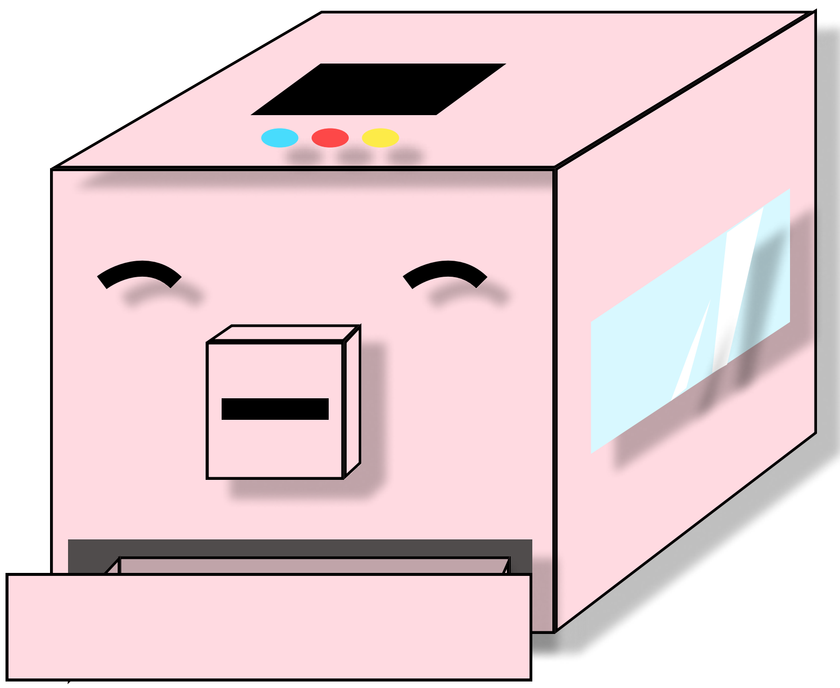

IAT 267: Final Project

# The Ultimate Piggy Bank


**Max Nielsen**
**Alessandra**
**Ningzhi**
**Len**

**Instructor:** Mark Nazemi
**TA:** Dan Peng

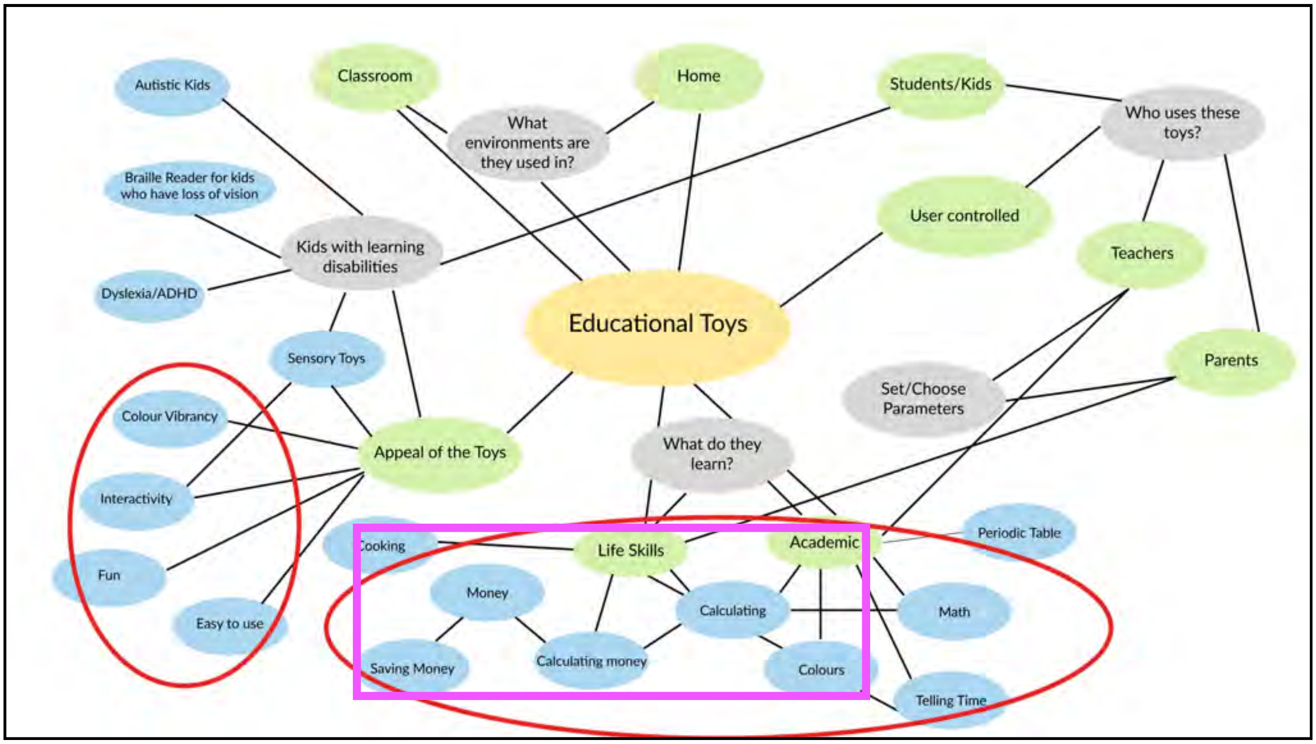


*Figure 1.* Ideation Mindmap (2023). Chung, A.

