.2.3 Reference Websites

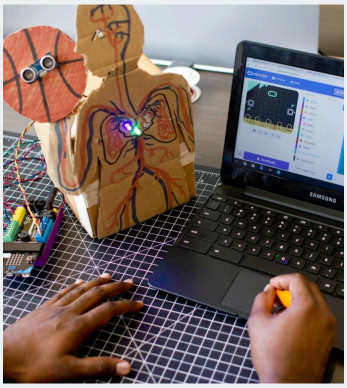
We looked into products in the below websites for project inspiration and tutorials, and for referring to the difficulty level for Grade 6-8.

https://pbskids.org/designsquad/build/

Design Squad website provides maker activities utilizing cardboard and drawing, with step-by-step instructions. Instructors could use this website to find inspiration to design practice. Students could also frequently browse the website to develop their interests, and learn hands-on abilities from the websites.

https://www.birdbraintechnologies.com/

Both Instructors and students could refer to this website to have an understanding of the difficulty level and the expected results.



https://www.birdbraintechnologies.com/

https://www.tinkercad.com/learn/circuits/learning

This is a tutorial website from TinkerCad, it includes clear tutorials and examples provided by TinkerCad. Instructors could refer to the tutorials for their lecture, also design assignments based on this website. Students could also practice and explore by themselves using this website.

https://www.arduino.cc/en/Tutorial/HomePage

This is a tutorial website from Arduino. Instructors are encouraged to refer to the tutorials for preparing their lecture. However, because of the website is highly text-based, it is not recommended to be used directly by students.

2. Learners in Contexts

2.1 Context Considerations

2.1.1 Learners

This Project is designed for students from Grade 6-8, focusing on international schools' students in Shanghai, China. International schools in China are very different from local schools in China in terms of educational goals and teaching methods. International schools employ Western style of education, focusing on "creativity and individualism" in students, while Chinese traditional education mostly uses rote-memorization to get good scores [9]. Another huge difference between these two types of school is that international schools always have high tuition fees, and local schools are free until Grade 9. There are several types of international schools in China, including the private international schools run by global institutions (such as Nord Anglia Education), or international departments run in local schools, or local schools that are qualified to accept foreign students. In this project's case, we focus on the first type of international schools, the global institutions' international schools. The average yearly tuition fee of these international schools is around 250,000 RMB (36000$). Considering their educational styles and Socio-economic status, students from international schools are confident, brave, lively and creative. They could express their difficulties and bravely ask questions.

How to Avoid this?

Once, I participated in the instructor team of a summer camp for international schools' students from Grade 3-6. Students are very lively and love to communicate, but they also have the problems of listening too little. One of the students thought he already learned the course materials, so that he played iPad during class time and played it with other classmates who haven't learned the materials before. But actually, he couldn't answer basic questions related to course materials.

To analyze this case without denying the influence of relatively younger age, it is possible that because of their socioeconomic status and education background in China, some of the students are a little proud and may show disrespectful attitudes towards the class. Therefore, it is necessary to set the norms that the class environment should be respectful, supportive and collaborative (**Big Ideas: Build Interactive & Supportive Learning Environments**). Instructors also need to consider learners' prior knowledge with pre-assessment, observation and communication, and further help them realize how to make use of it and learn more (**Big Ideas: Consider Differences in Students' Prior Knowledge**). Another problem that exposes in this case is students' lack of cognition of "intelligence is incremental" [10, p.158]. Therefore, it's important to integrate instruction and assessment for developing metacognitive skills as well (**Big Ideas: Become Self-regulated Learners**).

2.1.2 Contents & Focus

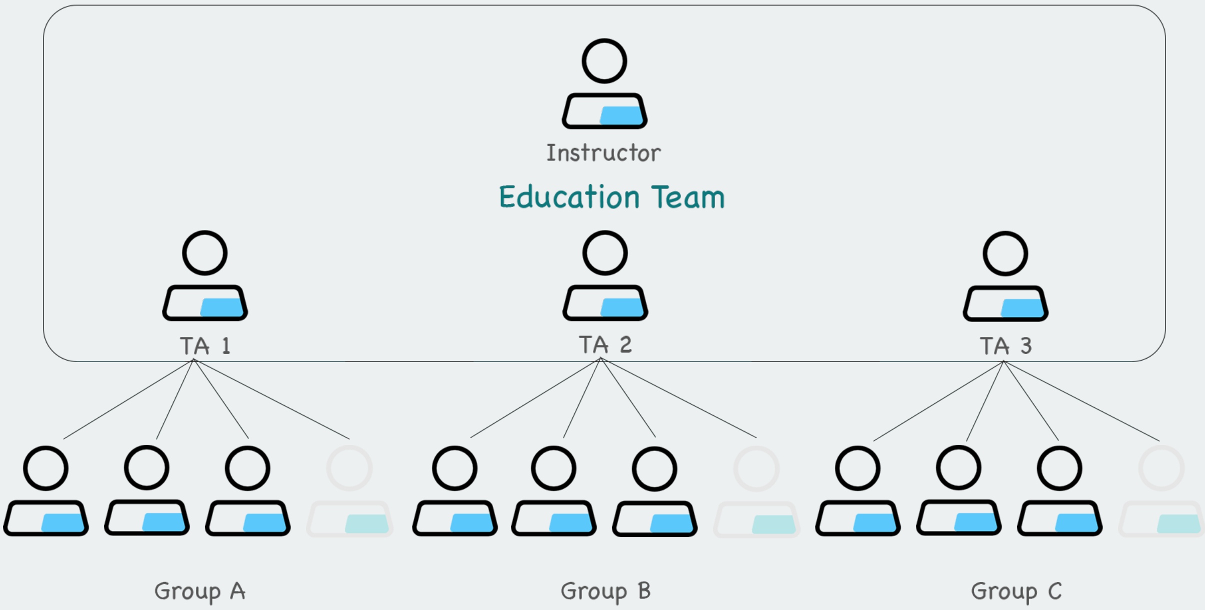
This camp will be a ten-week sequence with 1 hour in-person meeting and 1 extra hour for completing assignments. The focus will be the following three parts:

1. A basic understanding of the engineering area and a view of design thinking. The **conceptual knowledge** that will be covered could be listed in the following structures.
   (1) Introduction to Arduino Board and the electrical components
   (2) Sensors control: Analog and digital inputs and outputs
   (3) Servos and Motors
   (4) Fundamental Programming concepts: variables, conditionals, iteration and
   (5) function Physical Interaction Design Principles
2. Build a product's prototype and present a live demo. Students will be given a scenario and start design their products from the beginning of the activity with assistance from the instructors' team. Through the process, students will gain maker experience and learn how to **apply** engineering knowledge and interaction design principles in DIY.
3. **Reflecting** on their working process based on self-reflection, self-evaluation and peer review session. Students will self-reflect their products every week after the 1-hour in person meeting by applying new knowledge and skills into the design and evaluate what are the strengths and what are the weaknesses. Students will also reflect on peer review feedbacks and made modifications on their products.

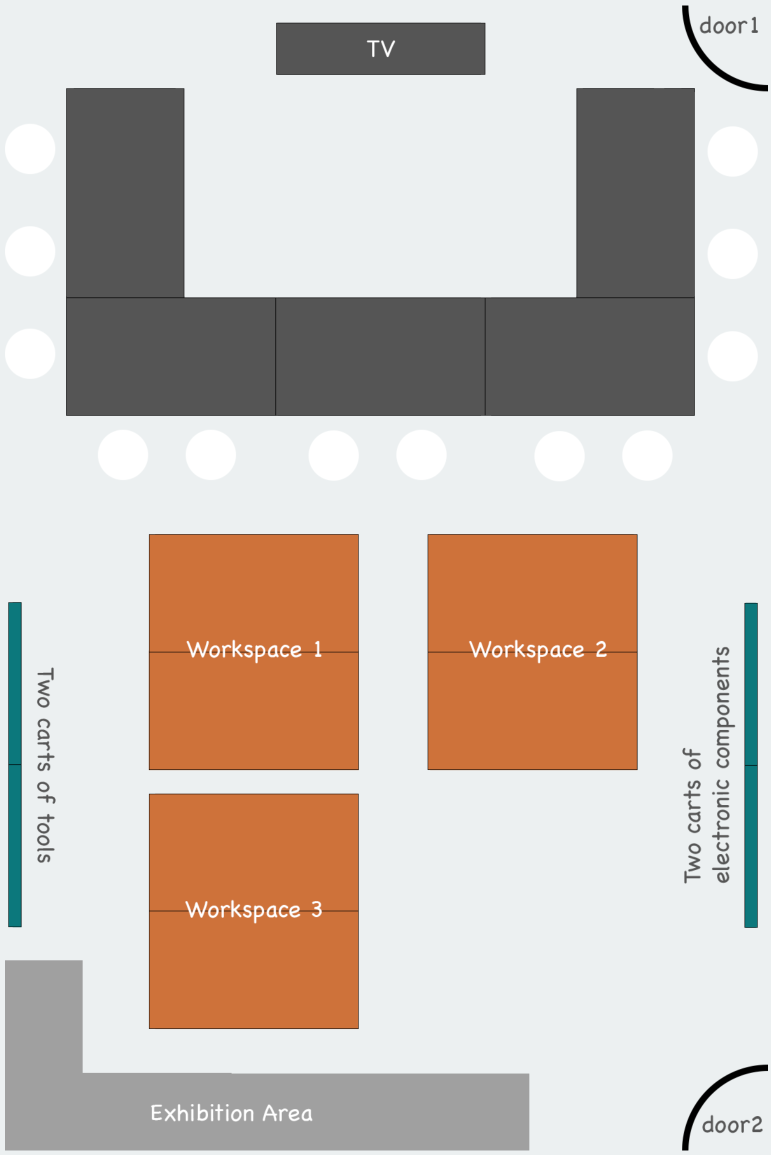
2.1.3 Class Size and Classroom Setup

The 1-hour in person synchronous event each week will be located in the classroom for Robotics Club, as an **after-school club activities**. Moreno et.al claimed that after-school programs can provide "enriched learning opportunities that are unavailable during the regular school day" since the programs wouldn't be limited by state requirements and are "potential to impact students' interest in STEM fields" [6, p,891]. Students are encouraged to come to robotics club classroom for the other 1-hour assignment each week as well, but it will be optional. Coming to the classroom have lots of advantages, for example, students could discuss with each other and ask for advice from peers, the classroom will also provide materials for students to practice hand-on experiments.

The class size will be 9-12 students in total, so that for their final group project, they will be divided into 3 groups, each group has 3-4 members. The education team will have one instructor and three teaching assistants. Each teaching assistant will closely work together with one team and play the roles of group tutor. Education team will work closely with each other and prepare the course contents together. Instructor will be in charge of each week's in-person meeting. And teaching assistants will share their observation and students' progress with instructor, in order to give students more targeted and timely instruction and feedback.



In terms of classroom settings, students will half surrounded the instructors and the TV monitors. There will be three additional workspaces for each group. We will also provide materials and tools needed, including paper, cardboard, magic clay, Arduino boards, sensors, batteries, chargers, rulers, pens, cutters, scissors… These materials and tools will located in carts besides the wall. Interactive products made by previous students will also be placed in the classroom. Students could see it both as inspiration and role models. The dynamic settings of the classroom could help students engaged [11]. The following sketch demonstrates how the classroom will be arranged.



2.1.4 Timeline

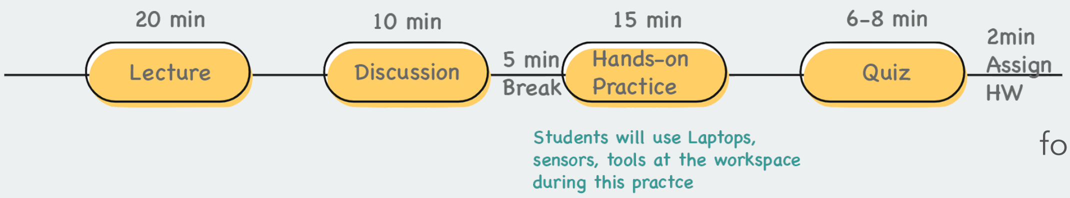
Since this sequence of lessons is an intro for students to get to know multidisciplinary subjects and a foundation of understanding basic design and engineering knowledges, and one of the most important goals is to encourage students' interests in STEAM careers, so the activity is considered as one of the foundation courses in robotics club. However, because the interactive products have physical interaction, therefore, we set **structural design** (one of the foundations in robotic club) as our pre-requisite. We will also have pre-assessment to assess students prior knowledge. More details will be included in Assessments Design section. The course will be situated in spring semester every year.

Beyond the courses provided from robotics club, students are expected to take some basic math course and some physics course. We expected students to know basic arithmetic and equation. This will benefit them students when learning declaring variables and conditional statement for programming language. We also expected some physics knowledge related to **circuit**. The physics course could be taking concurrently with this after-school activity, since the activity will focus more on using Arduino kit to connect circuit, where many circuits are already integrated in the sensors and the boards. Therefore, it is not as complicated as connecting circuits with pure electronic components. But having some prior knowledge in circuits will at least eliminate fear due to unfamiliarity.

From the cognitive perspective, students are expected to take courses involving lots of group discussions and group projects, since these develop students collaborative working skills and abilities.

