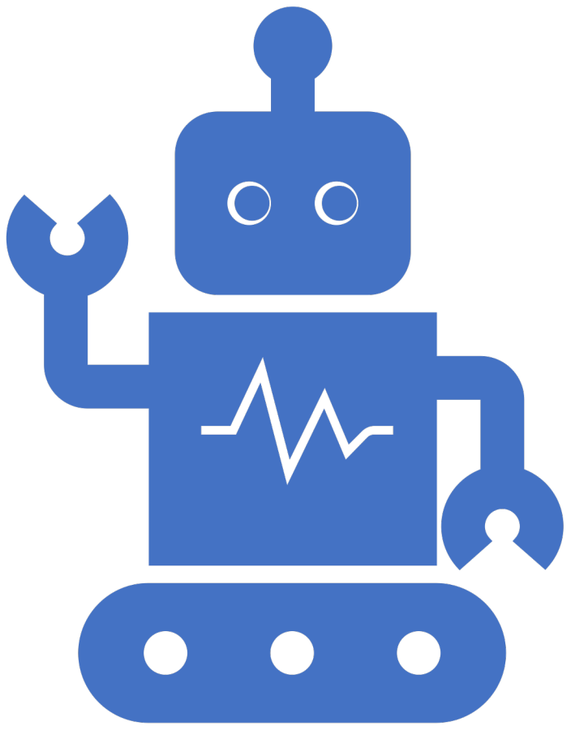


ROBOTICS: TEACHING EQUIPMENT PROJECT

PHASE I

NOND PHOKASUB

Research

COURSE OUTLINES

Source: https://school.dek-d.com/blog/kidcoding/computationalthinking/หลักสูตรวิชาหุ่นยนต์;

Gigo allows for students to build robots and objects through smaller pieces.

ป1 - Structure - gigo → robot part study

ป2 - Basic Structure - Block Wood

ป3 - Advance Structure - Block Wood

ป4 - อยู่พื้นฐาน - gigo

ป5 - Robot Building - Lego Mindstorms ; Visual Programming (Simple)

ป6 - Robot Building Automatic ไม่โครงสอนใหม่

Robot programming ภาษาซี - Arduiono

* Mechanic (Structure)

Lego Mindstorms allows students to build a robot and use software to code the robot.

This allows practice for structure and coding through simple block code.

Price: around 7000 THB

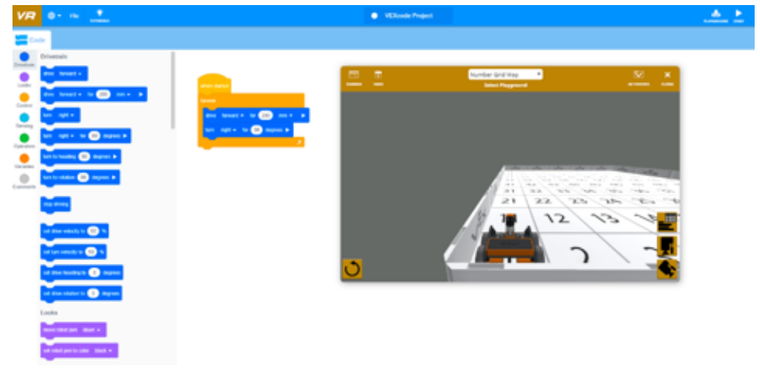
Programming language and with structure of robot.

Younger Audience

- Make X Block Coding App ; Makeblock

Makeblock coding uses block code (similar to coding in Robotics Course at school.

- Vex VR online



Vex VR online allows students to use block code and simulate/test the robot with that code virtually.

Different Robot Parts and application x40 hrs

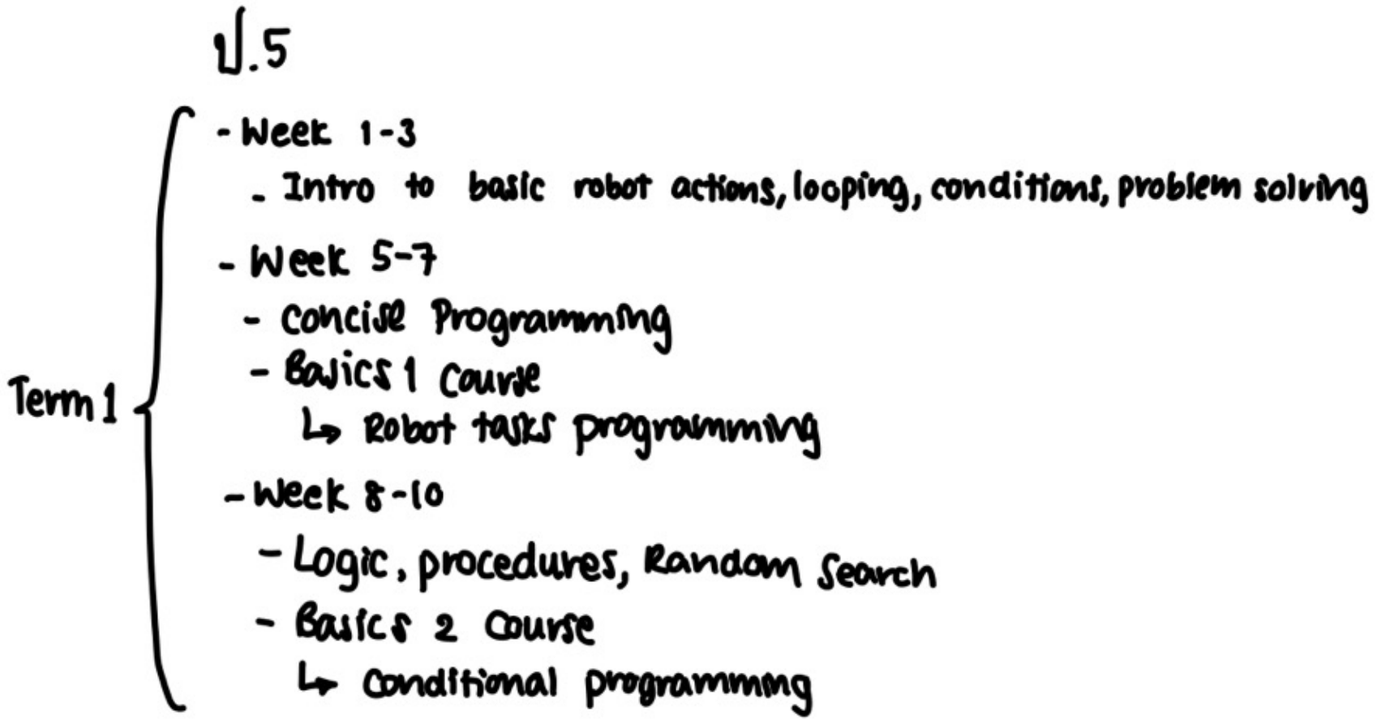
Design + Coding x20 hrs

Coding Robot to complete task x20 hrs
High Level

Build + code Robot for competition x20 hrs

Source: https://www.pratchatorn.ac.th/news/robot/ ; Teacher from Bangkok Patana School ; https://www.vexrobotics.com/vexcode-vr ; https://mblock.makeblock.com/

COURSE OUTLINES



Source: TSIS ; https://www.robomindacademy.com/navigator/courses

https://www.robomindacademy.com/navigator/courses
This website is used to teach at this school. Students enter into the website and they are presented with an introduction and then courses. Basic 1 includes basic robot programming tasks. Basic 2 includes conditional programming tasks.

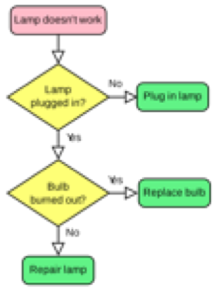
COURSE OUTLINES

Q: Course, Programme, teaching, students

A: ป1 ... ป4 ป5 ป6

↓ flowchart for logic

↳ use code blocks e.g. Scratch, iRobot
↳ build structure themselves - most are pre-built - just need to attach + follow guide
↳ solve problems, tasks
↳ sensors, bluetooth



Q: Aims

A: improve flowchart skills to build logic ⇒ move to code
Basics important to teaching

Q: Type of teaching + techniques

A: ↳ Activities
- coding games – code combat, code.org, algorithm, block code, microbit → show + do

Q: Problems in school; obstacles

A: 1. Students not understand english in code (ป6 no longer a problem as experienced to code language from previous years)
2. Thinking process + algorithm not clear as flowchart (start/base) not clear ⇒ error in robot
3. Hardware expensive

Teachers need to teach + design activities

Teaching kids Methods
↳ 1. Powerpoint
↳ 2. Clips
↳ 3. Code

Physical learning could help.