## The Concept

Our group chose to focus on creating a meaningful educational toy for children. During our initial brainstorming and ideation process, we realized that we wanted to create a toy that would bridge academic lessons and practical life skills.

After some research, we realized that finance was an important subject and that it could have both academic and practical application (Figure 1). Typically in the 1st grade, where kids not only just learn to add and subtract, they also learn specifically how to count money.  However, they are seldomly taught how the concept of money is applied into their own lives.

# The Concept

| | Parent #1 | Parent #2 | Parent #3 | Parent #4 | Parent #5 | Parent #6 |
|---|---|---|---|---|---|---|
| Parents | Father | Father | Father | Father | Mother | Mother |
| Sex/Age(s) of Kid(s) | 7(M)& 4(M) | 6(F) & 4(M) | 6(F) & 4(M) | 6(M) | 14(F) & 9(M) | 14(F) & 11(M) |
| What age did they start introduce the concept of money to their kids? | 4 | 4 | 5 | 4 | 5 | 5 |
| How do they give their kids money? | Cash | Cash | Cash | Cash | My Doh App | E-transfer (14), Cash (11) |
| Where do their kids keep their money? | Wallet | 2 Wallets | Separate container | Wallet | Apple Wallet | Wallet |
| Access to debit card? (Y/N) | Yes, but limited | No | No | No | Yes | Yes (14) & No (11) |
| How do they get money? | Allowance | Allowance & Chores | Allowance (Situational) | Allowance (Situational) | Allowance | Allowance & Chores |

*Figure 2.* Parent Interview Summary of Children's Financial Learning (2023). Chung, A.

After conducting interviews with different parents, we found a problem to be explored that is especially relevant in today's age (Figure 2). Living in a world of digital transactions, people are constantly buying and spending their money online. This is not an ideal medium for kids to not only have to learn how to count money, but also how it works, how it's earned, how they spend, and how they save.

While schools are typically responsible for teaching kids math and how to count, parents are responsible for its application in regards to money. This led us into wanting **to create a tool that can help parents teach kids both the calculations and the idea of saving money.**

***By giving a technological upgrade to the classic piggy bank, parents have easy access to a tool(toy) that can help their kids learn how to save their money. It allows a kid to have an active role in understanding the value of each coin and bill individually while keeping track of and look forward to their own savings goal that they can set themselves with their parents.***

# Understanding the Problem

A 2023 finance article by the Washington Post written by financial expert Caitlin Gibson, mentions a story on how a six year old kid spent a thousand dollars worth on food deliveries (Gibson, para 10). The child was unaware of the value of money and how it worked, especially since the transactions were made digitally.

It led us to wondering if cash is still a viable learning tool in a time where most transactions are digital. Through extensive research and user interviews, we determined so.

According to a 2019 study, education researchers in Indonesia uncovered that there was an improvement in an elementary student's ability to learn mathematics by using the CPA method (Figure 3). We considered and applied this method to how a kid learns how to handle money and how it works (Yulianto et al, p. 249).

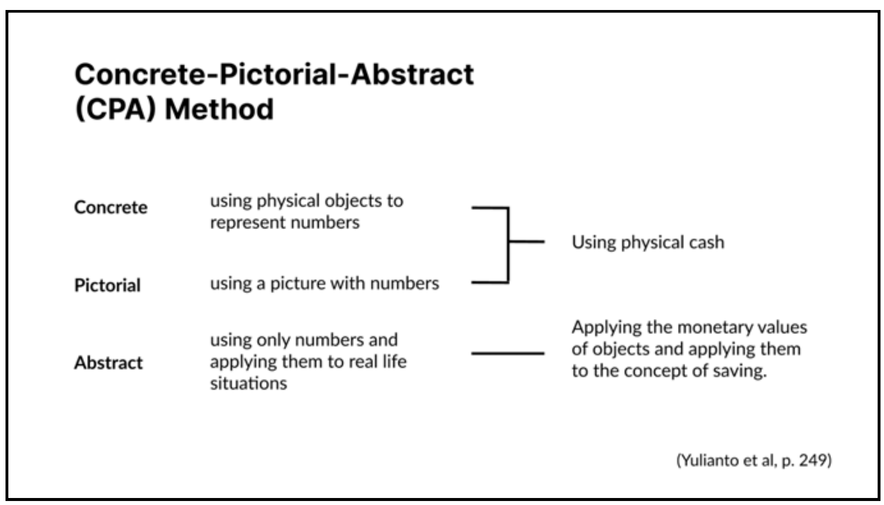


*Figure 3*. Screenshot of Presentation Slide on the Application of the CPA method to learning finance (2023). Chung, A.