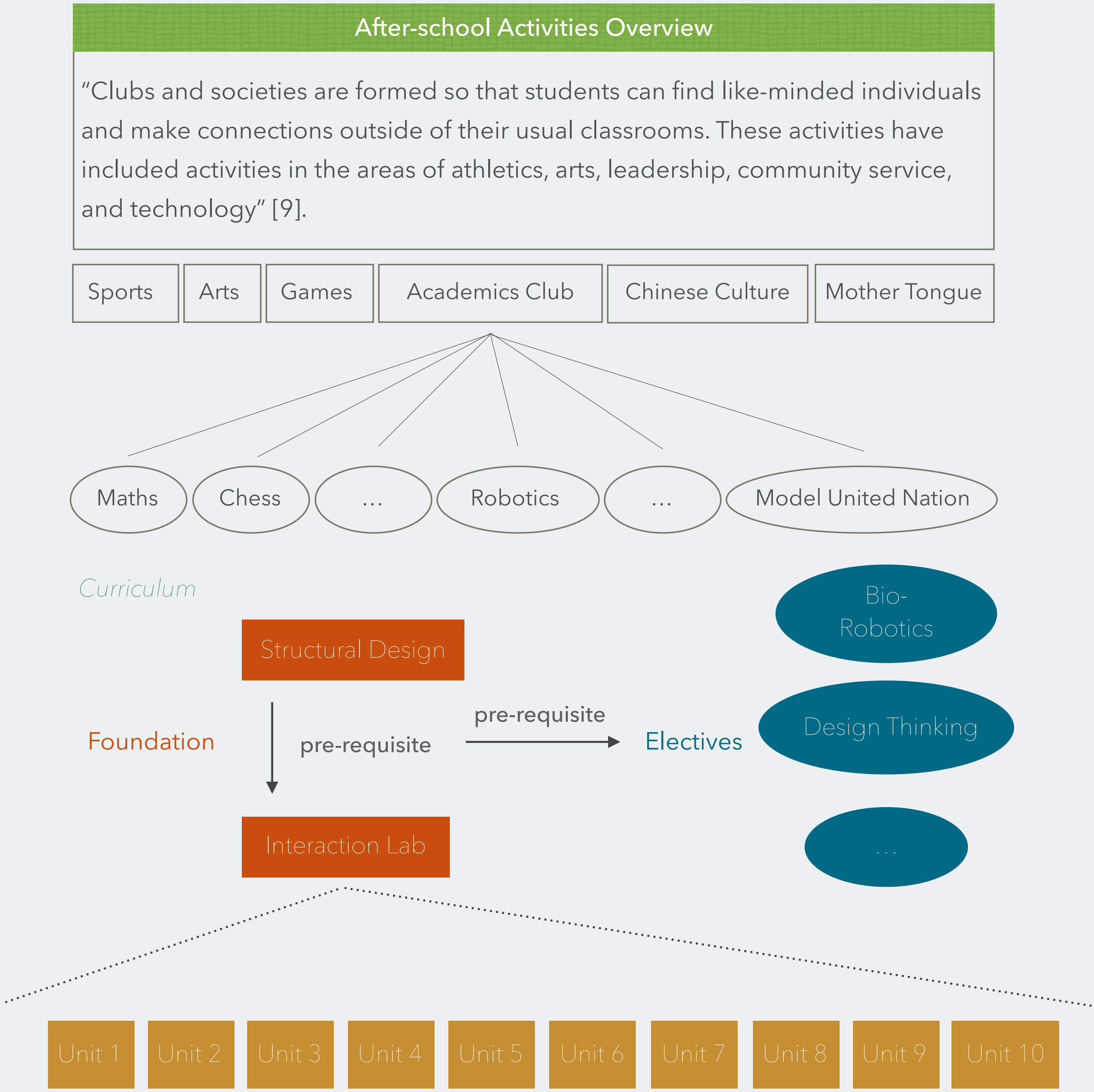
After taking interaction lab, students will gain the ability to apply their Electrical Engineering and interactive design knowledge into building their own projects. Therefore, students could take deeper robotics courses or design thinking courses afterwards.

In terms of the timeline and framework for interaction lab, we will have similar schedule for each course, though the user-testing lesson and final showcase lesson will be exceptional. Instructors will give 20 mins direct lectures first, in which will cover conceptual knowledge. Then, instructors and teaching assistants will facilitate a 10 mins discussion. After the discussion, students will take 5 mins rest. In the next 20 mins, students will do some hands-on practices individually, where instructors and teaching assistants will walk around and give students' direct assistance. The following will be a quiz assessing students' understanding of the course taking approximately 6-8 mins. For the rest of the time, instructors will assign the homework.



The following

diagram demonstrates the framework from macro to micro with reference to the examples shown in UbD [12, fig. 12.1].



Detailed Schedule for each lesson will be included in Instruction Design

2.2 Learner Characteristics as a Baseline Profile

Developmental Level:	Prior Experience:	Individual Differences:
Social Relationship: - Encounter peer pressure [13,14] Frequently discussion with students, give them confidence - More independent on their own interests and personalities [13] -> Align course goals with their interests and set explicit shared goals and norms **Cognition:** - Question things [13] -> Ask for the reason/understand their thinking through assessment, encourage discussion and conversation with peers - Self-identity and identity among peers [13,14] -> Collaborative work and help them realize their value - Decreased Motivation in Learning [15] -> Create engaging learning environment with explicit learning outcome.	**Structural Design:** - Know some simple structural design principles **Computer:** - Type on Keyboard - Use Mouse or Trackpad - Install Software **Mathematics:** - Use Ruler to Measure - Arithmetic Abilities - Logical Thinking Abilities **Art:** - Use pen or pencil to draw - Use scissors or cutters to cut cardboard or fabric, and use glue or tape to paste **Physics:** - Electricity: Know current, voltage, polarity, resistors, simple circuits Misconceptions: - Engineering area is for the industry and is used to solve professional problems only - Design is an art concept that engineers or makers do not need to know	- Levels of **technical** ability due to **previous experiences/prior knowledge** in related areas - Levels of **interests/attitudes** towards subjects - Levels of **reasoning abilities** -> Instructors need to provide extra help for students with weaker reasoning abilities, especially in programming learning where reasoning abilities are highly expected. - **Comprehension** Ability - **Communication** Ability -

3. Goal Specification

3.1 Established Standards Analysis

This course follows Engineering Design Standards [16], [17], [18], [19] from Next Generation Science Standards. The methods to analyze standards are adapted from *UbD*, in which it summarize the key features and big ideas and procedural tasks [12, p.64].

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Criteria and constraints of an engineering design problem and its solutions.

List several real-life examples using engineering design as solutions.

Examine the possibility of solutions under real-life contexts

Possible Questions:

- What is a design for? What is criterion? What is constraint?
- How criteria and constraints influence a successful solution?

Understanding:

- Engineering design could help us identify and solve problems.
- Clearly defined Criteria and Constraints could limit the possible solutions and more likely to come up with a successful solution.

Procedural Tasks:

- Students identify a real-world problem that could be solved by engineering design and think about possible solutions.
- Students consider the criteria and constrains, and examine the possible solutions critically, and choose the most successful and efficient solution among all possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Systematic process for competing design solutions' evaluation

Evaluate several real-life design solutions

Critically assess the applicability of the systematic process

Possible Questions:

- What is the process for developing potential design solutions?
- What is the systematic process for evaluation?

Understanding:

- Models could help engineers predict and visualize the design and the possible modifications.
- Analysis from models could help evaluate how well the products behave under the criteria and constraints. But models should be considered critically, so that it won't mislead engineers.

Procedural Tasks:

- Analyze two different products which solve the same problem by reviewing their reasoning and arguments about the merits, identify and explain their problems.
- Students could propose modification suggestions based on the comparison and evaluation process and use physical or computer to draw the models.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Similarities and differences among each solution from tests' data

Evaluate several real-life design solutions

Critically assess the applicability of the systematic process

Possible Questions:

- How can the various proposed design solutions be compared and improved?

Understanding:

- Value judgements vary based on contexts, situation, users need and time and space.
- Identifying the characteristics of each design solution and making trade-offs among competing criteria could help examine and optimize possible solutions/designs.

Procedural Tasks:

- Design a test (user testing) for evaluating different solutions of one real-life problems, record and analyze the results of how each design performs, and then conclude the characteristics.
- Under different contexts, make trade-off matrix and determine how to combine or modify each example in order to optimize the solutions.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Model for iterative testing and modification

Identify the several iterations of a real-life product/design by a model

Develop a model for identifying a product and proposed possible modification

Possible Questions:

- What is the model for testing?
- How to make iterative modification according to the model?

Understanding:

- Specialized Computer-based simulations could test the engineering design. For example, computer simulated models with physical laws and material properties being considered are essential to test the structure design.
- Models/prototypes have limitations. Design should be considered under situations and evaluate the reliability of models.

Procedural Tasks:

- Students could choose a design/ product and apply different computer-based simulated models to identify the characteristics and evaluate whether it meets the criteria and considered the constraints.
- Students could think about and find an example that using models/ prototype failed to evaluate its functions and analyze the limitations of models/prototype.

3.2 Goal Specification and Tasks Analysis

3.2.1 Conceptual Goals

C1. Students are able to **identify** the criteria and constraints of design in different contexts and **explain** the importance of criteria and constraints.

- C1.1. *Explanation the definition of criteria and constraints*

  Essential Questions: What is criteria and constraints?

  Standards: MS-ETS1-1

  Criteria and constraints are:

  - *Criteria are things the design needs to do in order to be successful--its requirements* [20]. *In this course, it will mostly be the interactive design principles and the notes of using Arduino.*
  - *Constraints are limitations on the design* [20].
- C1.2. *Explanation on the importance of criteria and constraints*

  Essential Questions: Why is defining criteria and constraints important?

  Standards: MS-ETS1-1

  Criteria and constraints are important because:

  - *Precisely defined criteria and constraints would benefit designing solution.*
  - *Considering scientific principles and relevant knowledge when specifying constraints could limit possible solutions.*

C2. Students are able to **describe** the general design process of a product.

Essential Questions: What is the process of designing a product?

Standards: MS-ETS1-1, MS-ETS1-2

- *Identify a problem to solve and the targeted audience. (a)*
- *Specify the criteria and constraints for the products. (based on C1) (b)*
- *Design clear goals with priority based on* **a** *and* **b**.
- *Identify the materials and skills required.*
- *Update from low-fidelity to high-fidelity with multiple iterations.*

C3. Students are able to **describe** and **explain** the command in TinkerCad.

Essential Questions: What can TinkerCad do?

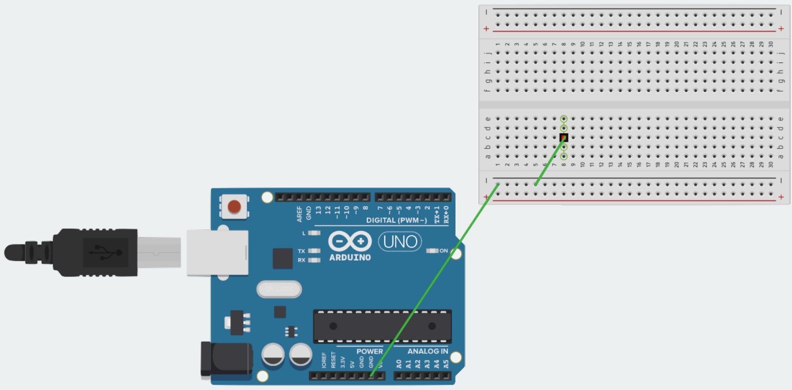
Standards: MS-ETS1-4

- *Students will be able to know:*
  - *How to create a new electrical design model.*

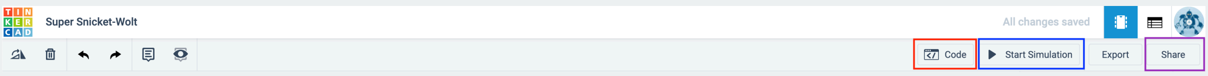
    Answer: TinkerCad Website -> Circuits Tab -> Create new Circuit Button
  - *Which is the command to import microcontrollers and sensors' model into TinkerCad.*

Answer: Drag the microcontrollers/sensors from the menu to the main sketch.

- *How to add wires and connect the components in TinkerCad.*
  Answer: Click on two pins.



- *Where is the place for writing code in TinkerCad.*
  Answer: Change the tab to code
- *What is the command to start the stimulation.*
  Answer: Click Start Stimulation
- *What is the command to share their model with others.*
  Answer: Click Share



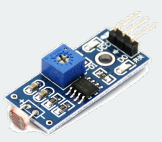
C4. Students are able to **identify** and **introduce Arduino** Board and different types of electronic components.

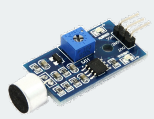
Essential Questions: What are the functions of the electronic components? What is the function of the Arduino Board? What is the relation between Arduino and Electronic Components?