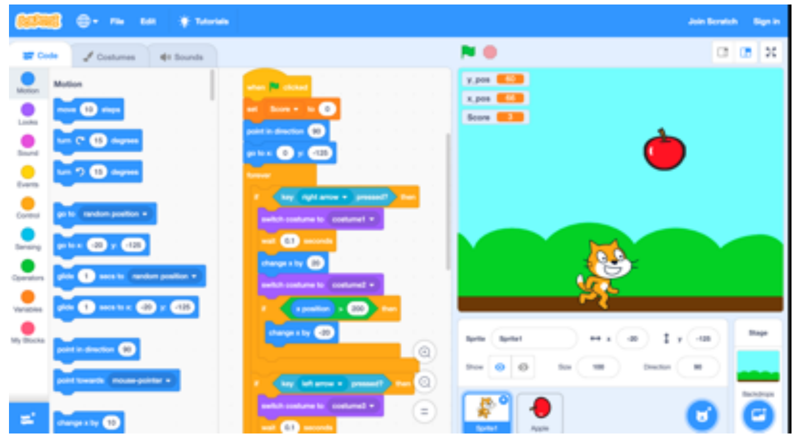
Q: What kids enjoy

A: Competition (which help kids) ⇒ incentive, innovate, motivate
Robot actually working
games

Q: Competion

A: At Paradise
Set by Robotic Company e.g. Inex ฯลฯ microbit
[illegible]
only selected students

<u>Scratch</u>



Scratch is a programming software which uses block code to solve tasks. This allows students to develop coding skills visually with simple language and then see the results of their code in a simulation.

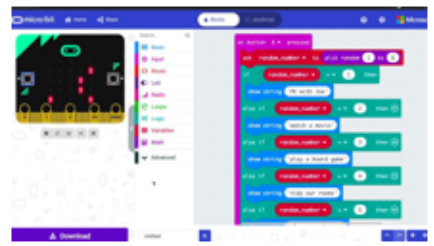
<u>iRobot</u>

iRobot is a coding software which uses simple symbols to allow students to develop logic and learn simple coding.

<u>Code.org</u>

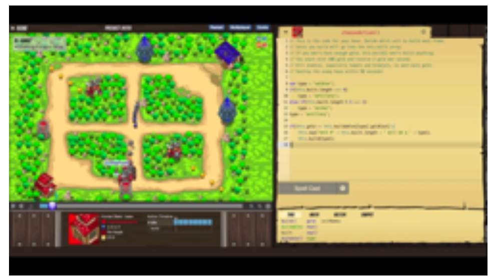
Code.org is a website that allows students to complete tasks through simple block coding.

<u>Micro:bit</u>



Microbit uses block code to allow students to program a robot.

<u>Codecombat</u>



Codecombat is a game that allows students to develop coding skills. ป6

Source: Teacher from Lasalle School ; https://en.wikipedia.org/wiki/Scratch_(programming_language) ; http://www.nattapon.com/2019/07/เกม-scratch/ ; https://en.wikipedia.org/wiki/Flowchart ; https://edu.irobot.com/ ; https://www.commonsense.org/education/website/codeorg ; https://microbit.org/news/2020-05-09/microbit-at-home-activity-picker/ ; https://www.robotsiam.com/product/198/microbit-smart-robot-car-v2-0 ; https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DIFvfZiJGDsw&psig=AOvVaw3tfVxfJO1hh1JsafvqMrYl&ust=1624184525618000&source=images&cd=vfe&ved=0CAsQjhxqFwoTCLig8oC9o_ECFQAAAAAdAAAAABAD

QNA

Q: If I help, what do you want to help

A: Help with group prepaing for competition

Other Problems

↳ Still using same activity/content
- follow straight line
- need other content

PID language

Q: If collabrate, what can we do

A: Need for more specialists

Help as a ที่ปรึกษา competitions

Help build/design model to teach

use for other complex algorithms

now cannot do chess board robot track (courses for robot)

Q: Problems in other schools

A: 1. No budget / Resources
2. Teaching equipment / aids
3. Problems with teaching, kids lack interest

Problems:

Small school	Medium School	Others
No Budget	Teaching equipment	Lack of interest Teaching