We also uncovered that a parent's guidance in this learning process was key on how a kid values money and their knowledge (Gibson para 8). It deepened our understanding of our users we are trying to reach and how we could gear our design towards a useful product for them.

# Planning

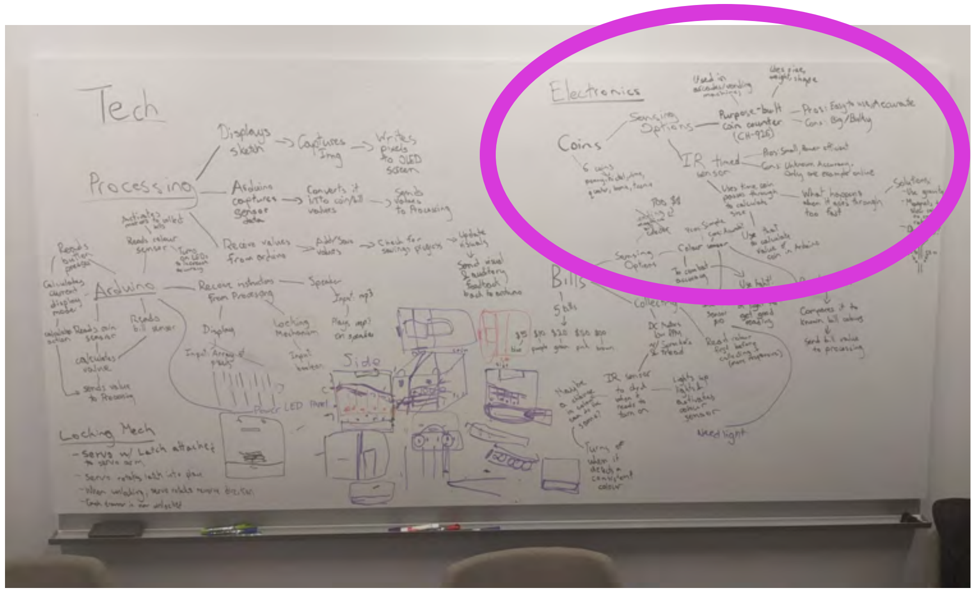

*Figure 5.* Mind map of the Planning and Ideation Process (2023). Annotated by Chung, A. Taken by Nielsen, M.

Our planning stages consisted of the discussion of mapping out the steps and tools we needed to make this project.

As a group, we flushed out and discussed different ideas as to how we can create a coin detection system. We brainstormed what sensors to use, the benefits of each one, and how they can be implemented (Figure 4). We compared different solutions such as using IR distance sensors, IR proximity sensor, and even a purpose-built coin counter. Because we wanted to keep the design a reasonable size, we decided to try out an IR distance sensor for our prototype.

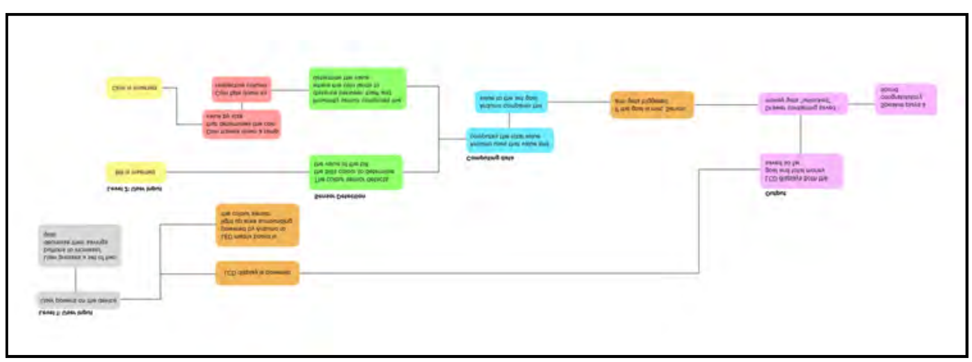

*Figure 5.* User-Interaction Flow for the Ultimate Piggy Bank (2023). Chung, A.

Next, we mapped out how the flow of user interaction, the inputs and outputs, and how user interaction would affect them (Figure 5).

## The Prototype

The original prototype was created solely out of cardboard (Figure 6). We had struggles with the creation of the coin ramp as we had to precisely hand cut each hole to make sure that the coins would not only drop smoothly but also fall into their respective holes.

*Figure 6.* Original Cardboard Prototype (2023). Wang, L

After making adjustments to the hole sizes and the ramp angle, the coins were able to fall in their holes semi-consistently. Once it was built, we were able to place the Arduino and wiring in the leftover empty space.

# Redesign Process

After our Prototype presentation, we received four key pieces of feedback.