- *Students will be able to:*
  - *Identify different electronic components' names with picture given: LED, Buzzers, Light Sensors, Sound Sensors, Buttons, Potentiometers, Temperature Sensors, Motors, Servos.*


LED

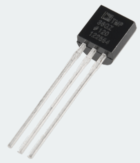

Buzzer


LDR

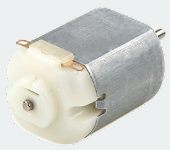

Sound Sensor


Push Button

Potentiometer



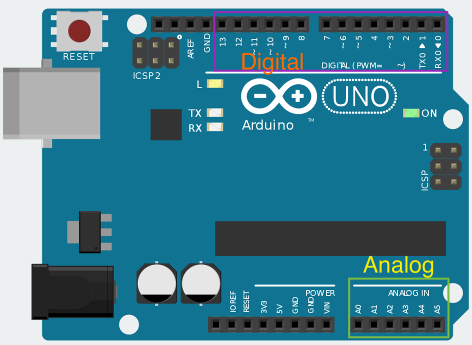
Temperature Sensors



Motor

Servo

- *C4.1. Differentiate whether the electronic component provide digital information or analog information.*
  Digital: LED, Push Button
  Analog: Buzzer, LDR, Sound Sensor, Potentiometer, Temperature Sensors, Motor, Servo
- *C4.2. Differentiate whether the electronic component is an input sensor or an output component.*
  Input Sensors: LDR, Sound Sensor, Push Button, Potentiometer, Temperature Sensors
  Output Sensors: LED, Buzzer, Motor, Servo
- *C4.3. Identify and explain the function of each pin on the electronic components: which is Vcc, which is GND and which is signal pin? What are those pins for?*
  Answer: There are Vcc, GND and S0/SIG/A0/D0 symbols on the sensor. S0/SIG/A0/D0 are the symbols for signal pins. Signal pins should be connected with analog/digital pins on Arduino Board, so that Arduino could read and write data to the sensors.
- *C4.4.* Identify 5V and GND on Arduino Board, and which pins on Arduino Board are for digital inputs/outputs and which pins are for analog inputs/outputs.



Answer: 5V and GND pins on Arduino Board is for power supply. Digital pins read/write data for sensors providing/receiving digital information, analog pins read/write data for sensors providing/receiving analog information.

C5. Students are able to **identify** and **explain code** for controlling **Arduino Board** in Arduino IDE.

Essential Questions: How to control Arduino with the code?

- *Students will be able to:*
    - *Explain what is variable, what is conditional statements and iterative statements.*
      *Answer: **Variables** are used to store information to be referenced and manipulated in a computer **program**. **Conditional Statement** is an if-else statement, if a condition is true, X will be executed, otherwise, X won't be executed. **Iterative Statement** is for-loop or while-loop, repeatedly executes a statement until the controlling expression is false.*
    - *Explain what is the code for read data and write data for electronic components.*
      Answer: The code for reading data is digitalRead (pin_number) or analogRead(pin_number), depending on whether the sensors are digital/analog.
    - *Describe how to upload code into the Arduino Board.*
      Answer: In Arduino IDE, there is an upload button. When Arduino is connected with computer, click upload button on the Arduino IDE could upload code into the Arduino Board.

C6. Students are able to **explain** the importance of different designs comparison.

Essential Questions: Why comparing various designs is important?

Standards: MS-ETS1-3

- *It's important to compare different designs because identify each design's characteristics under contexts could help optimize solutions.*

3.2.2 Procedural Goals

P1. **Identify** the problem from a given real-world scenario.

Essential Questions: How to identify a real-world problem?

- *To conclude a problems, students are expected to find out the challenging part in proposed scenarios and determine the targeted audience of the products. instructors and teaching assistants will lead students **placing** themselves in the **scenario** and guide **discussion** for students to **summarize** and **synthesize**.*
    - *Step 1: Instructors will form students in groups as a **facilitator**. Some students will be the **players** and some students will be the **observers*** [21].
    - *Step 2: **Briefing phase**: Instructors will assign the roles and discuss with students about the characters and scenarios* [21].

- *Step 3: Play phase: Instructors will introduce the scenario's context and let players play roles. Instructors may need to intervene in the role playing at the beginning and give directions, descriptions and comments. Instructors will provide a conclusion if no one bring out anything [21].*
- *Step 4: **Debriefing phase***: Players will share their feelings after the role playing activity. Observers will also share their points based on what they see [21].

- *Students are not expected to evaluate whether the problem could be solved with engineering knowledge only by themselves. Instructors will analyze the resolvability with students together.*

P2. Apply interaction design principles and Electrical Engineering principles to prototyping process.

- *P2.1 Brainstorm the solutions to the identified problems with interaction design principles and electrical engineering knowledge with teaching assistants.*
  - *Step 1: Make a list, identifying what are the problems from the scenarios.*
    ** Based on the learners' profile, identifying 1 to 2 problems is enough.*
  - *Step 2: For each problem, what are the possible solutions.*

Problems	Solutions
Problem 1	Solutions 1.1
	Solutions 1.2
Problem 2	Solutions 2.1
	…

** In this step, teaching assistants could also directly give students' some options, as an inspiration for students to discuss further, or as one of the possible solutions.*

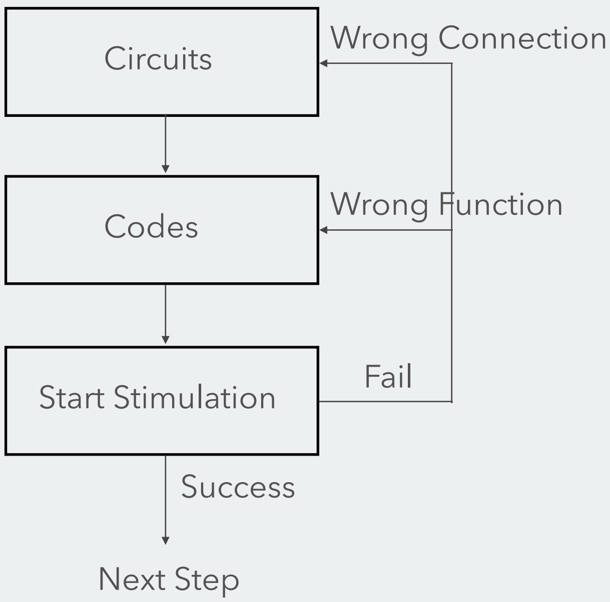
  - *Step 3: Select the Materials and Electronic Components for each solution*
    ** In this step, teaching assistants could directly tell students what sensors could reach their expectation.*

Solutions	Sensors or Electronic Components
Solution 1.1	Sensors…
…	…

- *Step 4: Compare different solutions by evaluating the alignment with constraints and select the optimal one.*
  Standards: MS-ETS1-1, MS-ETS1-3
  Make a table to evaluate whether the solution is practical under the constraints, if so, fill in a check mark. And in another column, write down the reason.
  ** In this step, teaching assistants will evaluate with students based on observation of students' general performances and their academic knowledge.*
  Criteria: Feedback, Conventions
  Constraints: Familiarity to the certain sensors, Practicality of learning to use the new sensors in limited time

Solutions	Feedback		Conventions		Familiarity		Practicality	
Solution 1.1	√	Reason…		Reason…	√	Reason…	√	Reason…
Solution 1.2	√	Reason…	√	Reason…		Reason…	√	Reason…
Solution 2.1	√	Reason…	√	Reason…	√	Reason…		Reason…
…								

- *P2.2 Build the Initial Design.*
  - *Step 1: P2.2.1 Use TinkerCad to make Computer-aided Models.*
    - *Step 1: Students will first use TinkerCad to stimulate the circuits.*
    - *Step 2: Students will write code in TinkerCad and start stimulation in order to see whether the circuit is connected correctly, and whether the function could be realized.*



- *Step 2: P2.2.2 Students will connect the real circuit with electronic components and Arduino. And upload the code into Arduino.*
  With the stimulation of the circuits in TinkerCad, if the stimulation result is accurate, students could start to connect the wires of the circuit with reference to the circuit in TinkerCad, and write the same code in Arduino IDE, and upload the code.
- *Step3: P2.2.3 Use cardboard or carton or fabric to build the simple structure or the outer package of the products (Prior knowledge) and place the electrical part into the structure.*

- *P2.3 Optimize Design in Iteration.*
  Essential Questions: How to make iterative modification?
  Standards: MS-ETS1-4
  - *Step 1: P2.3.1 Apply interactive design principles and Electrical Engineering knowledge to self-evaluate the prototype and evaluate others' prototype.*
    For both self-evaluation and evaluating others, students will use the form below.

Criteria	Feedback
Forms follow Functions	
Usability	
Feedback	
Logical Mapping	
Conventions	
Consistency	
Feedback on Sensors	Here, students will self-evaluate or comment whether the sensors are appropriate to use for solving certain problems. Are there any other sensors that are more appropriate?

  - *Step 2: Modify design based on the self-evaluation and user-testing*
    ** Teaching assistants could give explicit hints and guidance for students to make revision.*
    With the above forms, students could list the problems received, and use the same step from building the initial design to revise.

3.2.3 Dispositional Goals

D1. Students should be curious

- *Students are curious about the real-world challenges and how to solve problems.*

D2. Students should be flexible in designing process.

- *Students are prepared to make modification on the design concept.*
- *Students are flexible to change designs' structure and code arrangement.*

D3. Students should be reflective.

- *Students will reflect and assess their design in different contexts and well-defined expectations and constraints.*
- *Students will reflect their design after user-testing*

D4. Students should be collaborative.

- *Students could brainstorm with group members and could present their ideas and feelings in group.*

3.2.4 Meta-Conceptual Goals

MC1. Students will self-evaluate their understanding of electrical engineering

- *Instructors could guide students to ask themselves:*
  - *How can I use Arduino and Sensors?*

MC2. Students will self-evaluate their understanding of Modeling Software

- *Instructors could ask students to answer:*
  - *Where should I use TinkerCad?*
  - *Did I use TinkerCad to model before I connect the circuit?*

MC3. Students will self-evaluate their understanding of coding

- *Instructors could ask students to think:*
  - *Can I design the logical framework using conditional and iterative statements?*
  - *Did I use the conditional and iterative statements in an accurate way, which*
    means is it necessary to use these statements, and is it working as it supposed to be?

3.2.5 Meta-Procedural Goals

MP1. Students will self reflect and self-evaluate their problem identification process.

- *Instructors will ask students the following question:*
  - *Why you think this is the most challenging things in the scenarios comparing to other?*

MP2. Students could self-evaluate their product making process.

- *Instructors will ask students to answer:*
    - *Why you choose these sensors?*
    - *Why you decide to use certain structure?*
    - *Why you make certain modifications?*
    - *What could you improve more in next iteration?*

MP3. Students could self-evaluate whether their user-testing sessions are effective.

- *Students could answer:*
    - *What feedbacks do you take into consideration and what not? Why?*
    - *What feedbacks do you give that well aligned with the feedback guidelines? What not?*

MP4. Students could monitor whether they are being reflective in design process.

- *Students could ask themselves:*
    - *Did I check my design after each lesson? Did I incorporate my new learning into the design?*
    - *Did I listen to peer feedbacks and think about how to make changes accordingly? If yes, what modifications I made. If not, why?*

3.2.6 Meta-Dispositional Goals

MD1. Students will self monitor whether they are flexible in design process.

- *Students could answer:*
    - *What are the other possible design?*
    - *What if a certain function couldn't work? What is your plan B?*

MD2. Students could self-monitor whether they are responsible in collaborative projects.

- *Students could ask:*
    - *Did I complete tasks assigned timely and reach the expectation?*
    - *Did I express my ideas/concerns well with my group members?*
    - *Did I listen to my group members' ideas and provide feedbacks on their ideas with respect?*

4.Assessment Design

4.1 Overview of Assessment Evidence

Because of the types of the activity, which is an after-school camp, we will not provide official grades such as letter grades to students since we would want to make the atmosphere relaxing. We will only provide feedback based on the scoring rubric. We will praise students if they are outstanding in certain criteria, and we will give students improvement suggestion if they have weakness in certain criteria.

Considering middle schoolers' developmental levels and prior knowledge, it will be too challenging for them to think and research about social challenges without limitation. Therefore, combined with the current social contexts, students will be provided with scenarios during pandemic because of COVID-19. Students are encouraged to identify the problems from the given scenarios. And the final project should be designed and created related to the topic of COVID-19.

We will also make use of quizzes and tests, documentation, and final project as the assessment methods. The multiple types of assessment enhance the sufficiency and reliability of assessing students' performance. Each assessment are well-aligned with goals, which also shows the validity. **(Big Ideas: Align Assessment and Instruction with Goals)**

Below table provides each course' assessments. We provided the detail assignment in Instructional Design section.