using base

build base

ป4 most problems

ป4 not understand

ป5 understand

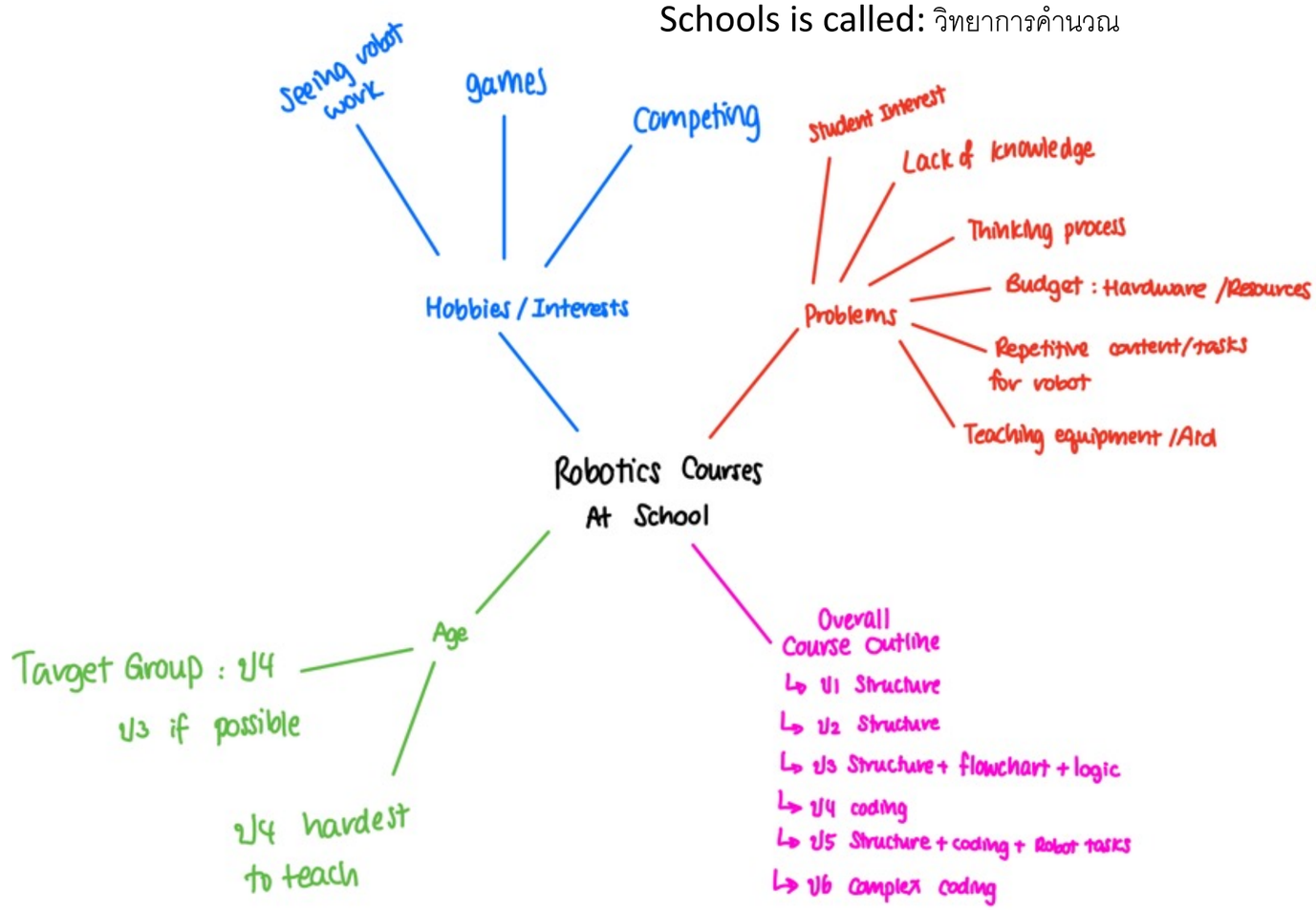
unplugged module

building logic ป5 ม flowcharts

Source: Teacher from Lasalle School

BRIEF SUMMARY

Robotics Course in Thai Schools is called: วิทยาการคำนวณ



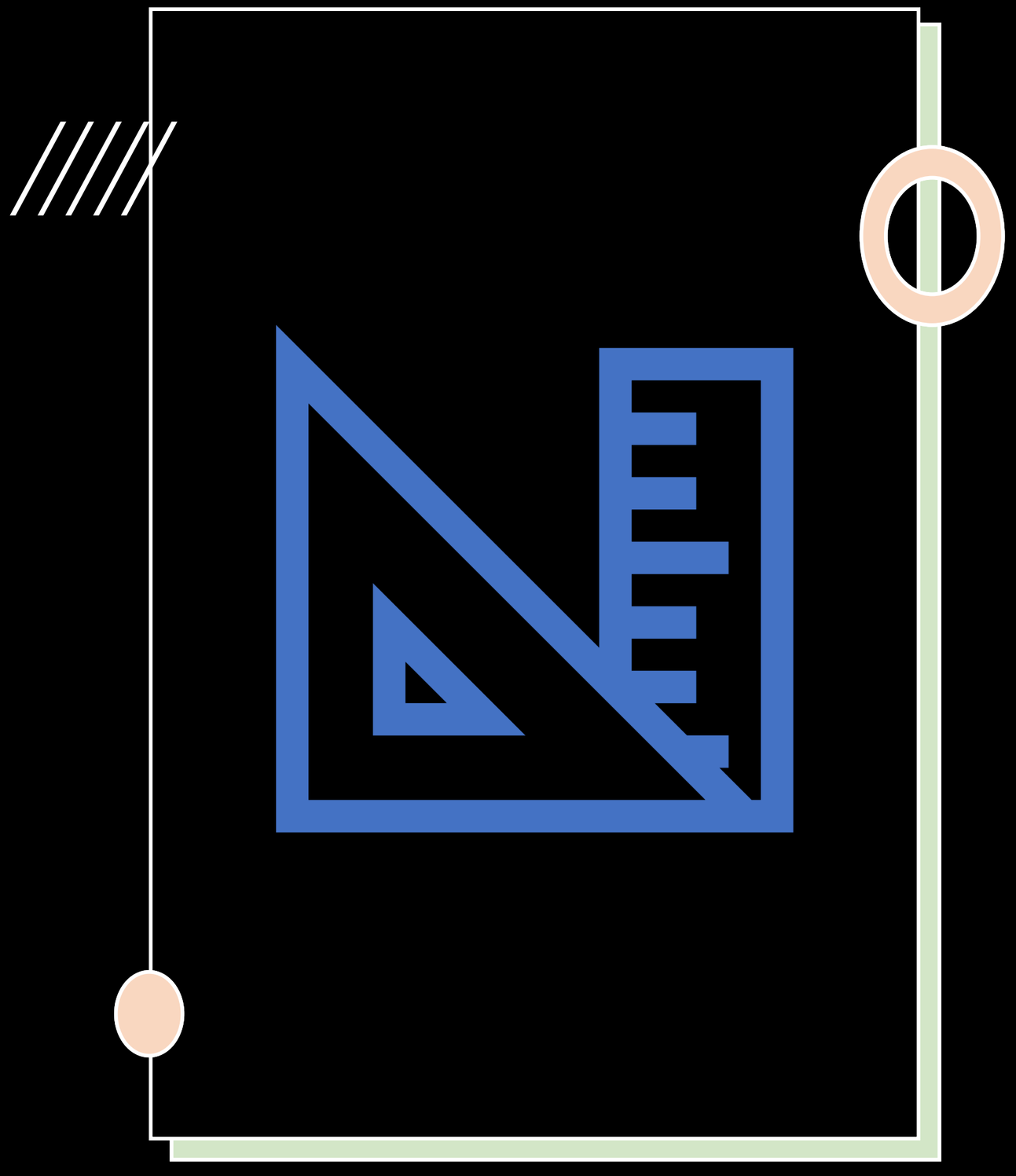
SPECIFICATIONS

	Criteria	Specification
1	Aesthetics	The product should appeal to the user and each component needs to work efficiently.
2	User	The product should satisfy user's interest and gain user's interest.
3	Function	The product needs to be efficient in building logic and allow the user to interact successfully to build robotic related skills.
4	Environment	The product needs to be efficient and easy to use in a school and safe to the user.
5	Materials	The product needs to use strong materials, which are suitable for the user, and they need to be easy to find and supply at minimal cost.
6	Manufacture	The product needs to be easy to manufacture as a prototype and as a full product by the school.
7	Cost	The product needs to be at minimal cost as budget is a problem for robotic courses.
8	Time	The product needs to be designed and manufactured before the end of summer 2021.

(platform used : Notability)

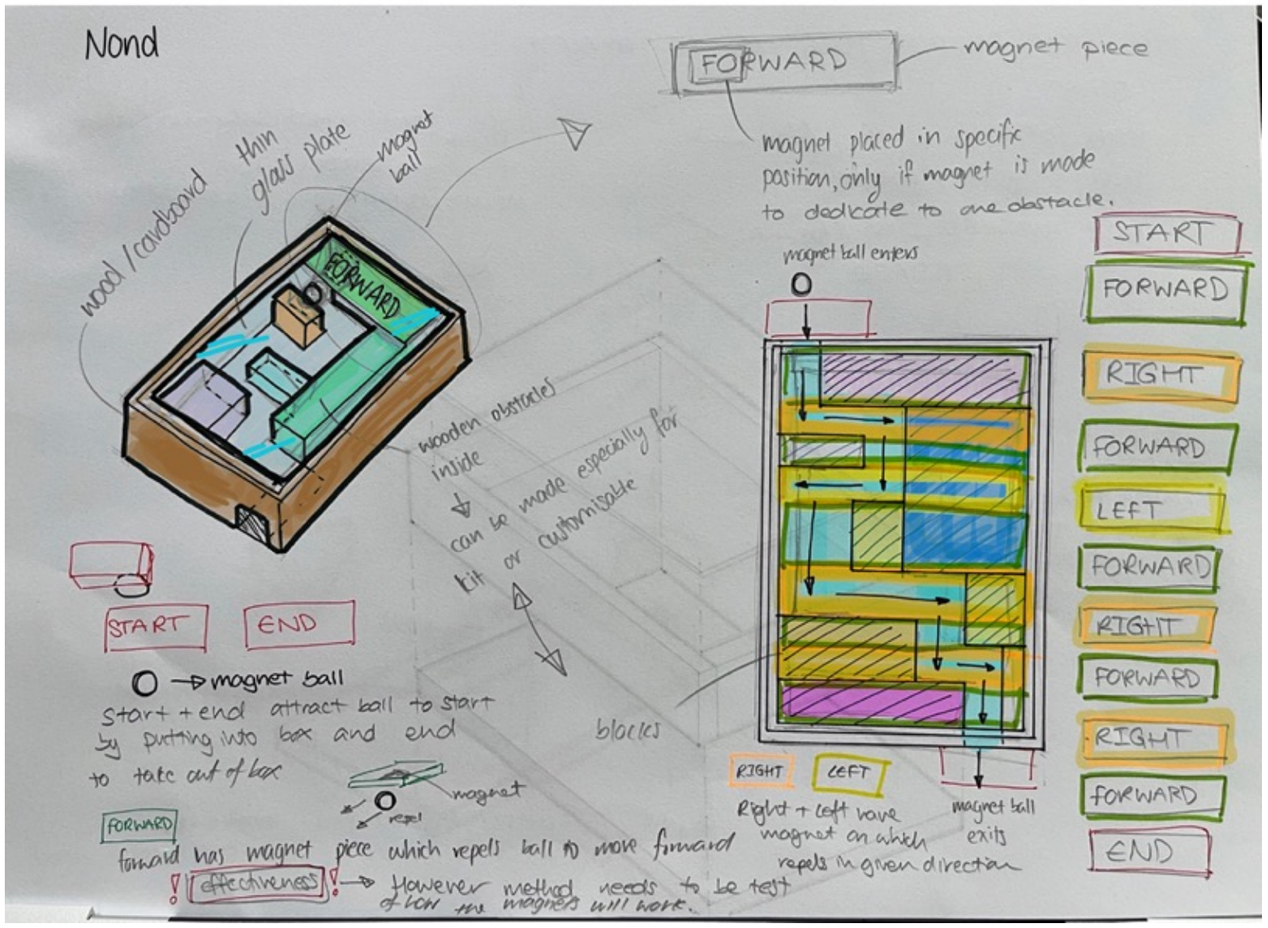
I think the problem that I need to solve is the lack of equipment that can be used to teach younger students. The product I need to design needs to build logic and introduce robotics to a younger audience. I think a product that can solve and add efficiency to teaching is a physical product that is 'unplugged'.