1. **Size:** Make the final product smaller
2. **Creating better interaction:** Adding a clear window to allow users to see the money fall through.
3. **Electronics placement:** Make the product more accommodating to our sensor and wire placements.
4. **Reliability:** Create a more viable solution for the coin and bill detection.

## Redesigning the structure

A major problem that we had with our original prototype was the lack of planning. As the prototype was being built, a lot of constant adjustments had to be made to fit the electronics components. We created a series of sketches with the goal to house each component comfortably while still being able to make it look like a "piggy bank" in a sense (Figure 7).

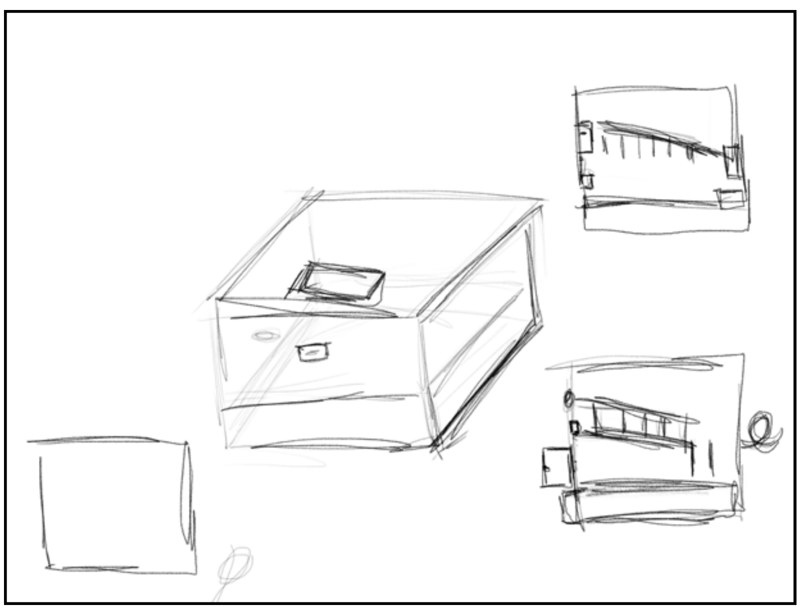

*Figure 7.* Series of Initial Final Product Sketches (2023). Chung, A

**Redesigning the structure**

We created a detailed sketch (Figure 8) that can be referred to during construction of the final product. That way we had a solid foundation before building it.

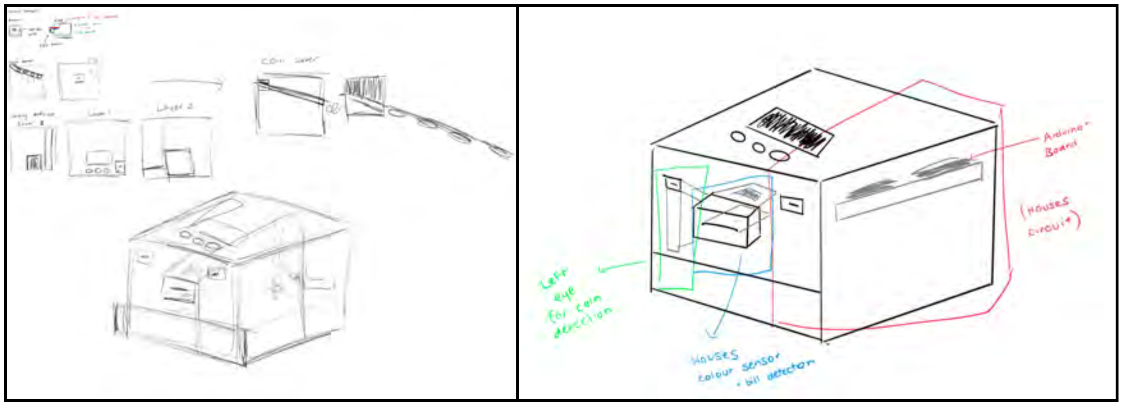


*Figure 8*. Detailed Sketches of the Piggy Bank with Annotations (2023). Chung, A

Since our previous design had a lot of unused space, our redesign had a better layout that accommodates for all electronics while still having proper user interaction. We shrunk the product down by 10cm in every dimension and made use of the leftover space.

In the redesign, the pig's snout was dedicated completely for the bills, colour sensor, and LED matrix with its own Arduino board. The left side houses the coin ramp that is part of the pig's eye. The right area has shelves that could hold our breadboard and main Arduino (Figure 9).