Lesson	Assessments	Goals	Formative/ Summative
Pre-Assessment	1. Students are asked to fill in a survey before the class. The survey will ask students what is their favorite products and why? Instructors will provide an example first. **The pre-test links students daily life with the course, and stimulate students' interest. This could also reflect students' prior knowledge related to interactive design (Big Ideas: Consider Differences in Learners' Prior Knowledge).*	C1, C2, C6	Formative
Lesson 1: Introduction to Interactive Product Design	1. Quiz at the end of the class. Students will be asked to identify which are good designs and which are bad designs. 2. Assignment: Prepare for the role-playing session	C1, C2, C6 P1	Formative
Lesson 2: Brainstorm for COVID-19 Challenges & Introduction to Arduino	1. Quiz at the end of the class: What could Arduino do? What are the pins' functions? How do we control Arduino Board? 2. Assignment: Write down a project proposal in group.	C4.4 P2.1	Formative

Lesson	Assessments	Goals	Formative/ Summative
Lesson 3: Electronic Components: LED, Buzzer, Light Sensor, Sound Sensor, Temperature Sensor, Ultrasonic Sensor	1. Quiz at the end of the class: Identify the electronic components and the functions of each component. Find out which is the signal pin and which are the pins for power supply. Distinguish whether an electronic component is digital/analog, inputs/ outputs. Identify the accurate circuits connection. 2. Assignment 1: Discuss with group members and select sensors 3. Assignment 2: Prepare a Project Proposal Presentation next class	C4.1, C4.2, C4,3, C5 P2.1	Formative
Lesson 4: Conditional Statements & Project Idea Presentation	1. Quiz: Write a pseudo-code of how to turn on a fan while the room is hotter then 35 degrees, and turn it off otherwise. **Check conditional statement* 2. Assignment: In group, write down a reflection of the projects' ideas. What feedbacks do you receive? What do you want to change based on the feedback? What are the other possibilities?	C5, P2.2.2 D2, D3, D4, MP3	Formative

Lesson	Assessments	Goals	Formative/ Summative
Lesson 5: Iterative Statements	1. Quiz: Write a pseudo-code of counting from 1-100, with a difference of 2, and print the number in the Serial Monitor. **Check Iterative Statement* 2. Assignment 1: Write a short paragraph in group on what materials and sensors do you plan to use for your final project, and explain the reason. Also reflect whether you incorporate new learning in, and whether you make modification on your previous design. 3. Assignment 2: Make a "**breathing light**"	C5, P2.2.2 D3, D4, P2.2.2, MC1, MC2, MC3, MC4, MD2 P2.2.2, P2.2.3	1,2. Formative 3. Summative
Lesson 6: Actuators: Servo and DC Motor	1. Quiz: What is the differences between servo and DC Motor. Write pseudo-codes to control the movement of servos and DC motors. 2. Assignment 1: Start to draw sketch of your product in group. Update your group and document your individual contribution.	C4 D3, D4, P2.2, MC1, MC2, MP2, MP4, MD1, MD2	Formative

Lesson	Assessments	Goals	Formative/ Summative
Lesson 7: Modeling Software: TinkerCad	1. Assignment 1: Document your project update. If you have time, start to connect your circuits. 2. Assignment 2: Prepare the project update presentation in group for next class	P2.2.1, D4, MC1, MC3, MP2, MP4, MD1, MD2, P2.2.2 (Optional)	Formative
Lesson 8:Project Update Presentation & Group Working Session for Projects	1. Assignment: Make an Alpha A prototype of your project, from making models to building real circuits to adding hand make structure/casing for the product. Document your project updates as a group and what you did individually. Add a short reflection on whether you are responsible for your work.	P2.2, D2, D3, D4, MP3, MC1, MC2, MC3, MP2, MP4, MD1, MD2	Formative

Lesson	Assessments	Goals	Formative/ Summative
Lesson 9:User Testing Sessions	1. Assignment 1: Documents whether you give constructive feedback individually. Documents as a group what you want to improve based on the peer feedback. What you want to modify after considering the interactive design principles. 2. Assignment 2: Complete your modification and prepare for the presentation	P2.3, D2, D3, D4, MP2, MP3, MP4, MD1, MD2	Formative
Lesson 10:Showcase & Final Presentation	1. Present your work as a group in class and answer other students questions. 2. Write a thorough documentation on your group project, from deciding the project ideas to several iterations to using modeling softwares and Arduino to make prototype to project Demo. Write a reflection on whether you apply the knowledge and skills while making the product, whether you are responsible in the group, whether you are flexible while making the project.	D2, D3, D4, MC1, MC2, MC3, MP1,MP2, MP3, MP4, MD1, MD2	Summative

<table>
<tr>
<td rowspan="2">Performance Tasks:
1. Design a product with usable prototype in groups by the end of this course
- This project require students to identify problems, place themselves into the contexts and applying the skills. Students also need to present their products with models, prototypes and their design process. This project perfectly fit at least four of the six facets of understanding [12].
The final product are expected to be presented at the last class. However, the update should be documented every weekend. Feedback will be provided in the following week before Friday.
(Big Ideas: Targeted and Timely Feedback)</td>
<td>Other Evidence:
1. Quizzes on Software use and Circuits Design each week
- With direct and indirect words and phrases, quizzes could check students knowledge on skills and knowledge in a straightforward way [12]. The quizzes will focus on every lecture's conceptual knowledge.
Quizzes will take place at the beginning of each class, evaluate the previous lesson. Feedback will be provided in two days.
(Big Ideas: Targeted and Timely Feedback)</td>
</tr>
<tr>
<td>Student Self-Assessment / Reflection:
1. Weekly Documentation and Reflection on the lecture and their project update
By reviewing how students conclude and synthesize from lecture, projects and other resources, instructors could reveal the misconceptions/ misunderstandings, and check their level of understanding.
Students are required to do this every Sunday and Monday. Instructors will provide feedback before the following Monday. (Big Ideas: Targeted and Timely Feedback)</td>
</tr>
</table>

4.2 Specific Assessment

Here, I include three different types of sample assessments, quizzes, self-reflection and final project.

4.2.1 Final Group Project

Summative Assessment - Performance Tasks: Design a product solving a challenging scenario in pandemic with usable prototype in groups.

Cognition: This performance task focus on goals P1, P2. It also demonstrates students understanding and transferability in goals C1-C6. The project requires multiple iteration and reflection, which demonstrates D2, D3, MP1,MP2, MP3, MP4, MD1, MD2. The **group** project reveals D4 as well.

Observation: By using GRASPS technique, this part will discuss the goal, students' roles, target audience, specific situation, product and standards.

1. **G:** Students are expected to create a well-structured prototype that could solve real-world problems related to COVID-19 pandemic. By completing this projects, students are going to identify the pain point of the problem first (D1, P1). Then, students are expected to discuss/brainstorm in group (P2.1, D4). After brainstorming, students could start prototyping by using informal sketches to formal models to real physical products (P2.2.1). Students need to frequently reflect on their work and evaluate their product by self-evaluation and user-testing (P2.2, D3, MP1,MP2, MP3). After identifying the strengths and weaknesses, students are expected to optimize their design (P2.3, D2). Lastly, students are able to present their product including design process in class.
2. **R:** Students are expected to play the role of product designers and developers. Students should be able to think in designers and engineers' perspective.
3. **A:** The project audience varied depending on the scenarios. Generally speaking, the audience should be the people facing certain challenges in different contexts.
4. **S:** Students should identify the challenges in given context, and find out the problems that could be solved by engineering approach.
5. **P:** Students could make a prototype that could solve certain challenges and present to "product managers" with presentation and written documents by reasoning the design process.

6. **S:** The design should solve target audience' problem in terms of design thinking perspective. Students could write an accurate and clear report and make presentation introducing the products. The design could satisfy engineering principles.

More detailed contexts are included in Instructional Design Section.

Interpretation: Students will be evaluated based on project design, technique used, team work, documentation and presentation of their work. Below shows the scoring rubric (refer to NYUSH Interaction lab course syllabus with modifi cations).

Project Design:

Did students consider the design principles: functionality, usability, feedback, logical mapping, conventions, consistency ?
C1, C2, C4, C5, C6 P1, P2

Criteria	Outstanding	Acceptable	Weak
Forms follow Functions	The solutions could solve all the problems identified.	The solutions could solve part of the problems identified.	The solutions couldn't solve the problems identified.
Usability	Users could understand how to use the product without giving further explanation.	Users could understand how to use the product with guidance given. This may because of some some of the functions are covered because of the design.	It is unclear for users to understand how to use the product even with guidance given. This may because the functions are covered by the bad design, or the instruction is unclear, or both.
Feedback	When users do something, the products give certain appropriate feedback.	Not all the interactions trigger feedback. This may because of technical issue (sensors broken) or because of bad design.	There's no feedback when users do something.

Logical Mapping	The instruction for how to use the product match with the product. For example, in the instruction, it mentioned the red button, there should be only one red button on the product, which won't cause any confusion.	Some of the instruction doesn't match with the product.	None of the instruction match with the product
Conventions	The design follows the common sense, therefore, users could understand the meaning of some interaction right away. For example, if you want to turn on the product, you'd better use green button, and use red button to turn off.	None	The design doesn't match with common sense.
Consistency (we won't have high expectation here, because this is not the emphasis. This is a bonus for students who design the products with consistency)	The design is consistent by using the similar shapes, colors…	None	None

Technical Used:

P2, P3

Criteria	Outstanding	Acceptable	Weak
Safe	Designers test this in TinkerCad before connecting real circuits.	None	Designers didn't use TinkerCad to model first, and the connection have safety issues, for example, shortcut.

Appropriate	The sensors are being used correctly both in terms of its functions and the code. By correctly making use of its functions, for example, students use LED because they want to make light or light-related art, not because they want to use LED to bring heat. By the code, it means students are using the accurate code to control.	Students only use sensors in its correct functions or only correctly control sensors.	Neither the functions of the sensor or the controlling code are incorrect.

Team Work:

- Communication and Collaboration:
  D4, MD2
    - Outstanding: Evident mutual respect and close collaboration, valuably individual contributions and superior teamwork thoroughly focused on project objectives are revealed in final paper documentation.
    - Acceptable: Mutual respect, close communication and collaboration are revealed in final documentation. However, individual contribution are a little unequal.
    - Weak: Respect, communication and collaboration lack among members are revealed in documentation. Some work only on their own.

Presentation:

- Comprehensive:
  D3, MC1, MC2, MC3, MP1, MP2
    - Outstanding: The presentation answer to all the questions with high quality. By high quality, it means that the explanation of the answers are reasonable with evidence provided.
    - Acceptable: The presentation answer all of the questions, however, some questions are answered with low quality. For example, the reason behind

the answer is not provided, or the provided explanation is not evidence-based.

- Weak: The presentation didn't answer to all of the questions.

Documentation:

- Process Documentation:
  MC1, MC2, MC3, MP1, MP2, MP3, MP4, MD1, MD2
    - Outstanding: Work is well documented with steady paced movements in time, and detailed, clear pictures of both process and progress are presented. Students answer all of the questions in self-reflection with high quality. By high quality, students analyze their learning and could conclude some interesting findings or further improvements.
    - Acceptable: Progress is recorded, but the pace is slow, and work are only partially documented without sufficient use of pictures. Students answer all of the questions in self-reflection, but some of which with low quality, which means students didn't show their thinking in the reflection.
    - Weak: Progress are insufficient and work documented are not useful for others to understand. Many questions are not answered.

In this assessment, it covers every range of learning goals, which shows sufficiency [12]. The instructors and all three teaching assistants will participate in grading, which keeps the reliability [12]. What's more, the project requires multiple iteration and modifications, give students enough time to refine their projects, which makes the project result more reliable when showing students' learning performance. The scoring criteria are closely related to the goals as well.

4.2.2 Quizzes

Formative Assessment - Other Evidence: Quizzes for each week lecture

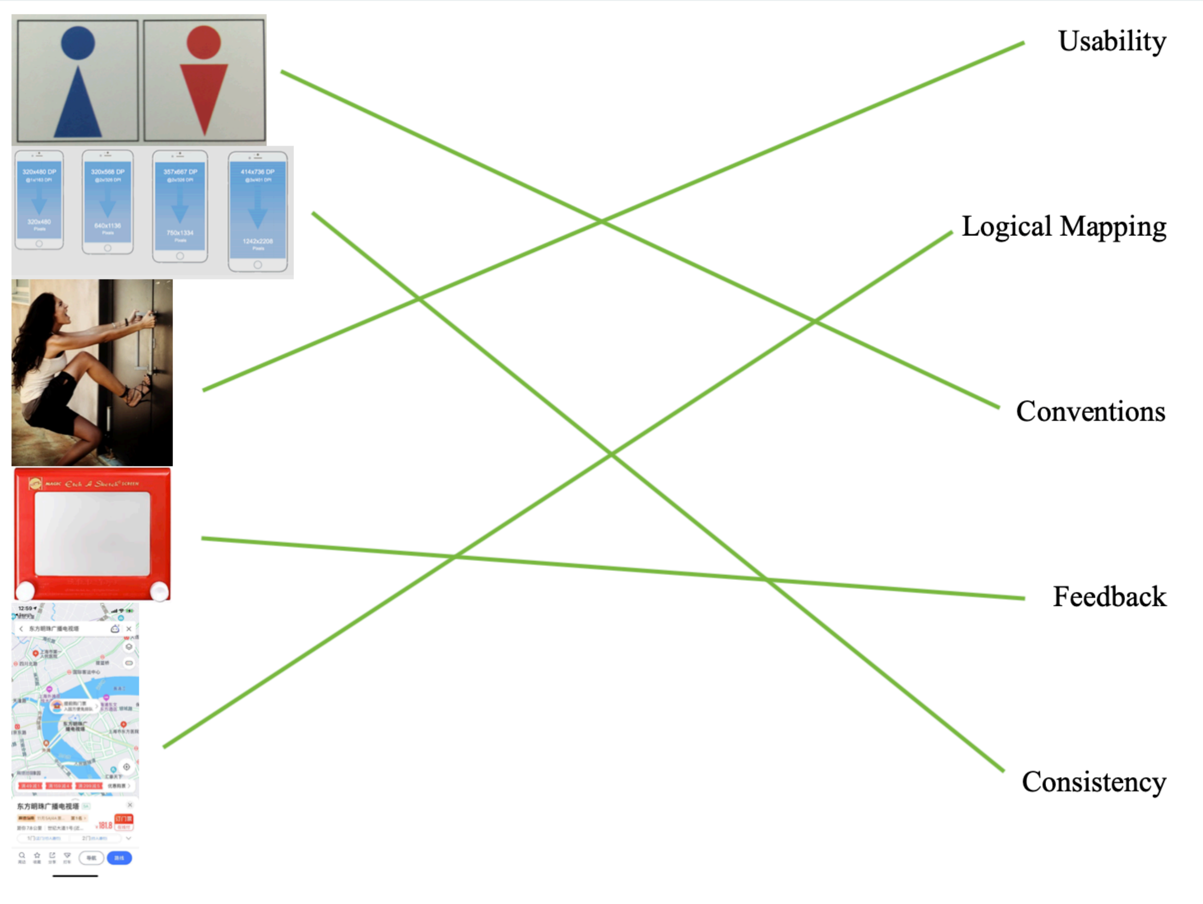
Cognition: Quizzes focus on conceptual knowledge evaluation, including C1, C2, C3, C4, C5, C6. In Lesson 4 and 5, it also demonstrate P2.2.2

Observation: Students will complete multiple questions in the quiz. The questions are mostly multiple-choices questions and a few short answer questions. Multiple-choices questions focus on knowledge of electrical components, software use. Short answer questions ask students to write down the constraints and criteria or suggestions within given specifi c contexts. The questions will be phrased in direct way with clear cue. A few questions will be asked in an indirect way and less cue given.