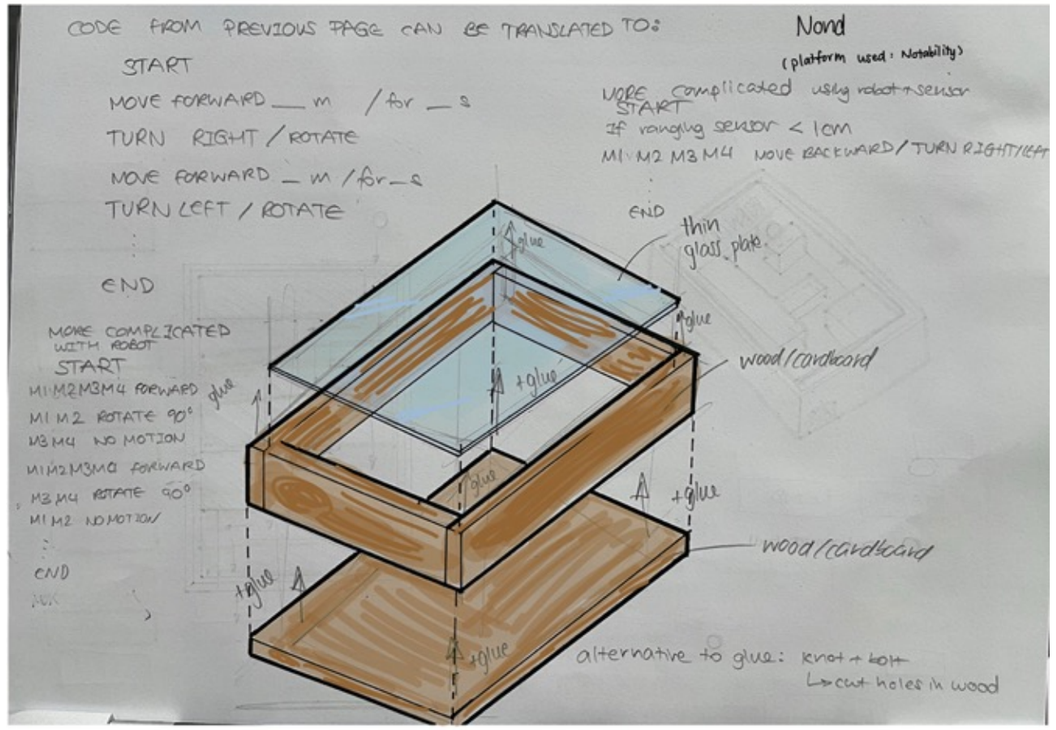
DESIGN IDEAS

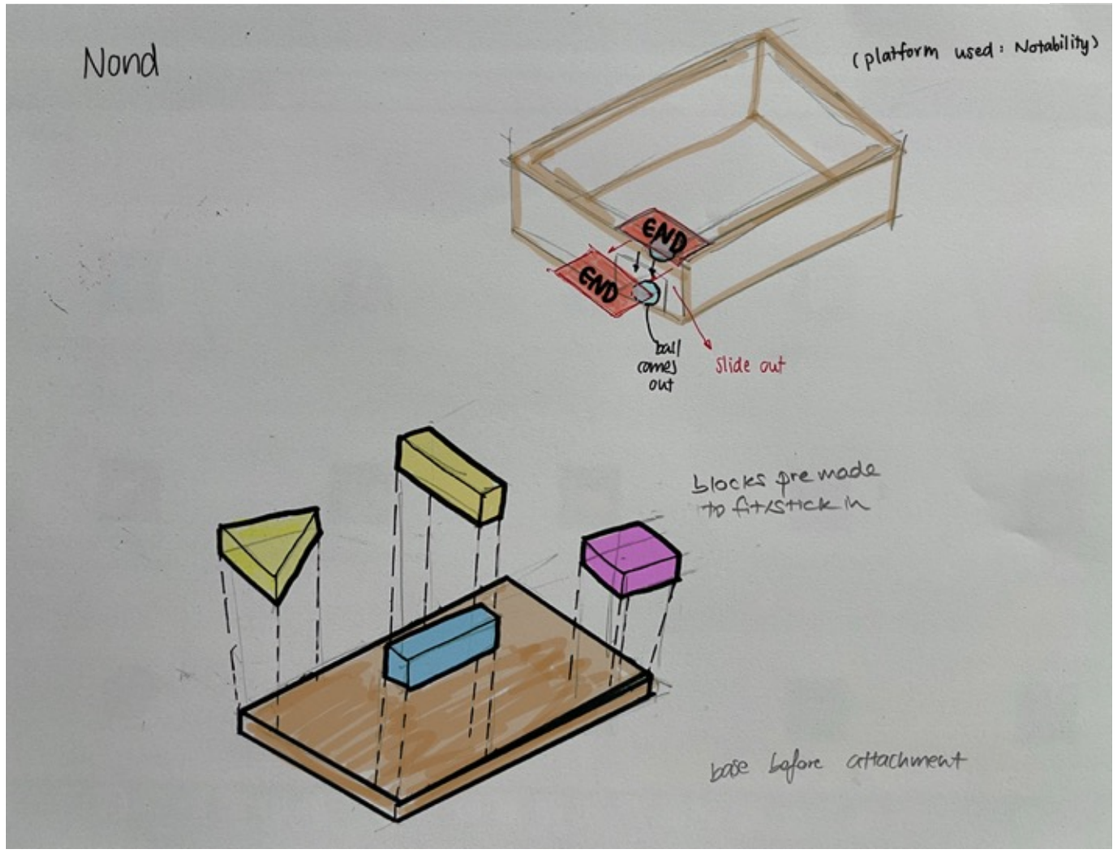


DESIGN IDEAS

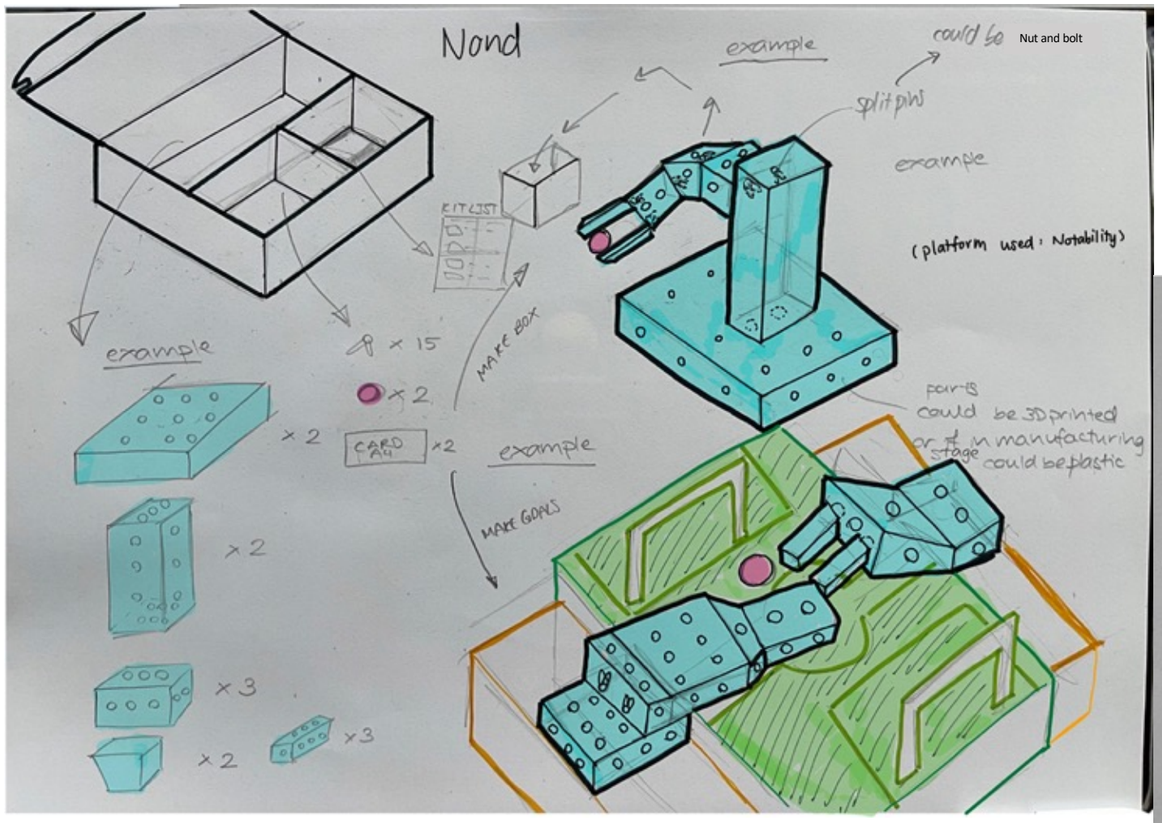
(platform used : Notability)