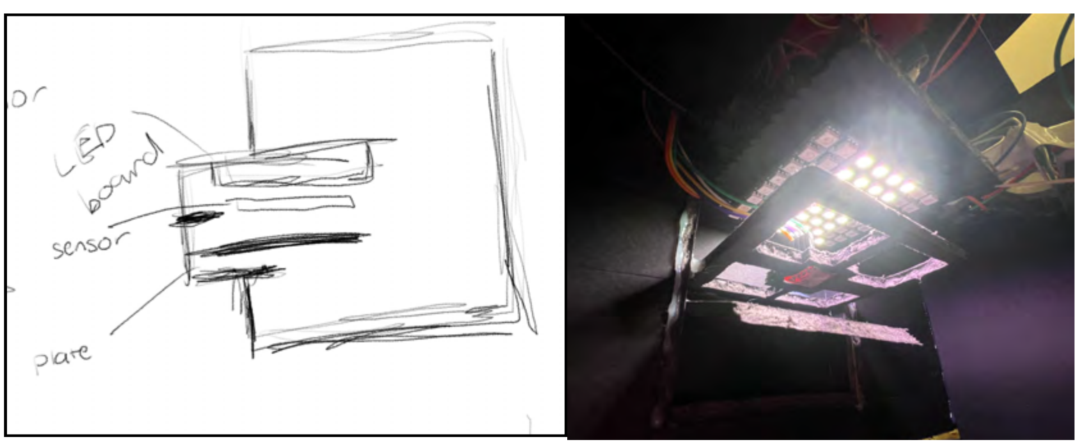


*Figure 9*. Side by side of Snount Sketch and an Image of final physical design of the pig snout (2023). Chung, A

**Solving the coin detection problem**

Our original prototype was created with cardboard and was hand cut which caused issues with coins not falling through consistently in the right hole. To solve this issue, we created a coin ramp in OnShape to be 3D printed with increased accuracy and a smoother material (Figure 10).

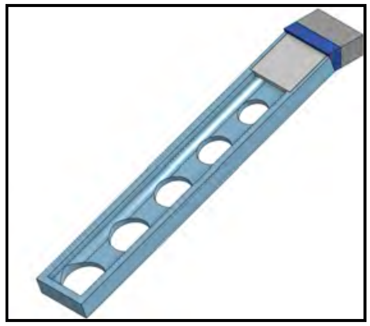

*Figure 10.* Screenshot of 3D Coin Ramp model (2023). Nielsen, M

We replaced the proximity sensor with 5 individual photocells that were integrated along the ramp, one for each coin slot. That way Arduino could individually read and control each slot. This dramatically increased consistency in detecting the correct coin.

# Retesting Stage

Even with the new redesign of the bill detection system, we were still running into issues with our code. Specifically with how we could differentiate the rgb values between the $5, $10 and $50 bills.

```
// Calculating color occurance
if(blue > green)
  if(green < 2700 || blue < 3000)
    purpleWins++;
  else
    blueWins++;
else if((float)red > (float)blue/blueMult)
  redWins++;
else if(green > 3200)
  if(blue > 3000)
    blueWins++;
  else
    greenWins++;
else
  purpleWins++;
```

*Figure 11.* Screenshot of Arduino Code (2023). Nielsen, M

The problem was solved by adjusting the placement order of the if statements and the ranges between the values.  On top of this,  a function was also created to give the rgb values a point like system to help control the if statements that would decide the value of the bill (Figure 11).

# Final Product

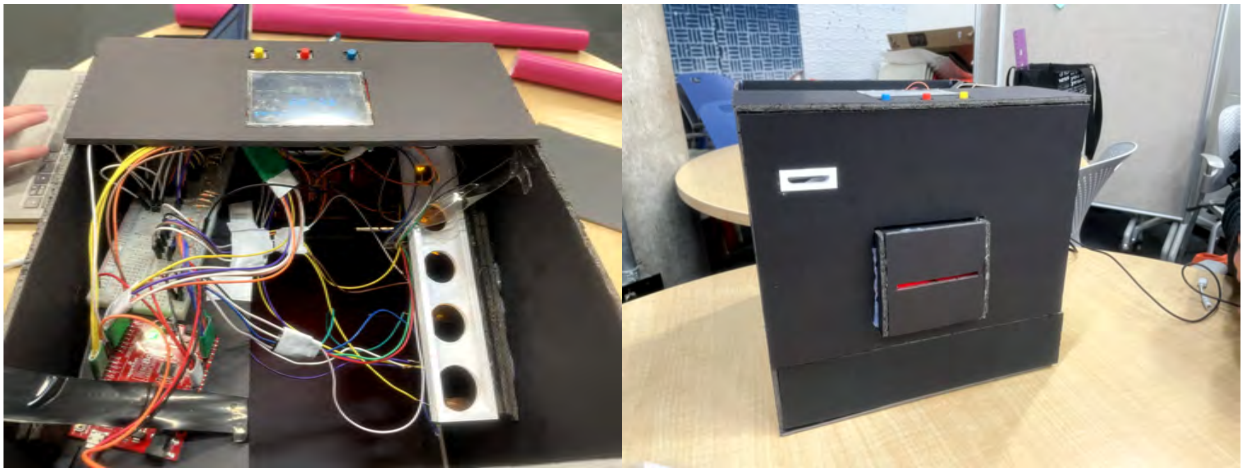

*Figure 12.* Side by side of the Final Piggy Bank (Front and Inside View). Chung, A