Interpretation:
Take Lesson 1's quiz as a sample. We also provide answer in the sample.
This quiz will be printed out and hand out to students at the end of the class.

Hi students from Interaction Lab, thanks for joining our class. We would like to ask you to answer the following questions. All the questions come from our today's lecture. Your response will tell us how could we better assist you in the future.

Q1. Matching the picture and the design principles. - C1
** Notes: All this picture will match with one of the design principle. Choose the one you think match the most. If you couldn't decide which design principle it matches the most, then write some explanation aside.*



Q2. Choose the best design from the following cups from the usability standpoint. And Explain Why? - C1, C6

A

B

C

D

E

Answer: D

In terms of Usability, A and B are very hard to drink, C is very hard to handle, the hand of E is too small for hands to hold.

Q3. Could you think about one example that could demonstrate the design principle "Feedback"? Write down the example you think of. Explain how does the example demonstrates the design principle "Feedback". - C1,

The quiz will be evaluated based on *accuracy* and *comprehension*. Below is the scoring rubric (Reference to link with modifications).

Accuracy:

- Completeness:
    - Outstanding: Students answer most of the problems correctly, and the reasoning process is well documented.
    - Acceptable: Students answer some of the problems correctly, and showed their attempts in the reasoning process.
    - Weak: Students left the problem blank, or students' only write down the answers without showing reasoning process.

Comprehension:

- Tasks analysis: Take Q2 and sample Answer as an example.
    - Outstanding: Students could answer the real-life stimulated case/problem solving questions accurately, which shows deeply understand the problems. Students could accurately identify what knowledge and skills are being evaluated and how should the knowledge and skills be used.
    - Acceptable: Students could answer the multiple-choices problems accurately, and understand what knowledge and skills are being evaluated in problem solving questions, but some of the knowledge and skills are inappropriately used.

    - Weak: Students couldn't identify what knowledge and skills are being assessed, and knowledge and skills are not used accurately and appropriately and sufficiently.

Quizzes and tests are suitable for evaluating conceptual knowledge. This assessment could test most of the conceptual knowledge goals and some of the procedural goals, which shows the sufficiency. Quizzes will take place every course, and will include some accumulated knowledges. The quizzes will be based on the materials from each course, and students could write down their reasoning process in the quizzes, and the assessments are evaluated considering the comprehension hidden under the answers, which shows the internal validity.

4.2.2 Self-Reflection

Formative Assessment - Self-Assessment/Reflection: Weekly Report on lectures, projects and assignments

Cognition: Self-reflection are necessary for a project. It reveals students' understanding of design thinking, but more importantly, it demonstrates students meta-cognition. **(Big Ideas: Become Self-Regulated Learners)** Weekly Report assess all the Metacognitive Goals and D2, D3, Procedural goals P2.2 could also be reflected from the report.

Observation: Students should write down what they learned, and how they could make use of this knowledge in the documentation. Also, students should reflect their level of understanding after thinking about how to apply and transfer the knowledge and skills. Students should also reflect on their project timeline plan, and monitor themselves. **Detailed design are demonstrated in the Assignment in Instructional Design Section.**

Interpretation: The self-assessment will be evaluated by *reflection* and *documentation*. Below shows the scoring rubric

Reflection:

- Depth:
    - Outstanding: Students could deeply apply the knowledges and skills in different contexts. And students could give a detailed and clear reason on how they evaluate their understanding.

    - Acceptable: Students could apply the knowledges and skills in an evident way. And students could state some reason on how they evaluate their understanding.
    - Weak: Students couldn't apply the knowledges and skills. And students couldn't evaluate their understanding.
- Breadth:
    - Outstanding: Students could apply the knowledge and skills in many contexts, not limited to engineering aspect.
    - Acceptable: Students could apply the knowledge and skills in engineering aspect, and students think about many cases in engineering aspect.
    - Weak: Students did not document any cases/contexts that could apply the knowledge and skills.

<u>Documentation</u>:

- Outstanding: Documentation answer to all the questions, and explains the reasoning process explicitly and clearly and in thorough details.
- Acceptable: Documentation answer to all the questions, and the reasoning process are not explained sufficiently.
- Weak: Documentation doesn't answer to all the questions, and shows students lack of understanding by using improper and unprofessional terms, and couldn't explain students reasoning process.

Weekly Report could review students' cognition and metacognition. This assessment focus on the metacognitive goals, and could evaluate some procedural knowledge at the same time, which shows the sufficiency. Weekly report are reviewed by 2 raters (TA + Instructors), the TA won't review the group he/she worked with. This shows the reliability [12]. The reflection is written based on the week's lecture and feedback, and are all aligned with goals, which shows the internal validity [12].

5. Instructional Design

5.1 General Description

5.1.1 Classroom Climate

In 2.1.3 class size and classroom setup, we mentioned that we will have 9-12 students and 1 instructor with 3 teaching assistants in the class. We also provided the sketch to demonstrate the classroom setup and materials provided. Here we will list all the sensors, materials and tools provided.

- Sensors and Boards:
  - Arduino Uno + Cable
  - Breadboard
  - Ultrasonic Sensor
  - LED
  - Push Button
  - Buzzer
  - Light Sensor
  - Potentiometer
  - Temperature sensor
  - Motor
  - Servo
  - Joystick
  - Resistor
- Tools and Materials:
  - Laptops
  - Cardboard
  - Fabric
  - Magic Clay
  - Tapes
  - Hot glue
  - Rulers
  - Scissors

- Cutters
- Pencils and Pens
- Soldering Irons
- Screwdriver and Screws
- 3D Printer
- Laser Cutter

* *The course won't expect students to use laser cut or 3D print skills to complete the final project. However, if students have these skills and abilities from their personal experiences, the instructors and the assistants will support the students to realize.*

We expect the class environment to be active, supportive, and respectful. Students are encouraged to make interactions with each other and with instructors. There will be user-testing session and presentation session. Both peers and instructors will provide solid and effective feedbacks for each other.

5.1.2 Established Weekly Routines

The activity will last for ten weeks. Each week, students are expected to meet in-person for one hour, and to spend one hour to complete the group and individual assignment. Students will be asked to design a project from the beginning of the class. During the ten weeks, students will focus on their final collaborative projects, update the project every week, and revise their previous steps. The in-class meeting will involve lectures covering the conceptual knowledge, in-class hands on practices, role playing activities, group discussion, peer review session and presentation.

Students are expected to respect to a shared norm. Instructors will paste the norm in the robotic classroom, and will hand in the norms to the students and explain the norm at the beginning of the first class.

- Students should be respectful in the classroom.
  - This helps instructors to conduct direct instruction more fluently. Direct Instruction is a good way to introduce conceptual knowledge and skills. Thus, a respectful atmosphere could enhance the learning of Conceptual knowledge.

  Students should be respectful to instructors and to peers. Students should listen to and accept different ideas and opinions. Students should talk in a respectful way when presenting their own ideas or presenting an opposite ideas.

(Big Ideas: Build Interactive & Supportive Learning Environments)

- Students should be prepared for the class.
  - This aligns with the goals for students to be curious (D1).

  It's very important for student to complete the assignments assigned, especially the assignment of making preparation for the next class. With limited class time, to maximize the learning outcome, students need to prepare some materials in advance, so that the class could discuss directly.

- Students should work collaboratively.
  - This aligns with the goals for students to be collaborative (D4).

  In the collaborative working process, students could hear ideas from different perspectives. Also, working together develop students ability of taking responsibility. Collaborative working help creating a friendly and engaging environment as well.

  (Big Ideas: Build Interactive & Supportive Learning Environments)

- Students are encouraged to ask questions in class.
  - This aligns with the goals for students to be curious (D1).

  Students should express their concerns and confusion to instructors or to peers. Students will gain better understanding by asking questions. Students will also be more engaged if they could freely express their questions.

  (Big Ideas: Build Interactive & Supportive Learning Environments)

- Students should reflect on their own project frequently.
  - This aligns with the goals for students to be reflective (D3) and flexible in design (D2). This helps realize MP2, in which suggest self-evaluating their project making sessions.

  Students should always reflect on their design after learning new knowledge, gaining new insights after discussion, or receiving feedbacks from user-testing. Weekly reflection improves students' metacognitive skills.
  (Big Ideas: Become Self-regulated Learners)

5.1.3 Design Teaching Approaches Using WHERETO Analysis

Where & Why	The course is an after-school activities for novice students with interests in interaction design. They are expected to understand what is Interaction design, and what is electrical control. They are also expected to apply their learning in interaction design principles and electrical engineering knowledge (sensors, coding) into their self-presented product, which could solve real-life challenges for others and themselves.
Hook	Students will design their own products for the challenges in pandemic time. Students also have lots of interesting **Hands on activities** in class to learn the use of sensors and programming. From Schwartz et.al, making products could enhance students' intrinsic motivation [22]. **(Big Ideas: Enhance Students' Intrinsic Motivation)** Instructors will also arrange role-playing session to grab students' interests.
Equip	Instructors will give **Lectures** on design principles, and programming knowledge, and engineering knowledge. Instructors will organize **role-playing** session and **discussion** session to let students explore the scenarios with experiences by themselves. Students are required to complete after-class **small projects assignments** to explore the use of sensors and programming, and modeling software.
Rethink/Reflect/Revise	Students will be asked to make modifications to their final projects' ideas, making process, application of conceptual knowledge in several **iteration** based on self-reflection, feedbacks from presentation and user-testing session. Students are also asked to provide **weekly self-reflection** on their project update and their responsibility in team.

Evaluate	Students will be asked to self-evaluate their understanding of knowledge and skills after the middle of the class. Each week, students are asked to complete a project reflection, including self-evaluating the choice of the design, the selection of materials, the use of applications, even the reflection after receiving feedback.
Tailor	Students are asked to do an analysis on their favorite products (including games, softwares, physical toys…) Students are encouraged to form their own group and propose their own product related to pandemic based on their personal experiences/personal interests.
Organize	In each course, it will start with Lecture, following with group discussion/role playing/hands-on in-class practice, and there will be a quiz at the end of the course. Students need to complete their individual and group assignments in the following week.

5.1.4 Unit Sequence

	Time	Contents	Format	Goals
Lesson 1	Week 1, Wed 4PM-5PM	Introduction to Interactive Product Design	Lecture (25 min) & Discussion (15min)	C1.1, C1.2, C2, C6 D1
Lesson 2	Week 2, Wed 4PM-5PM	Brainstorm for Real-World Challenges & Introduction to Arduino	Role Playing Session (30 min) & Lecture (15 min)	P1, P2.1, D1, D4 C4.4
Lesson 3	Week 3, Wed 4PM-5PM	Electronic Components: LED, Buzzer, Light Sensor, Sound Sensor, Temperature Sensor, Ultrasonic Sensor	Lecture (15 min) + Worked Examples (20min) & Discussion (10 min)	C4.1, C4.2, C4.3, C5, P2.2.2 P2.1, D4, MC1

	Time	Contents	Format	Goals
Lesson 4	Week 4, Wed 4PM-5PM	Conditional Statements & Project Idea Presentation	Lecture + Worked Examples (20 min) & Presentation (25 min)	C5, P2.2.2 D3, MP1
Lesson 5	Week 5, Wed 4PM-5PM	Iterative Statements	Lecture (25min) & Discussion (20min)	C5, P2.2.2 D3, D4, MC3
Lesson 6	Week 8, Wed 4PM-5PM	Actuators: Servo and DC Motor	Lecture (25 min) & Hands on Practice (20 min)	C5, P2.2.2, MC1
Lesson 7	Week 9, Wed 4PM-5PM	Modeling Software: TinkerCad	Lecture + Worked Examples (30 min) & Hands on Practice (20 min)	C3 P2.2.1, D4, MC2
Lesson 8	Week 10, Wed 4PM-5PM	Project Update Presentation & Group Working Session for Projects	Presentation (40 min) & Making Projects (15 min)	D3, D4, MP1, MP2, MP4 P2.2, P2.3
Lesson 9	Week 11, Wed 4PM-5PM	User Testing Sessions	User-Testing (60 min)	P2.3.1, D2, MP3
Lesson 10	Week 12, Wed 4PM-5PM	Showcase & Final Presentation	Presentation (60 min)	P1, P2, MP1, MP2, MP3, MP4, MD1, MD2

In summary, instructors will make use of lecture, worked examples, discussion, hands on practice, presentation, user-testing, role playing as instructions in course.