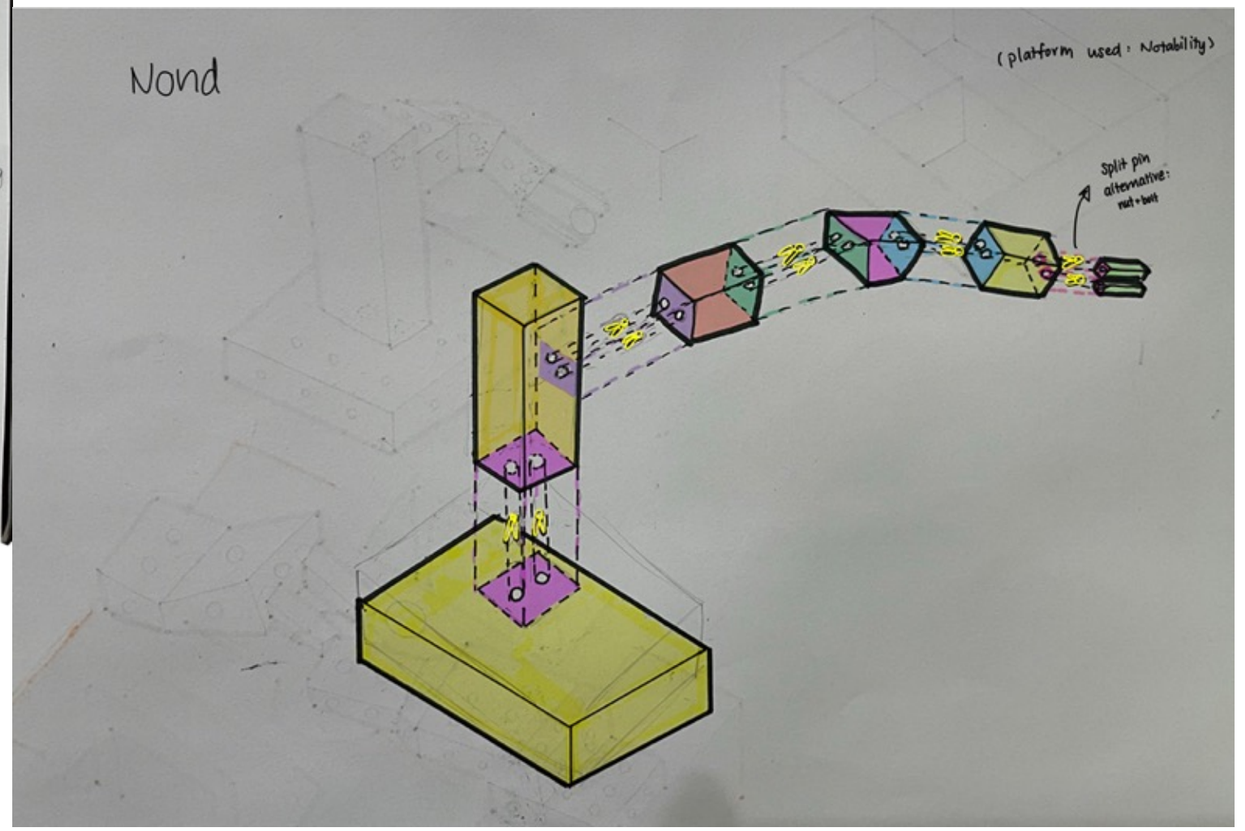




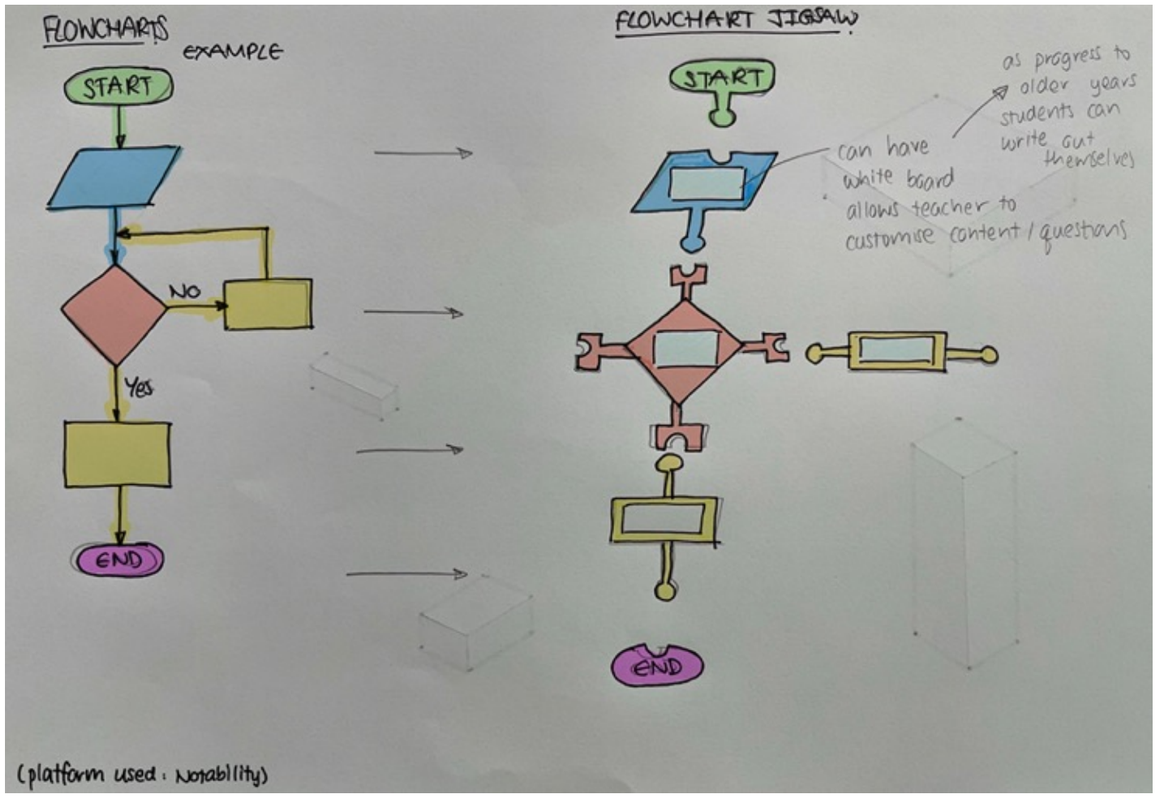


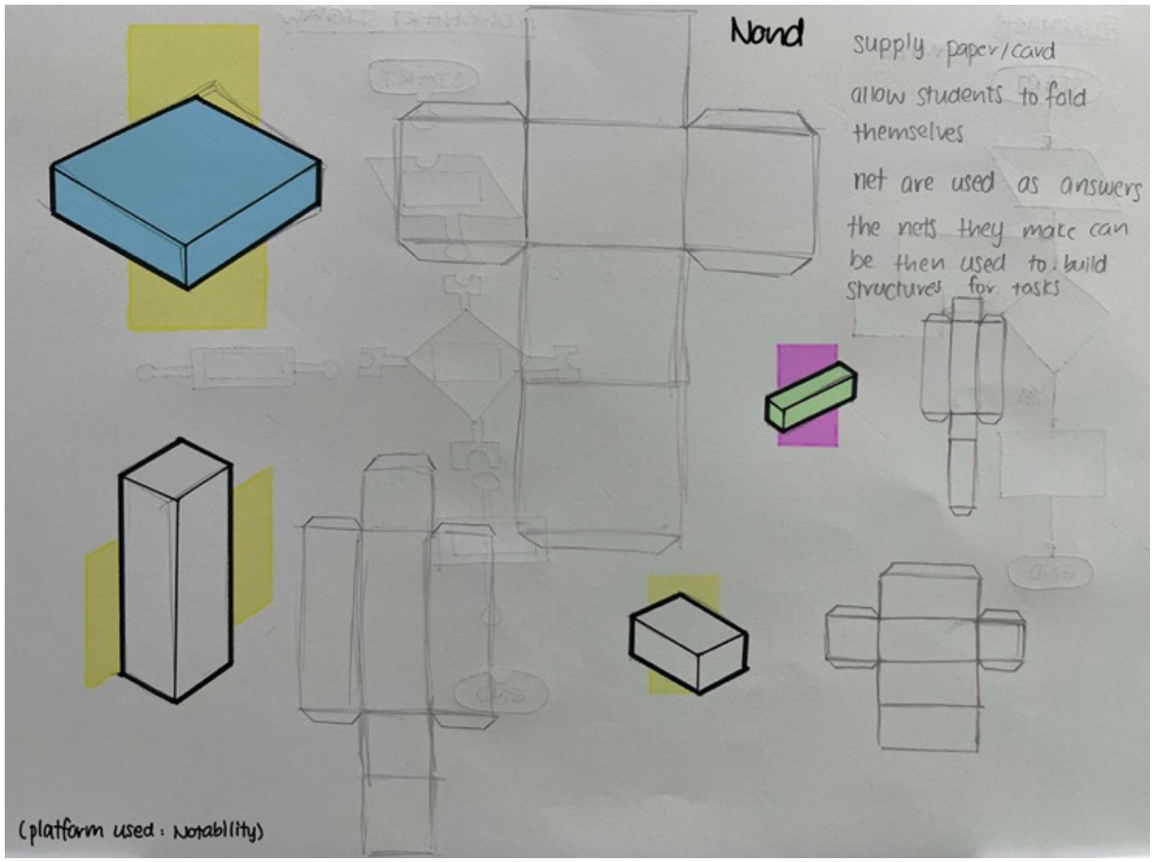
DESIGN IDEAS





DESIGN IDEAS

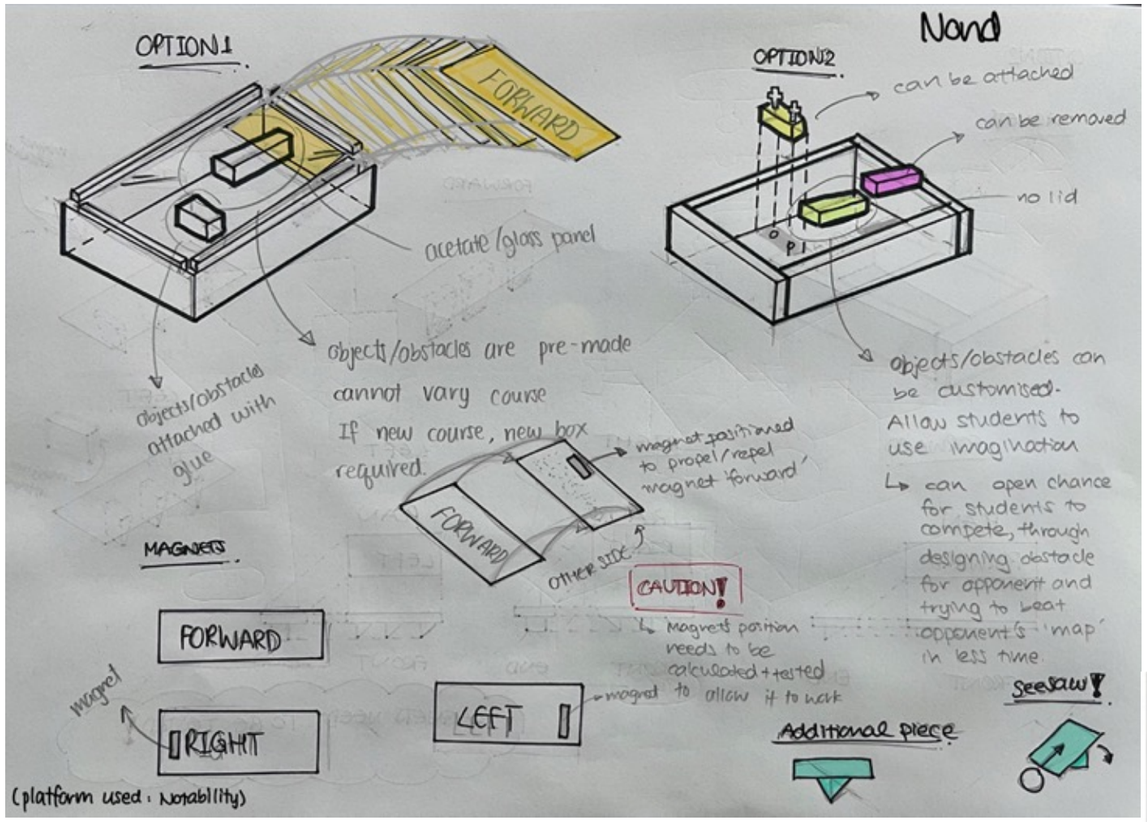


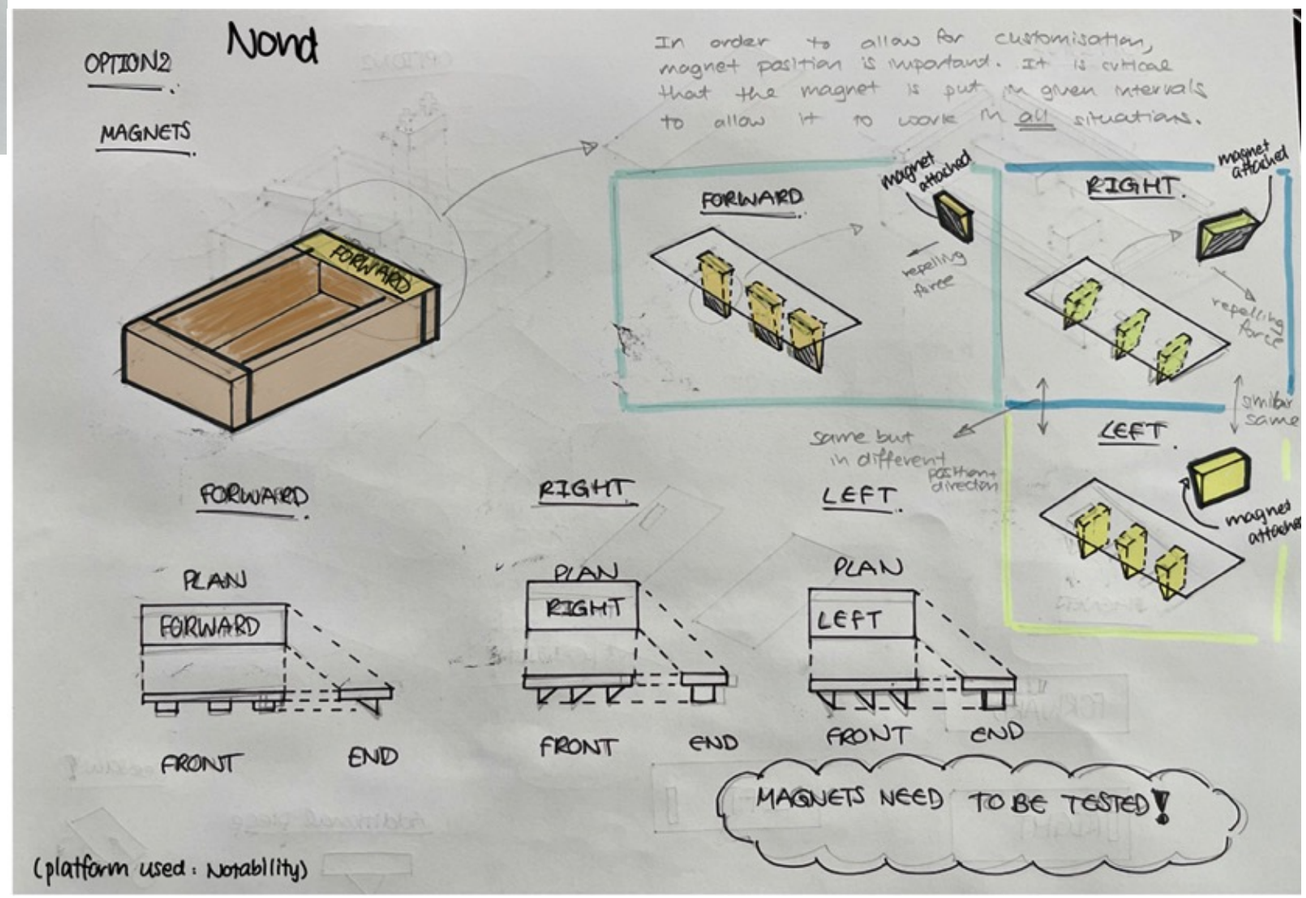


FLOWCHART ACTIVITY

- Students can start with mapping out simple processes in a flowchart form, for example, their alternative decisions to their house.