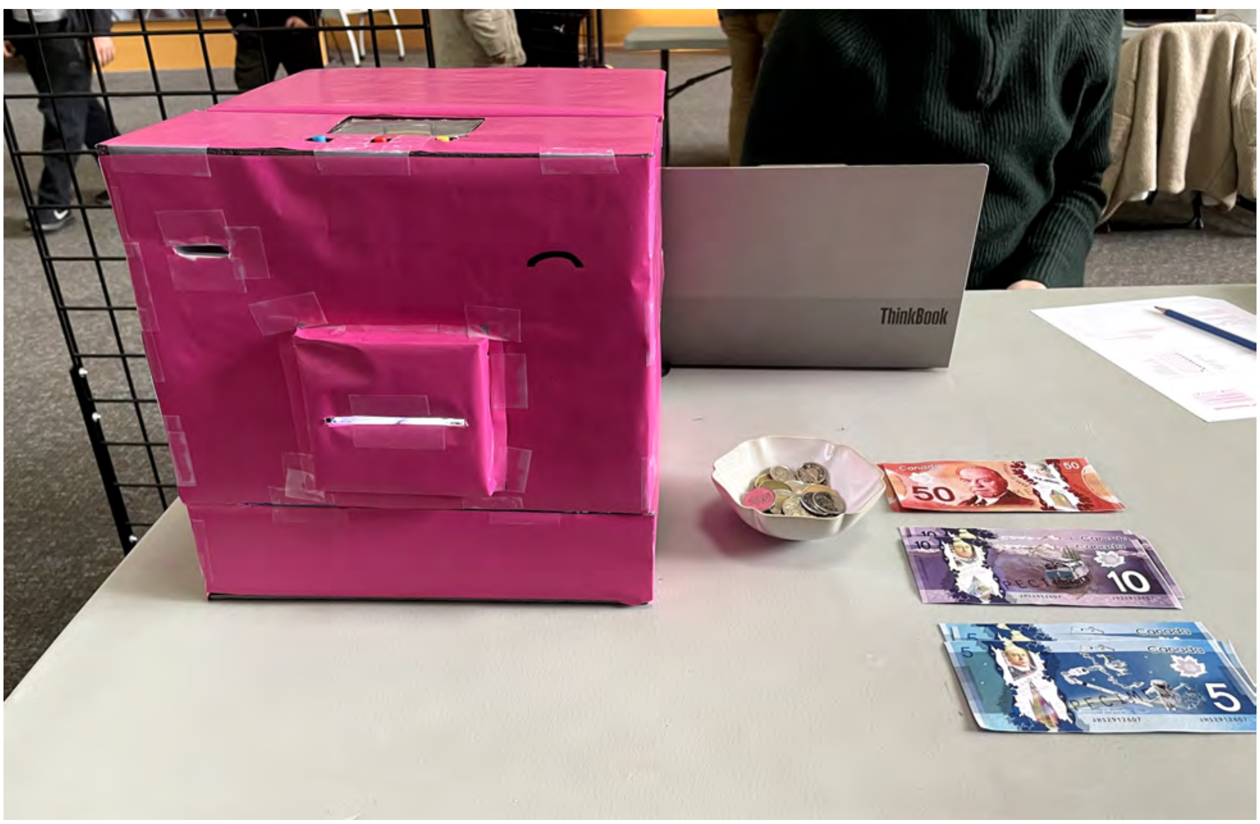


*Figure 13.* Final Setup in the exhibition. Chung, A

# Final Code

## Arduino

We used two separate Arduino Unos. One is allocated for the LED matrix and colour sensor, while the other is interfacing with all other sensors as well as communicating with Processing.

### Bill Detection

To detect the bills, when a bill is inserted, multiple colour readings are stored in a buffer. When the buffer is filled or the bill is no longer within range of the sensor, it calculates the colour using a mix of comparison statements and hard-coded values. It then determines the proper value and sends it to the main Arduino board, where it adds that amount to the total money saved.

The main Arduino board calculates every other sensor value. The screen, buttons, photocells, and LEDs are hooked up to it.

### Coin Detection

To count the specific value of coins, the coins travel down a 3D-printed ramp and falls through their respectively sized hole. As they fall through their hole, a photocell below detects a decrease in brightness. That decrease is then read by Arduino and adds the value of the coin to the total amount of money. To prevent duplicate readings, we have implemented a small cooldown timer and a requirement that the sensor must be unobstructed before it can count a coin.

### Buttons

We coded buttons to only trigger upon release. This is a small but crucial feature to limit the potential for accidentally double-pressing them.