- Lecture:
  Direct Instruction
  In lecture, instructors will explain
  - The class norms and the course overview.

  - Conceptual knowledge like "what is inputs/output", "what is analog/digital".
- Worked Examples:
  Coaching
  - Instructors will make step-by-step instruction and build circuits/model circuits in class. Instructors will also think aloud what they are doing and why.
  - Students will follow instructors step-by-step instruction and make the circuits with instructors. They could also ask teaching assistants for help.
- Discussion and Role Playing Session:
  Facilitation
  - Instructors will present prompt for discussion or provide scenarios/cases for role playing
  - Students will explore and experience by discussing with others or placing themselves into the scenario by role playing
    * Clarification: In this project, discussion and role playing session is only an instruction methods but not an assessment. We only want to let students to connect with their personal experience and reflect on their project in the discussion, and also to correct the misconceptions students may hold, but not to assess their understanding.
- Hands-on in-class Practice:
  Coaching
  - After giving lecture to a sensor/to a piece of code, instructors will ask students to build their own circuits using the sensor or the code.
  - Students are expected to do the basic tasks with sensors. However, students are highly encouraged to do a small task with the sensors or the codes if they complete the basic tasks easily.
- Presentation
  Facilitation
  - Instructors will facilitate the order of presentation, and the course discipline during presentation.
  - Instructors will provide feedback and comments after students present their work.
- User-Testing Session
  Facilitation

- Instructors will provide a guideline of providing feedback and how to make use of feedback before the user-testing session.
- Instructors will give feedback to the projects and their performance of giving other feedback.

5.2 Specific Activities Design

Sample Activities:

Lesson 1 Lecture, Discussion

Lesson 2: Role-playing session

Lesson 3: Worked examples

Lesson 6: Hands-on in-class Practice

Lesson 9: User-testing session

Lesson 10: Presentation

Other activities will be a general framework.

Pre-Assessment:

Pre-survey before the class start: Instructors will ask students to fill in a quick survey shown as below. This could give instructors information of students prior knowledge. And by asking students' favorite products, students could link their daily experiences/personal interests with the course. A connection of personal interests and prior knowledge could arouse students motivation and result better learning outcomes.

Survey:

Hi, Students from Interaction Lab. Before the class starts, in order to help us to get to know you well, we would like to ask you to fill in this short survey.

Q1. What is your favorite product? Upload a picture with a description of the products. (It could be a game, a software, an app, a necessities in your daily life.)

Q2. Why do you like this product?

We provide an example for these questions, so that you could understand better.

My favorite product is this game called Stardew Valley. Here is a screenshot of the game. This is a Role-playing game. The players will run the farm in Stardew Valley. Players could earn corns by farming, foraging, fishing, mining, raising animals and making products. With the corns, users could set up their life in the virtual world.

I like this game because:

My Favorite Product: Stardew Valley

1. The game is easy to handle. It has clear instruction of how to move, how to open things, how to farm… And the ways to operate are mostly the same as the traditional standards, which makes it easier to get hand on.
2. There are abundant contents in the game, that could alway stimulate my interest. Also, I could experience different life styles in the game.
3. The visual interface is beautiful. They use pixel graphic style and stay consistency in every scene.
4. The game gives me instant rewards and penalties.

Lesson 1. Introduction to Interactive Product Design

Activity 1: Lecture with Examples - Direct Instruction - 25 min

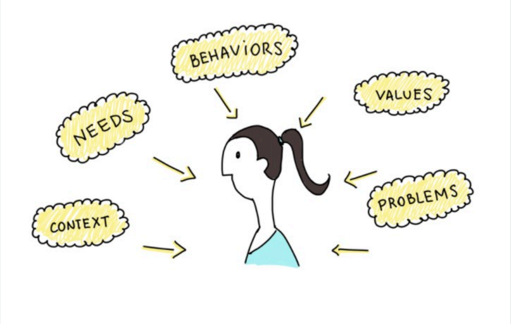
Goals: C1.1, C1.2, C2

We use Lecture because this instructional methods is more suitable for conceptual knowledge. **(Big Ideas: Align Assessments and Instructions with Goals)** We also frequently asked students questions in the lecture because we want students to be engaged and think actively. **(Big Ideas: Build Interactive & supportive Learning Environment)**

Using Lecture to tell students what are the design principles, and provide some real-life examples of good design and bad design to explain the concept.

1. What is Design?

   Design is a process of conceiving, planing, and producing. We design for a purpose.
   To meet a need in a new way
   To meet a need in a better way
   To achieve a goal
   To make a statement



2. What is Interaction Design?
   Interaction Design is a design discipline that involves the human-centered design of objects, environments, and systems. Interaction Design is a discipline that draws on many diverse subjects, such as design, engineering and psychology.
3. What are Interaction Design Principles? (C1, C2, C6)
    1. "Form follows Function": "For designers, form is the element that makes up our designs and our pages. Function is the objective of the design whether it is a sign giving directions or a book that entertains with a story." [23] Design products should start from thinking about the purpose and the targeted group, then the shape. (C2)

       Instructor said: Use this cup as an example, the function of a cup should be drinking, and then designers could think about how to design good looking cups. However, if you use this cup to drink, water will pour out easily. The function of drinking could not be satisfied. No matter how artistic the cup looks like, the design won't be considered as a good cup. Pay attention that here we said it won't be considered as a good cup. However, if this cup is considered as an artistic piece instead of a cup, we will need to reconsider and re-evaluate the product.
    2. Usability: Usability is a measure of the ease with which people can use something. See the right picture, are these something easy to use for you? If so, how to use it? If not, why?

       Students may answer the questions. If not, instructors could ask again or ask certain students directly. If students only state the yes or no, instructors should ask for the reason.
       After asking Students, instructors will conclude this problem by saying, "it is not easy to use because the button are covered by tapes, so we couldn't see the number on the button, also it will become harder to

press because of the block."
Let's consider the below picture, which design is easy to use for you? (Here not only include C1, but also C6)

As the previous question, students may answer the questions or not. If not, instructors could ask again or ask certain students directly. This time, instructors should also ask students to imitate how he/she answered the previous question.

3. Feedback: Feedback means that when a user does something, something should happen.

Instructor will ask students to describe what is happening in the above picture.
Students may say the boy is turning off the light.
If so, instructors need to further ask, how does the boy turn off the light? And after students answer, instructors will conclude: "pulling the rope, which is the switch of the light will turn off the light. After user pulling the light, which means triggering the switch, the light will turn on or off as the feedback for user."

4. Logical Mapping: Logical Mapping suggests the logical associations and relationships. After giving the definition, instructors could raise a real-life example of logical mapping first.
"For example, the table of contents in the book suggests a logical mapping of certain topics and the pages." Then see the following picture and ask "why this is an example of logical mapping?"

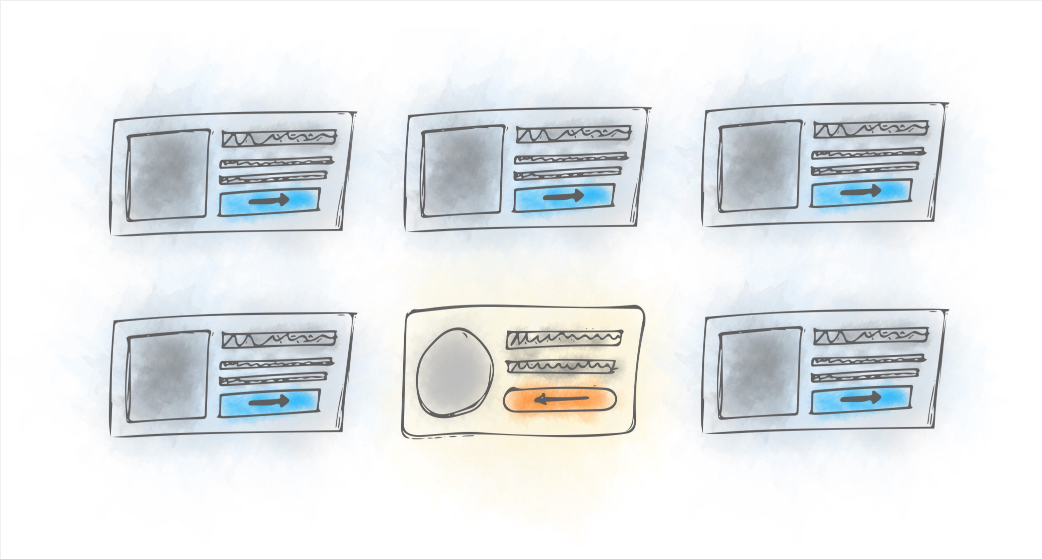
As always, instructors could ask certain students to answer, if students' answers demonstrate that the icon is logically mapping with the different functions, instructors could further conclude. If not, instructors could ask students: "what do you see on the iPhone, what is the meaning of those icons in the control interface" to guide students' thinking.

5. Conventions: Conventions is how people commonly consider or a common sense. Instructors will raise some examples like "people will see green light as pass and red light as stop, green as success and red as fail". Show the following two pictures, and ask students which one is the turn off icon, the left one, or the right one, and why?

After students' answer, instructors will conclude that, in common sense, which is conventions, we may think red as stop, close, or turn off and green as run, open and start. Therefore, when design products, it's important to consider conventions to better express your idea.

6. Consistency: "When consistency is present in your design, people can transfer knowledge to new contexts and learn new things quickly without pain. This way they can focus on executing the task and not learning how the product UI works every time they switch the context." [24] Check the below picture provided in Nikolov's post, and think is this consistent? If not, where is not consistent?



Students may said the bottom one in the middle column is inconsistent, since the color is different, or the shape is different, or the direction of the button is opposite…

If students only present one inconsistencies, instructors should ask anything else to all the students, and ask for 3-4 rounds. If students present every inconsistencies, then instructors will quickly summarize all the inconsistencies. If students fail to find all the inconsistencies, instructors need to emphasize the ones that students didn't pay attention to. To summarize the inconsistencies, instructor could list them out:

1. The overall card shape is rounded rectangle instead of rectangle
2. The general color is yellow instead of blue
3. The frame on the left is circle instead of square shape
4. The button is rounded rectangle instead of rectangle
5. The arrow on the button is placing left instead of right
6. There' only two lines of texts instead of three, and there's no text hierarchy

5 min break here

Activity 2: Discussion - Facilitation - 25 min

Goals: C1, C6

Discussion could establish interaction between students, and better develop a creative and active learning environment. Students will be more engaged with discussion. In discussion, they will share their ideas and opinions, and also listen to others' opinions from different perspectives. This could help learners to explore more. **(Big Ideas: Build Interactive & Supportive Environment)** Besides, each teaching assistant and instructor will join a group, if any students have some misconceptions, instructor and teaching assistants will correct the misunderstanding right away. **(Big Ideas: Timely and Targeted Feedback)**

To Facilitate Discussion in Lesson 1, Instructors will first split the students into 3 or 4 group, each group has a total number of 3 students, maximum 4 students. If there are 3 groups in total, each TA will join one group for facilitating and instructors will walk around and provide extra assistance and facilitation. If there are 4 group, each TA and instructor will join a group.

Total Students	Group
9	(3+1 TA) + (3+1 TA) + (3+1 TA)
10	(3+1 TA) + (3+1 TA) + (4+1 TA)
11	(3+1 TA) + (4+1 TA) + (4+1 TA)
12	(3+1 TA) + (3+1 TA) + (3+1 TA) + (3+1 Instructor)

Then, Instructors will deliver the following prompts to the classroom:

1. Share your favorite products, which you have shared it in the pre-assessment in your discussion groups.
2. Identify the good and the bad of this design in reference to the design principles we just learned.
3. What will you and your group members do to improve it?

During the discussion, instructor and TA will guide students to think deeper by asking questions like:

1. What's your opinion on other students' favorite products?
2. Could you compare the similarities and differences between the design principles used in different products?

3. Why different types of products focus on different design principles?

Except for asking questions, instructors also need to observe students' engagement and participation. For students who speak less, instructors could give positive feedback on what those students presented, and ask questions directly to them. For students who speak a lot, but the responses are not very related to the discussion prompts, instructors should quickly wrap up the students' responses and ask him to answer a related question.