- Students can then use the flowchart jigsaw to solve problems and tasks set by the teacher. The teacher can write the different parts of the flowchart symbols on the whiteboard on each piece of jigsaw. Some parts may be false statements so students must use knowledge and logic as well.
- After the previous tasks, students can use their own flowcharts and design them for their robot task.

DESIGN ITERATIONS





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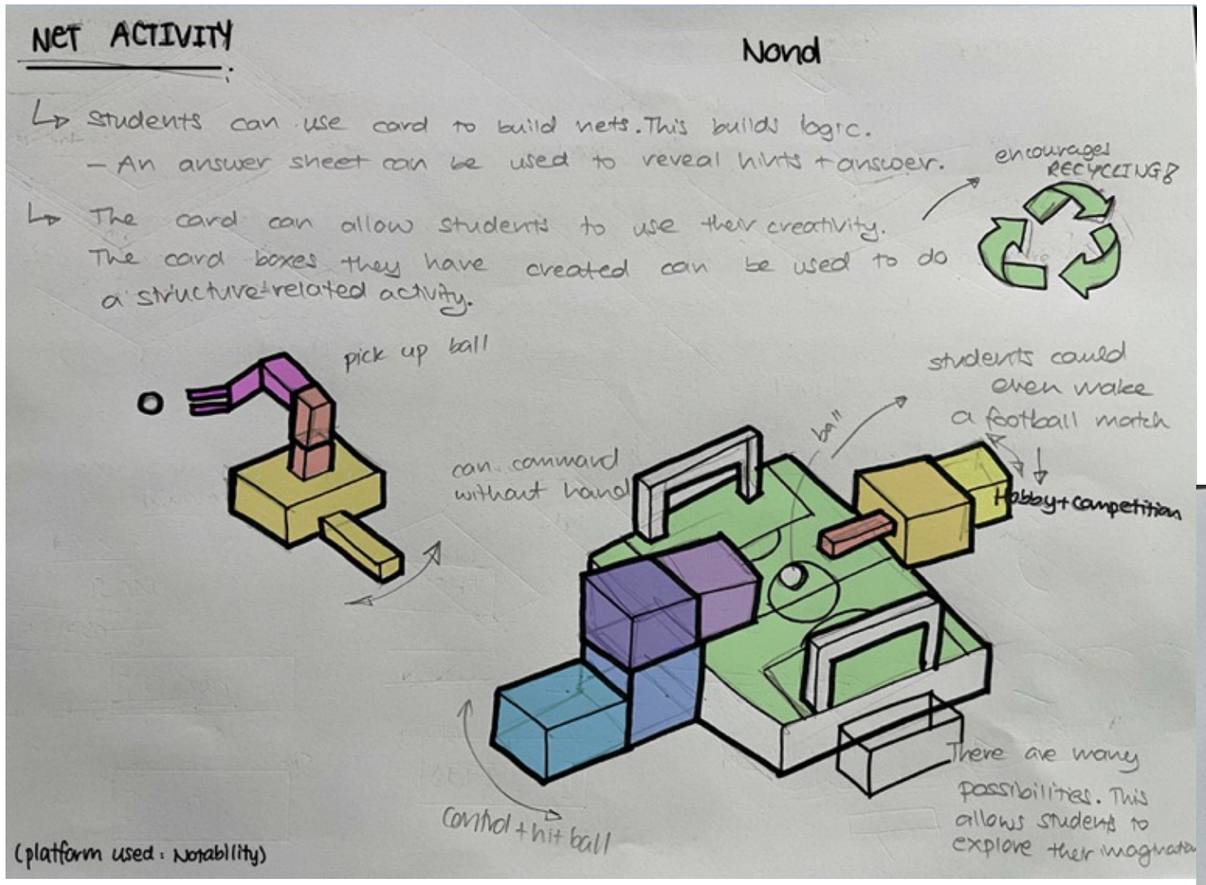