### TFT Screen

Refreshing the entire screen takes a long time. To combat this interaction latency between putting in a coin and the screen reflecting that value added, we implemented refresh zones. This function only overwrite pixels that are constantly changing, like the savings goal and total amount saved.

## Processing Integration

Processing was used for the sound library to help feedback, by providing a sound for the following conditions:

1. When a coin is dropped into a slot
2. When a bill is inserted into the snout
3. Buttons are pressed
4. A goal is reached

# Final Code - Screenshots

## Arduino

### Goal Detection

```
// Checks if the goal has been reached
void checkGoal() {
  // Unlock drawer if you reach your goal
  if(totalMoney >= sGoal) {
    servoPos = 0;
    if(goalReached == false && sGoal != 0) {  // Only triggers if goal has changed
      Serial.println("A4");
      showCongratulations(true);
      goalReached = true;
    }
  }
  // Lock drawer if the goal has been set
  else if(sGoal != 0) {
    servoPos = 90;
    if(goalReached == true)  // Only triggers if goal has changed
      showCongratulations(false);
    goalReached = false;
  }

  if(prevServoPos != servoPos) {  // Only triggers if servo has changed
    servo.write(servoPos);
    delay(500);
  }
  prevServoPos = servoPos;
}
```

*Figure 14.* Screenshot of Code Detecting if Player has Reached Goal (2023). Nielsen, M

### Bill Detection

```
void checkBills() {
  delay(10);  // Ensure sensor readings have time to change

  // Step 1: Read raw value
  unsigned int red= RGB_sensor.readRed();
  unsigned int green= RGB_sensor.readGreen();
  unsigned int blue= RGB_sensor.readBlue();

  // Step 2: Check if bill is present
  if(blue > 1000 && green > 1000 && index < 150 && red > 800) {
    values[index][0] = red;  // Add values to buffer
    values[index][1] = green;
    values[index][2] = blue;
    index++;
  }
  else if(index != 0) {  // Store at least one reading
    faults++;   // Bill is not present
  }

  // Step 3: Calculate value after buffer is filled or bill is no longer present
  if(faults > 10 || index >= 150) {
    readValue();  // Calculate value and send to other Arduino

    // Reset values
    faults = 0;
    index = 0;
    for(int i = 0; i < 200; i++)
      for(int j = 0; i < 3; i++)
        values[i][j] = 0;
  }
}
```

*Figure 15.* Screenshot of Code Detecting Bills and Saving Colour Readings Into Buffer (2023). Nielsen, M

### Button Detection

```
void checkButtons() {
  btnPressed = -1;  // Reset button value

  // Iterate through each button
  for (int i = 0; i < numBtns; i++) {
    btnValues[i][0] = digitalRead(btnPins[i]);

    // Ensure action executes on button release
    if (btnValues[i][0] == 0 && btnValues[i][1] == 1) {
      btnPressed = i;
      Serial.println("A3");  // Send sound request to Processing
    }
    btnValues[i][1] = btnValues[i][0];  // Save value for next cycle
  }

  // Execute actions if button has been pressed
  switch(btnPressed) {
    case 0:  // Add to savings goal
      sGoal += 5;
      regularDisplay();  // Refresh display
      break;
    case 1:  // Reset all values
      sGoal = 0;
      totalMoney = 0;
      showCongratulations(false);
      goalReached = false;
      regularDisplay();  // Refresh display
      break;
    case 2:  // Subtract from savings goal
      sGoal -= 5;
      regularDisplay();  // Refresh display
      break;
  }
}
```

*Figure 15.* Screenshot of Code Detecting Button Presses on Release (2023). Nielsen, M

### Coin Detection

```
// coinSlots array: 0 = raw value of photocell, 1 = brightness sensitivity,
//                  2 = timer, 3 = value of coin, 4 = ready to accept another coin
void checkCoinSlots() {
  // Iterate through each sensor
  for(int i = 0; i < numCoins; i++) {  // Check sensor values
    coinSlots[i][0] = analogRead(sensPins[i]);

    // Determine if photocell is allowed to accept coins
    if(coinSlots[i][2] + interval <= millis() && coinSlots[i][0] > coinSlots[i][1])
      coinSlots[i][4] = 1.0;

    // Determine if a coin has fallen through
    if(coinSlots[i][0] < coinSlots[i][1] && coinSlots[i][4] == 1.0) {
      totalMoney += coinSlots[i][3];    // Add to total amount of money saved
      Serial.println("A1");             // Send sound request to Processing
      regularDisplay();                 // Refresh display
      coinSlots[i][2] = millis();       // Reset timer
      coinSlots[i][4] = 0;              // Reset coin acceptance
    }
  }
}
```

*Figure 16.* Screenshot of Code Detecting Coins From Decrease in Photocell Resistance/Light (2023). Nielsen, M

# Individual Reflections

## Ningzhi

During the prototyping process, we encountered some problems in making the ramp for the coin to slide down. Since the angle of the ramp was difficult to determine, we conducted many tests, but there was still a certain probability that the coin would not enter the correct size of the hole. Also, there are some problems with the accuracy of our distance sensor, which is due to the coins falling too fast. This made me realize that even if a solution appears to be perfect at the concept and sketch stages, there are no problems that can be found without prototyping it for testing. If there is room for some extension of our project, I think it is possible to add the function of providing interest to the user for our smart piggy bank. Parents can also put a certain amount of interest in the bank in advance when setting the target amount and offer it to children at the end. I think this should be more encouraging for children to save money.