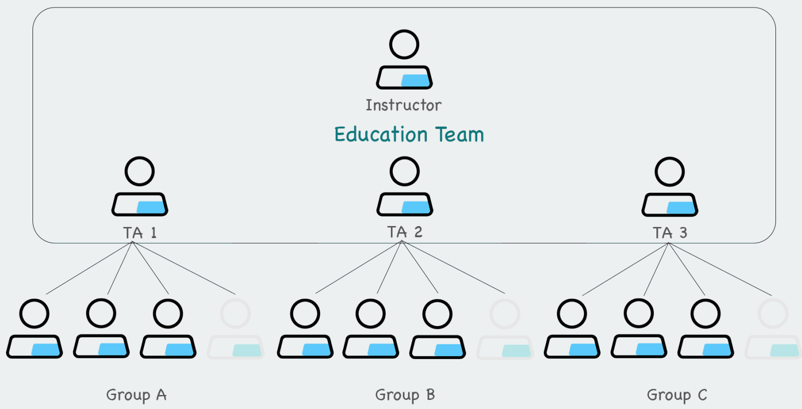
Activity 3: Quiz - Formative Assessment - 6 min

The sample quiz is provided in "Assessment Design", here we are assessing students conceptual knowledge in interactive design (C1, C2, C6) with multiple-choice question and short answer question.

Activity 4: Assignment: Prepare for the role-playing session next time.

Goals: P1

Instructors will first split students into 3 group, which is also the group for the final project, as mentioned in Learners in Context session. We will consider learners' prior knowledge when splitting into three groups. If two or more students have prior knowledge in interactive design or in electrical control, then we assign them in different groups, to make sure that in each group, there is at least one member has prior experiences, and instructor and TAs will ask that students to help other students. **In our project, we will assume all the students have similar prior knowledge level.**



After instructor splitting the group, instructors will provide three scenarios during the COVID-19 pandemic, one scenario for each group, and ask students to act them out next course. The scenarios are printed in paper, and hand out to students directly.

Scene A for Group A: Tom is an 13 years old middle school students. Because of the lockdown for COVID-19, schools are required to take online class for a long time. Recently, because the pandemic is getting better, schools are allowed to have in-person class. After long-time of online course, they could finally get back to school. To avoid any risks, just in case, school has a policy that students need to keep 1-meter social distance in school. However, in school, although teachers and public safety tried their best to control students to keep the social distance, it's not very practical because the number of students are much more than teachers and public safety. Therefore, we could always see students stay closer to each other. Tim thought this is not safe, and he wants to do something.

Scene B for Group B: Dave is a 13 years old middle school students. Because of the pandemic, many public spaces in China require people to show their Health QR code and a guard will check their temperature. One day, Dave went to a shopping mall, the guard block him and let him show the QR code and want to check the temperature. However, Dave noticed that while the guard is checking his temperature, there are many other people who pass by him and didn't show the QR code or check the temperature, because the guard couldn't take care of many people at the same time. Dave thought this is not safe, so he wants to do something to solve this problem.

Scene C for Group C: Mary is a 13 years old middle school students. The COVID-19 is spreading seriously. Her family is under quarantine now. To eliminate the risks of spreading, their family try to avoid touching the same thing at the same time. And they always clean up after touching things such as dishes, desks, chairs… However, one day, Mary and her mom are washing hands together, they use the sanitizer one after another, and they didn't clean up the sanitizer very often. Mary realize that sanitizer is something they all touched, but always neglected. Therefore, Mary wants to do something to avoid this contacts happening.

Teaching Assistants will help each group to assign roles and also discuss the script together during the extra hour for assignment each week.

Lesson 2. Brainstorm for Real-World Challenges & Introduction to Arduino

Activity 1: Role Playing - Facilitation - 30 min

Goals: P1, P2.1, D1, D4

As Wiggins & McTighe mentioned in [12], role-playing activities could help students situated themselves in the real-world scenario, and identify real-world problems. **(Bid Ideas: Active Learning Instruction)**

Instructors will ask students to act out the scenario during the class, giving 3 - 4 mins. Instructors will also give several prompts to other students. So that other students could think while seeing the play. The questions are:

- What is the problem of the main character in the scenario?
- Who needs help?
- How can we help them?

Students will be provided a form as following for students to take notes and think:

Problems	Solutions
Problem 1	Solutions 1.1
	Solutions 1.2
Problem 2	Solutions 2.1
	…

During the students' role playing time, instructors and teaching assistant should ensure students' role-playing is closely related to the difficulties and act out the script. TA could hint students if the students forget the scripts.

Instructors will facilitate the following discussion after the role-playing session.

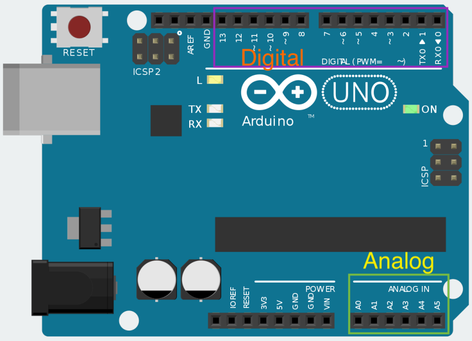
- Instructors could first ask students who play a role to share their feelings and what they think with the whole class.
- Instructors could also ask students to share what they wrote on the form, and conclude the difficulties together.
- Instructors could ask students do they have any solution suggested.
  Instructors and TA will evaluate the practicality of their proposed solutions and whether their proposed solutions could solve the problems.
  If students couldn't give any possible solutions to the problem proposed.
  Instructors and TAs will propose one possible solution as an inspiration.

5 min break here

Activity 2: Lecture - Direct Instruction - 15 min

Goals: C4.4

1. What is Arduino?
   What can Arduino do?
   What are the relationship between Arduino & Sensors?
   Arduino is an electrical control board that could read data from sensors and control the electrical components as well.
2. What are the pins?
   5V, GND, digital pins, analog pins.
3. Which are the digital pins and which are the analog pins? What are their functions?



Activity 3: Quiz - Formative Assessment - 6 min

Goals: C4.4

Activity 4: Assignment - 4 min

Goals: P2.1

Discuss with your group member and your teaching assistant on your scenario. Write down a project proposal in group. In the proposal, you will use the form we provided to brainstorm the solution to the given scenario.

Lesson 3. Electronic Components: LED, Buzzer, Light Sensor, Sound Sensor, Temperature Sensor, Ultrasonic Sensor

Activity 1: Lecture - Direct Instruction - 15 min

Goals: C4.1, C4.2, C4.3, C5

1. Introduce what is digital information and what is analog information, and demonstrate electronic components that provide digital information and analog information with figures.
2. Introduce what is input and what is output, and demonstrate the input sensors and the output components.
3. Identify each pin on the electronic components: Vcc, GND, and signal pin, with figures provided.
4. Introduce built-in methods pinMode(), DigitalRead(), DigitalWrite(), AnalogRead(), AnalogWrite(), and create variables, serial monitor in order to control the sensors.

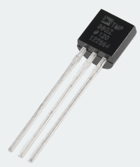
Activity 2: Worked Examples - Coaching - 20 min

Goals: C4.1, C4.2, C4.3, C5

We use worked examples because [22] suggested that for novice learners, instructors should make use of worked examples and **self-explanation**. Since worked examples show **step by step** goals/approaches. This could "reduce cognitive load" for novice learners.

Instructors: Now, let's move to the workspace, let's sit in groups, each instructor will help their own group. Let's use what we learned and build a circuit with one input sensor and one output sensor.

To choose the output sensor, I want to use the temperature sensor.



Temperature Sensors

The temperature sensor has three pins, we could see the text on the temperature sensor, where it noted which is GND, which is Vcc, and which is signal pin. (If students have problem finding the pins, TA will point it out to students.)

Now, let's insert it in the breadboard. We want to use breadboard because we will need to re-use the pins from Arduino board, and breadboard works as an extension of Arduino board. We will insert it in vertical direction. (TAs check whether students connect it right, if not, help them correct it.)

Let's use wires to connect the Vcc pins on the temperature sensor to the Vcc pin on Arduino Board, and connect the GND pins on the temperature sensors to the GND pin on Arduino Board. (TAs check whether students connect it right, if not, help them correct it.)

Because temperature sensor is an analog input sensors, therefore, we need to connect with the analog pins on Arduino Board. I will choose A0 to connect with the signal pin. (TAs check whether students connect it right, if not, help them correct it.)

Now, we need to write code in Arduino IDE, and upload to Arduino Board. We want to read the data from temperature sensor, so we will use AnalogRead(A0) to get the data. Because we will need to reuse this data later, let's create a variable first, I will called it temp. And then, let's store the data read from temperature sensor to the variable temp. We could do this by writing: temp = AnalogRead(A0) (TAs check whether students connect it right, if not, help them correct it. Instructor waits for 30 seconds, and ask if everyone is ready.)

Let's choose an output sensor now, I want to use LED. LED also has three pins, GND, Vcc, and signal pin. Let's insert it in the breadboard, and connect it with Arduino Board. Let's use wires to connect the Vcc pins on the LED to the Vcc pin on Arduino Board, and connect the GND pins on the LED to the GND pin on Arduino Board. (TAs check whether students connect it right, if not, help them correct it.)

Because LED is a digital output sensors, therefore, we need to connect with digital pins on Arduino Board. I will choose D6 to connect with the signal pin.

Let's first identify the pinMode of D6, because D6 is going to output a value to LED, therefore, in void setup(), let set D6 to output, by writing pinMode(6, OUTPUT). (TAs check whether students connect it right, if not, help them correct it.)

If I want to control the brightness of LED, I need to use analogWrite() as well. Although LED is a digital output, but because we want to control the brightness, which is a continuous value, we will need to use analogWrite(). This is a special case. (Instructors should ask if everyone understand this, if not, re-explain the special case.)

So now, to control the brightness of LED with the data from temperature sensor, we are going to make use of the temp variable. We will write the variable's value to the LED by writing analogWrite(6, temp). (TAs check whether students connect it right, if not, help them correct it.)

If everyone has completed this step, let's connect Arduino with your laptop using this cable, and select the board and port in Arduino IDE. (TAs check whether students did this step right, if not, help them correct it.)

Now, let's upload code to the Arduino board and see what will happen if we cover our hands on the temperature sensor and let the temperature increases .

Result: The LED will turn brighter when the temperature increases.

5 min break here

Activity 3: Discussion - Facilitation - 10 min

Goals: C2.1, D4, MC1

1. What sensors can you think of in your daily life?
2. How do the sensors work in that context?
3. If time allowed, discuss how could your group make use of the sensors?

Activity 4: Quiz - Formative Assessment - 6 min

Goals: C4.1, C4.2, C4,3, C5

Activity 5: Assignment - 4 min

Goals: P2.1

1. Discuss with your group member and your teaching assistant what sensors could be used with the forms (Provided in goals P2.1 step 3).
2. Prepare a Project Proposal Presentation next class.
   In the presentation, you will include the following sections, and answer questions to the given prompts, the presentation won't last longer than 6 min per group:
    1. What is the problem of your scenario?
    2. Who is the target Audience?
    3. What solutions did you come up with? Which solutions is the optimal solutions for your group?

4. What sensors do you plan to use? And how they are going to use?
5. If you have draft sketch, show it.

Lesson 4. Conditional Statements & Project Idea Presentation

Activity 1: Lecture - Direct Instruction - 10 min

Goals: C5

1. What is conditional statements? What are the examples in real-life?
2. How to write if, if-else, if-else if-else statements in Arduino?

Activity 2: Worked Examples - Coaching - 10 min

Goals: P2.2.2, C5

Make the LED turn on when the temperature is more than 35 degrees

5 min break here

Activity 3: Project Idea Presentation (More detailed demonstration in Lesson 10) - Facilitation - 25 min

Goals: P2.1, D3, MP1

Each group will go to the front, and present their project with the answers to the questions we asked them to think about. Each group has no more than 6 min to present. The rest two minutes will be instructors' feedback.

Based on their presentation, instructor will give feedback of:

1. Did they answer to all the questions? If not, which questions is missing?
2. Does instructor have other suggestions on the sensors?

Activity 4: Quiz - Formative Assessment - 6 min

Goals: C5, P2.2.2

Activity 5: Assignment - 4 min

Goals: D2, D3, D4, MP3

In group, write down a reflection of the projects' ideas. What feedbacks do you receive? What do you want to change based on the feedback? What are the other possibilities?

Lesson 5. Iterative Statements

Activity 1: Lecture - Direct Instruction - 25 min

Goals: C5, P2.2.2

1. What is iterative statements? What are the examples in real-life?
2. How to write for loop in Arduino? When to use for-loop to control the sensors?

5 min break here

Activity 2: Discussion - Coaching - 20 min

Goals: D3, D4, MC3, C5, P2.2.2

1. In group, discuss where in your life use iterative statements?
2. Discuss whether you project need iterative statements? Where should you incorporate in? Take notes of this

Activity 3: Quiz - Formative Assessment - 6 min

Goals: C5, P2.2.2

Activity 4: Assignment - 4 min

Assignment 1:

Goals: D3, D4, P2.2.2

Continue your discussion of how to incorporate iterative statement into your project? Also think about how to incorporate conditional statement into your project. In group, write a documentation on how do you plan to use.