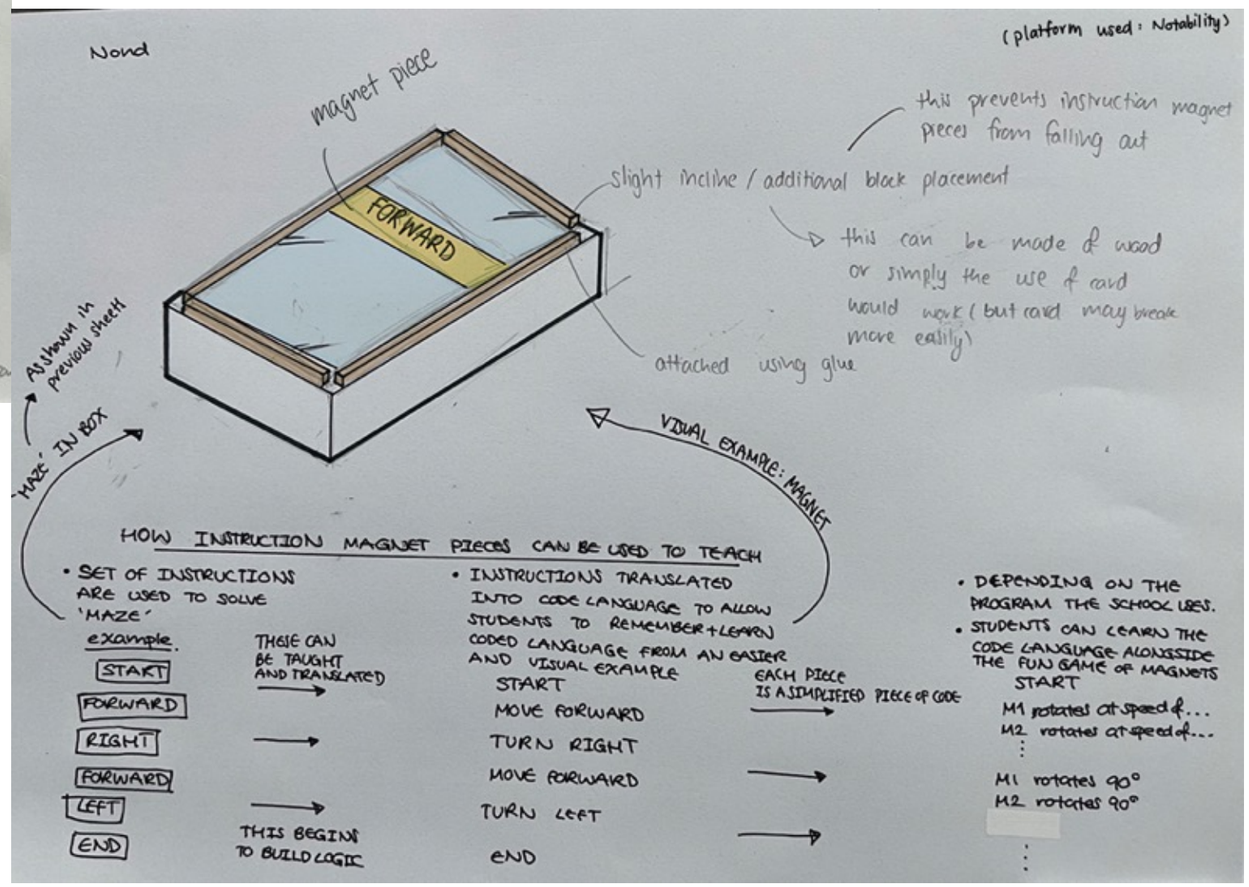

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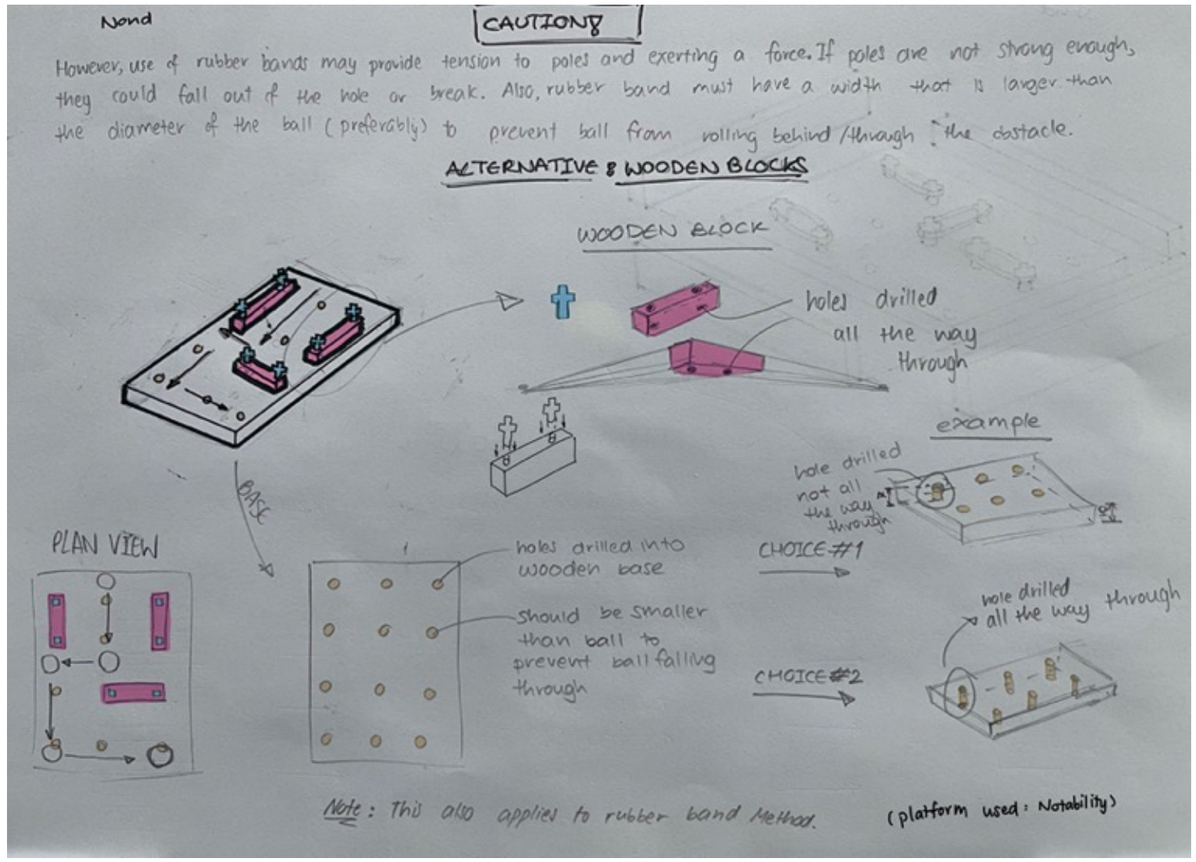
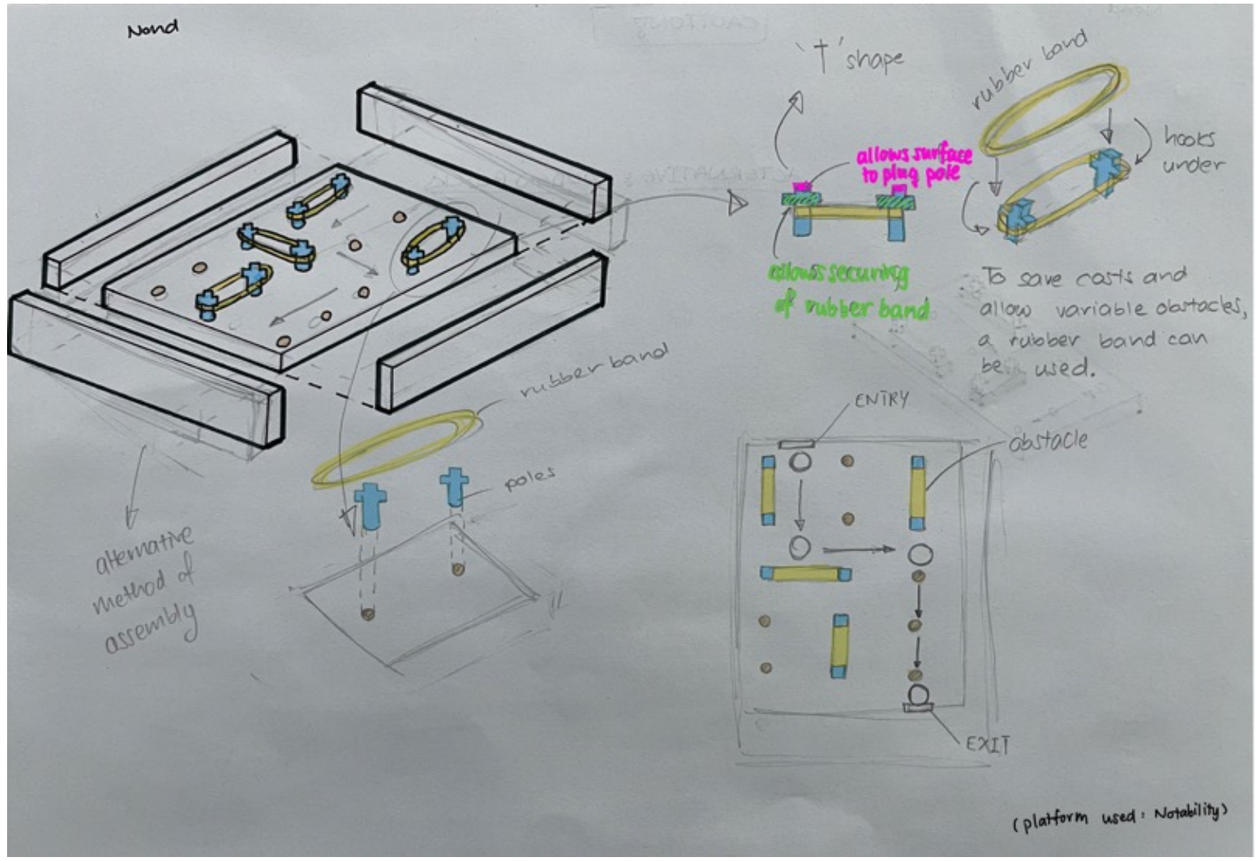
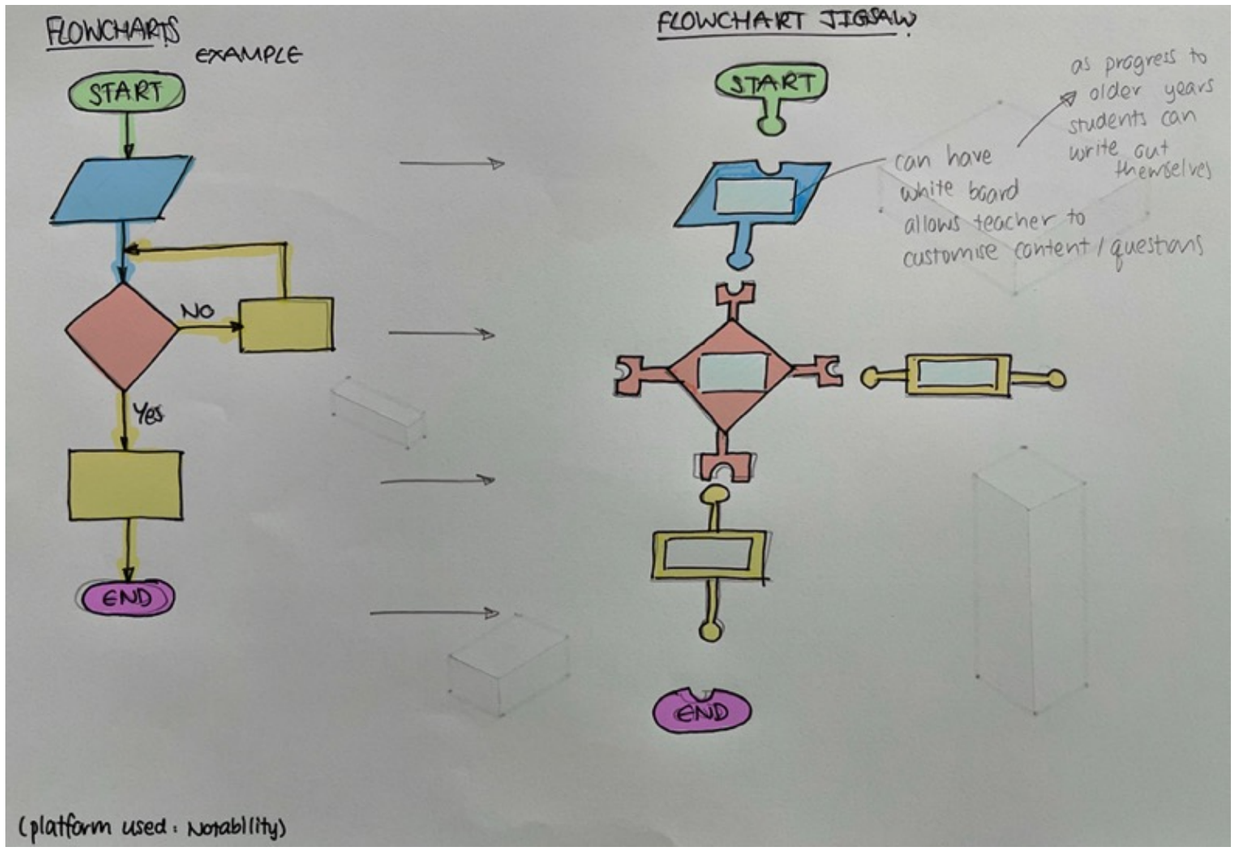