## Alessandra

The idea went through a lot of iterations. Max was the biggest contributor and took on the majority of coding and circuit building. Him and I tried many times to test out the colour sensor which was difficult since there was no consistency in controlling how the bill was inserted. In the future with more time and a bigger budget, Max and I thought of adding a belt that would take in the money. It would create consistency in how the bill will be inserted and would increase the reliability of detection. However, we did not have time to order the part due to time constraints and had to shift our focus to the bigger picture in creating something that mostly functioned.

My job was to work on iterating and creating a better design than our prototype. It was a challenge to create a piggy bank that could not just collect money but also house our Arduino, wiring, and sensors while still looking like a suitable product. Looking back with more time and resources, I would’ve loved to create a 3D model that would house the electronics better and be able to get each part printed rather than making it piece by piece physically and making adjustments if something went wrong.

# Individual Reflections

## Max

Looking back at the project, I feel like it is the best we could do with the limited resources we had. It was a multifaceted idea that involved design, engineering, and electronics to create a passable working solution. And as a group member, I performed to the best of my ability to ensure the code, ramp, and electronics were optimized. As a team, we did not synergize well. I felt like others were uninterested about the project and it reflected in their contributions from the beginning.

Regarding the product itself, I am proud of our progress from our prototype. It is smaller in every dimension, cleaner, and way more reliable. However, there's always room for improvement. As our main constraints were time and resources, if we had more of those, there are a lot of things that we would have added (see team reflection). However, our main goal was to get the project into a functional state, and I believe we accomplished that.

This project enabled me to dive deeper into electronics than ever before. I've always enjoyed working with Arduinos and Raspberry Pi's but never really had the time to focus all my attention to create something worthwhile. I refined my soldering, 3D modelling, breadboarding, and coding skills and learned new areas of electronics such as level shifting, the SPI interface, and the versatility of photocells. Overall, this was a fun project (albeit a tad difficult) that helped evolve my electronics skills.

# Individual Reflections

## Len

In the process of making the prototype model, we encountered some troubles. First one is the size of the piggy bank and the allocated area of each part. Although the draft is well drawn, it is still difficult to control these areas when making the physical model, because we do not know how much area our parts need to occupy. Secondly, it is difficult to determine the angle of the slope where the coins slide down, so we have conducted lots of  tests for this problem. Although the larger coin successfully slid into the corresponding hole, the other three smaller coins still have a certain probability of not entering the correct size hole. The conclusion drawn may be related to the speed of the coin sliding and the friction of the cardboard. Thirdly, there are some problems with the accuracy of the distance sensor. When the coin falls, there is a certain probability that it cannot be detected. This should be caused by the coin falling too fast.

This made me realize that the physical model is very important since even if the concept and sketch stage are looked good, without the test of prototype, we will not find any problems of it. If our project has room to expand, I think it is possible to add intelligent voice function to our smart piggy bank. When the child puts cash into the piggy bank, the piggy bank will emit beautiful music and friendly words, such as, well done, there is xxx dollar left from your target amount, persistence is victory, come on! I think this will make the piggy bank more interactive with children.

# Team Contributions

**Max:** **Lead Coder and Circuit Design**
**Alessandra:** **Product Design and Research**

# Team Reflection Summary

***The building and execution of the design was a huge challenge to overcome. There were a lot of things that had to be tested and reconfigured throughout the whole process and a lot of adjustments had to be made during the design process. While we did not come out with our original hopes, with more experience, time, and knowledge there is a lot of improvements that could be made that would improve the design and form it into real product.***

***Considering the time and budget constraint, we would use higher end materials to turn this into a real working product for the market. Rather than creating the physical model from scratch entirely, we could've created a 3D model using OnShape and get everything 3D printed or laser cut.***

***Another thing our group thought about to improve this project is creating a stronger code, that can create more interactivity with users and that better detect given inputs. Especially with the colour sensor which is very finicky and was inconsistent at reading values. We considered that if we could control with how the money being inserted, it would read the bill values better.***

***A list of things we could add/improve:***

- ***More suitable sound effects***
- ***Animation for each bill/coin inserted***
- ***Animation for completing goal***
- ***Refined the bill detection***
- ***Added motorized system to accept bills***
- ***Redesigned the UI to make it more child-friendly***
- ***Added physical icons to the buttons***
- ***Make the enclosure smaller and a more organic shape***

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