Goals: MC1, MC2, MC3, MP4, MD2

Add an **individual** reflection, where you should self-evaluate your use of knowledge, your roles in group, self-monitoring whether your are being reflective in design process.

Assignment 2:

Goals: P2.2.2, P2.2.3

Make a “Breathing Light” while the room is dark. Breathing light is a light which changes its brightness linearly from dark to bright and from bright back to dark. Write a documentation of your homework, and take photos and videos. Send everything through email.

Lesson 6. Actuators: Servo and DC Motor

Activity 1: Lecture - Direct Instruction - 25 min

Goals: C4, C5, P2.2.2

1. What is servo? What does servo do? What are the examples? How to control Servo with Library?
2. What is DC Motor? What does DC Motor do? What are the examples? How to control DC Motor?

5 min break here

Activity 2: Hands-on In-class Practice - Coaching - 20 min

Goals: P2.2.2, P2.2.3, C4, C5, MC1, MC3

Making activity could enhance students' individual interests in the topic, and further improve the motivation [22]. **(Big Ideas: Enhance Students' Intrinsic Motivation)** Also, hands-on practices could benefit students to consolidate the conceptual and procedural knowledge/skills.

Practice Prompt: Build a circuit that when the ultrasonic sensor detect an object is close, and the distance is less than 20 cm, it will slowly turn 15 degrees.

Document your work with pictures and videos after class. Send it to the instructor and learning assistant via email.

Step 1: Use Arduino to control the ultrasonic sensor, read the data from ultrasonic sensor

Step 2: Connect a servo, and use for-loop to slowly turn 15 degrees.

Step 3: Use conditional statement, if the hand is closer to the ultrasonic sensor, and the distance is less than 20 cm, execute the statements that let servo slowly turn away.

Step 4: Use glue or tapes and cardboard to place the ultrasonic sensor on the servo.

Step 5: Take photos and videos for documentation. Write a documentation that could show the thinking and working process, outcome demonstration and self-reflection. In self-reflection, students could reflect on their process by answering:

"Which step is unclear for me?"

"What difficulties did I encounter? Why"

"How do I resolve the difficulties?"

Instructors and teaching assistants will walk around, and check each students' process. If students ask questions, instructors or TAs will help them and coach them. If students didn't ask questions directly, however, instructor and TAs observed that the students are not working incorrectly, or having trouble in getting started, instructor and TAs will directly ask students how are their practices going, and provide guidance.

Activity 3: Quiz - Formative Assessment - 6 min

Goals: C4

Activity 4: Assignment - 4 min

Goals: D3, D4, P2.2, MC1, MC3, MP2, MP4, MD1, MD2

Start to draw sketch of your product in group. Update your group documentation and individual reflection

Lesson 7. Modeling Software: TinkerCAD

Activity 1: Lecture + Worked Examples - Direct Instruction + Coaching - 30 min

Goals: C3, P2.2.1

1. What is servo TinkerCad?
2. How to create a new electrical design model?
3. How to import microcontrollers and sensors into TinkerCad?
4. Use a worked examples to demonstrate how to build the model. We will use TinkerCad to model the circuit of a blinking LED, to show how to connect wires, how to write code, how to start stimulation.

5 min break here

Activity 2: Hands-on In-class Practice - Coaching - 20 min

Goals: P2.2.1, D4, MC1, MC3, MP2, MP4, MD1, MD2

In group, students build the model for their own project in class. Students should write documentation to update their final project. As before, students will be asked for a documentation reflecting themselves.

Activity 3: Assignment - 5 min

Goals: P2.2.1, D4, MC1, MC3, MP2, MP4, MD1, MD2, P2.2.2 (Optional)

Assignment 1: Document your project update. If you have time, start to connect your circuits.

Assignment 2: Prepare the project update presentation in group for next class.

Lesson 8. Project Update Presentation & Group Working Session

Activity 1: Project Update Presentation - Facilitation - 40 min

Goals: D3, D4, MP1, MP2, MP4

Each group will have 8 mins to present their project update. The rest 5 min, instructors and students will give them feedback:

1. Did they follow the step to create their design?
2. Did their solution solve their problem?
3. Did their design choose the most appropriate sensors?
4. Did their stimulation in TinkerCad demonstrate their proposed solution?
5. What other feedback do you have on sensors chosen, possible designs…

5 min break here

Activity 2: Making Projects - Coaching - 15 min

Goals: P2.2, P2.3, MP3

Students continue their work in group. They could discuss their feedback, or they could start to connect the circuits.

Activity 3: Assignment - 2 min

Goals: P2.2, D2, D3, D4, MP3, MC1, MC2, MC3, MP2, MP4, MD1, MD2

Complete the alpha prototype of your group project, from revising models to building real circuits to adding hand make structure/casing for the product. Document your project updates as a group. In your group documentation, also reflect on the feedback received and how you revised, as you did in Lesson 4.

In your individual post, document what you did individually. Add a short reflection on whether you are responsible for your work.

Lesson 9. User-Testing Session

Goals: P2.3.1, D2, MP3

Activity 1: User Testing - Facilitation - 60 min

This activity give students chance to share their work with others and receive feedback and comments from others, which help students to assess and reflect their work. As [22] mentioned, this session could also help students be more engaged. **(Big Ideas: Enhance Students' Intrinsic Motivation)**

- Each group will have a table to present their work.
- Every students will have two copies of the following form. So that they could give feedback to others with reference to the form.

Criteria	Feedback
Forms follow Functions	
Usability	
Feedback	
Logical Mapping	
Conventions	
Consistency	
Feedback on Sensors	Here, students will self-evaluate or comment whether the sensors are appropriate to use for solving certain problems. Are there any other sensors that are more appropriate?

There are 3 groups in total. While the user-testing session starts, 2 groups will stand behind the table, and the other group's members will walk around and see other groups' project.

- After 20 mins, the 3 groups rotate their roles. The groups that were giving feedback will start their exhibiting sessions, and the rest groups will give feedback instead.
- Instructors need to give feedback to each group, and also need to listen to and assess other groups' feedback. If instructors found that students' feedback is not provided in details, instructors could help ask some questions to lead the feedback session. The questions for the students who provided feedback could be:
  "Can you explain each component's function?"
  "Which part is unclear for you?"
  "How do you think this *** function? And Why?"
  "Could you give 3 comments on the projects' strengths and weaknesses?"

Activity 2: Assignment - 2 min

Goals: P2.3, D2, D3, D4, MP2, MP3, MP4, MD1, MD2

Write documentation in group, reflect what feedback you received? Which feedback will be the priority for you to revise?

Then, based on the feedback, modify your work and complete the final version of your project. Prepare for the showcase and presentation next class with reference to a guidance.

Lesson 10. Showcase & Final Presentation

Activity 1: Showcase & Final Presentation - Facilitation, Summative Assessment - 60 min

Goals: D2, D3, D4, MC1, MC2, MC3, MP1,MP2, MP3, MP4, MD1, MD2

At the end of the last class, Instructor will hand out a presentation guidance for every group. On the guidance, are the structure of the presentation, students need to answer to all those questions:

1. Problem Identification:
    1. What is your problem from your scenario?
    2. Why you conclude this as your problem?
2. Solution:
    1. What is the solution you propose?
    2. What changes do you make during the project making process?
3. Technical Use:
    1. What sensors do you use?
    2. Why do you think those sensors could solve your problem?
    3. How do you use those sensors?
    4. How do you control those sensors?
    5. What structure do you use to place all those sensors together?
4. Demo
5. Reflection:
    1. How do your team collaboratively working?
    2. What feedback do you incorporate?
6. Conclusion:
    1. In general, how would you evaluate your product?

2. What future improvement you would want to make?

In Class:

1. Every group will have 15 mins to present their work, including the demo session. During the demo session, the group need to use live demo. The group could either acts out by themselves, or ask other students to try with it directly.
2. After the presentation, instructors and students are welcome to give feedback. The feedback should also follow the form used in user-testing session.

Activity 2: Assignment - 2 min

Goals: D2, D3, D4, MC1, MC2, MC3, MP1,MP2, MP3, MP4, MD1, MD2

Write a thorough group documentation on your group project, from deciding the project ideas to several iterations to using modeling softwares and Arduino to make prototype to project Demo.

Write a self-reflection on whether you apply the knowledge and skills while making the product, whether you are responsible in the group, whether you are flexible while making the project.

6. Evaluation Research Design

6.1 Evaluation Research on Educational Implementation

The active ingredient of this course is the **documentation and Timely and targeted feedback**. Documentation is one ingredient from the group final project, which is also the maker activity. The activity is an accumulated project from the beginning of the class to the end. In this activity, students will make their own products, and will also write documentation which reflect on themselves, and make presentation at the end of the course. Timely and targeted feedback are provided throughout the assessments.

6.1.1 Fidelity check of teacher following the proposed instruction and assessment design

Data Collection:

1. Collect the prompts given to the students for each week's update. Is it explicit and clear for students to understand?
2. Record observation and notes from instructors. The notes and observation will be that instructors use the scoring rubric to assess the project, and see the changes and improvements students' made each week, and take notes of each project.
3. Keep track of students' documentation and instructors' feedback. Instructors' feedback should be given based on the scoring rubric.
4. If possible and students agreed, instructors could record video of the final presentation session.

Forms to be Used:

Instructors should answer a list of the following questions, and write down the reason of their answers:

1. How many times you give students late feedback in the semester?
2. Did I follow the **scoring rubric** while I assessed the project and students' documentation?
3. Is my feedback goal-oriented that could help students make improvements?
4. Did I lead students to give more comments and reflect more by asking leading questions during the presentation?

Scoring:

If the answer is Yes, then add 1 point, otherwise, 0 point. However, if the reason provided for each answer is thorough and reasonable, then add 1 more points. By thorough, it means it includes different situations and cases.

6.1.2 Fidelity check of students participating in instruction and assessment design

Data Collection:

1. Students' final projects

2. Students' documentation

Forms to be Used:

Just as fidelity check for instructors, the fidelity check of students participation could also be assessed by answering a list of the questions and providing the reason:

1. Did you make revisions based on the feedback provided? How?
2. Did your documentation provide comprehensive description of your work, and deep reflection and evaluation on their working progress?
3. Did you hand in the assignments on time? How many times did you hand in the assignments late?

Scoring:

If the answer is Yes, then add 1 point, otherwise, 0 point. However, if the reason provided for each answer is thorough and reasonable, then add 1 more points.

6.2 Evaluation Research on Educational Impact

This after-school activity implements PBL, making use of DIY and making activities. As Herro mentioned in [1], PBL has the internal connection with STEAM activities and proved its efficiency. However, in our activity, we not only asked students to make projects and do hands-on activities, we emphasized the importance of documentation during the making process, especially the importance of self-reflection in the documentation.

Research Question

Will writing documentation with self-reflection section enhance students' learning performances?

Experimental Design

This evaluation research makes use of now-and-later experiments, since all the students should learn to be thinking in metacognitive level (Big ideas: becoming a self-regulated learner).

Experimental group: The experimental group will be asked to include a self-reflection section in their documentation. They should answer some of the questions from below questions each week (the questions are different each week based on that weeks' activity):

1. Why you choose these sensors? Why you design certain structure? What modification could you make to improve?
2. What are the other possible designs? How do you compare different designs?
3. Did you complete tasks assigned timely with high quality?
4. Did you listen to your group members' ideas and did you express your ideas?
5. Did you incorporate new learning into the design?

Instructors will also give feedback on students' self-reflection.

Control group: The control group will be asked to write the documentation, but self-reflection won't be a requirement. Instructors won't provide much feedback on self-reflection section.

Variable: Whether the students are asked to write a self-reflection in the documentation.

Covariates:

1. Students have different prior experiences in self-reflection, so some students from control group may also unintentionally include high-quality self-reflection.

2. The project characteristics may affect the quality of self-reflection.

Methods

Since students are going to do project in groups, therefore, instructors could split experimental groups and control groups based on the projects' groups. Group A is the experimental group in the first five weeks. Instructors will provide feedback based on their self-reflection. Group B is the experimental group in the following five weeks, instructors won't ask students from Group A to write self-reflection session, and won't give feedback on their self-reflection. Instructors will compare their final project and each week's update with reference to scoring rubric.

Data Collection & Scoring

1. The experiment will collect students' projects and the revision made each week. Instructors will calculate students' project scores, and the differences of each week's update.
2. Record students' scores of their documentation, especially the scores for the self-reflection section.

Calculate the average project scores and average self-reflection scores of Group A and Group B for both first five weeks and the following five weeks.

Hypotheses and Related Predications

Group A students will have faster improvements in the first five weeks, and Group B students will have faster improvements in the following five weeks.

Assessment of Design Quality

Sufficiency: Performance task is related to most of the procedural skills, and writing documentation with self-reflection could help learners to think in metacognitive levels, which covers MP1, MP2, MP3, MP4, MD1, MD2, MD3.

Reliability: The sample size of control and experimental groups is relatively small, so the data analysis may be less reliable. Instructors and students will do fidelity check of their educational implementation every week, in order to increase the reliability.

Validity: From Big ideas to become self-regulated learners, self-reflection could enhance learning. Now-and-later experiments give all the students equal chance to receive the instruction.

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