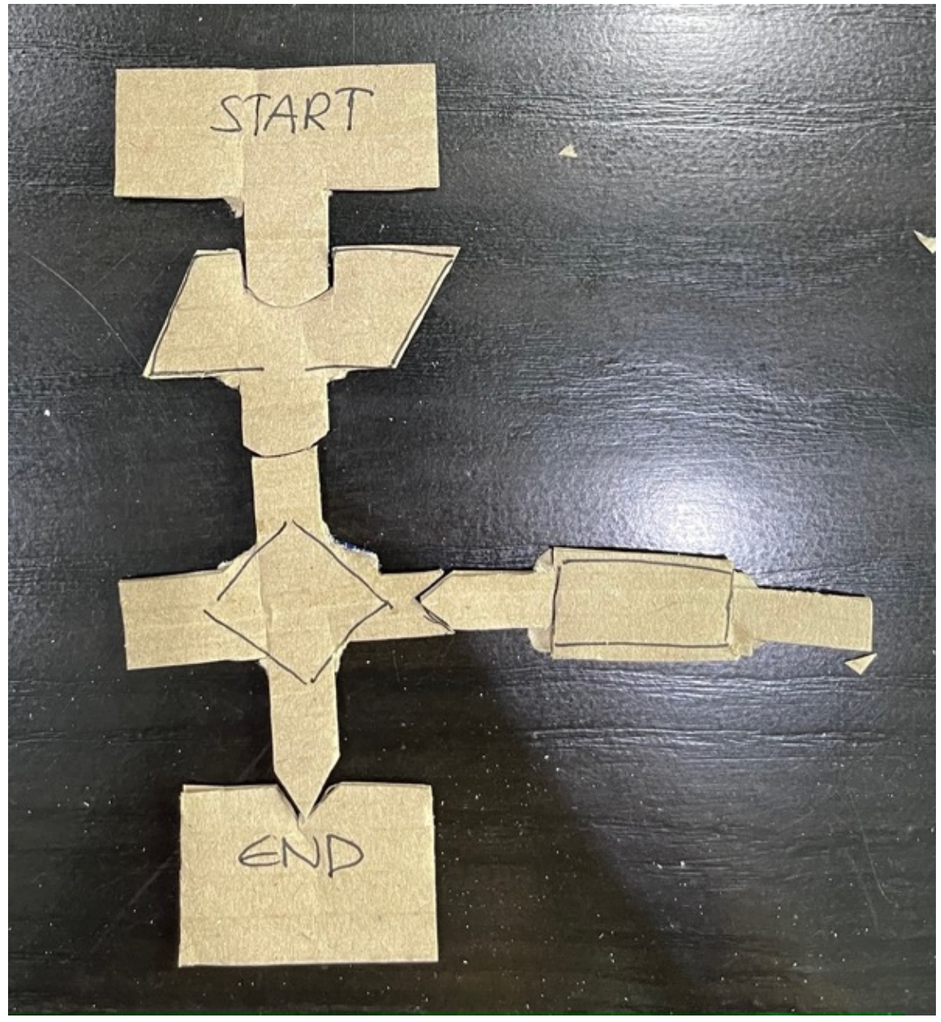


Testing

LOW FIDELITY MODELS

FLOWCHART ACTIVITY





Findings:

I think that the flowchart jigsaw is an effective way of bringing the important concept of a flowchart with a jigsaw (an aspect that could attract interest). However after prototyping with a low fidelity model, there are a few problems that arise.

1) The product is hard to make as a low fidelity model.
2) The joints are not effective in attaching.
3) The whiteboard may be hard to attach and hard to find.

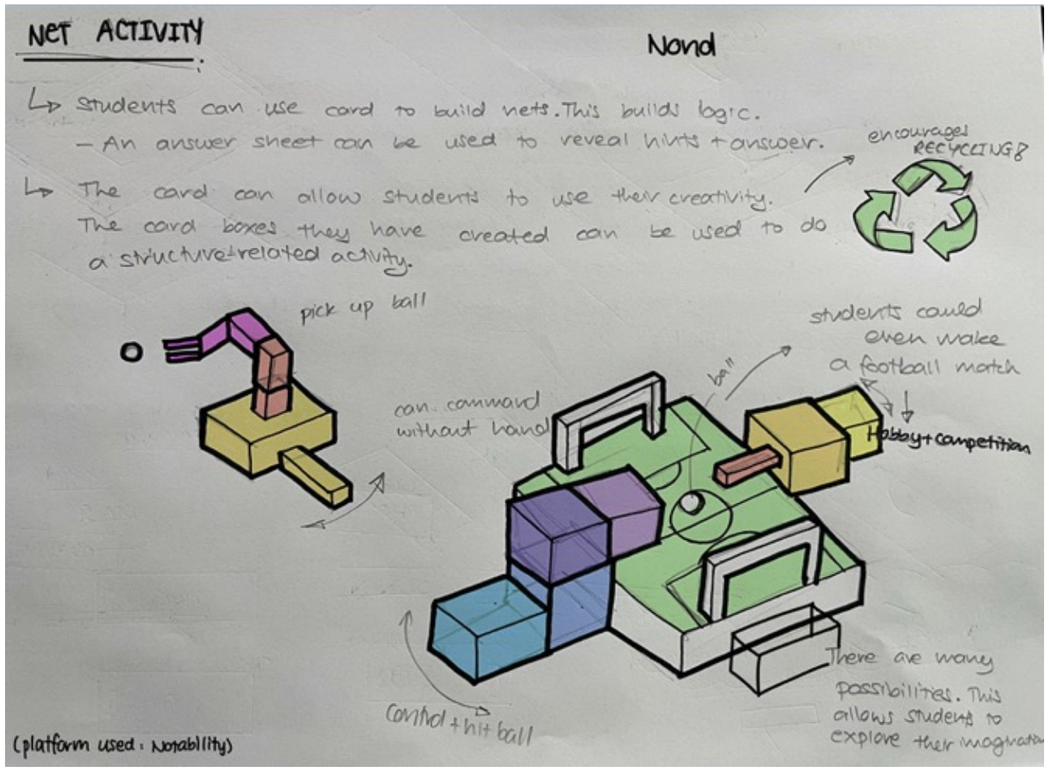
Overall, I think this product may not be efficient and I think it may need a redesign or it may not be used.

Efficiency

Budget-wise

LOW FIDELITY MODELS

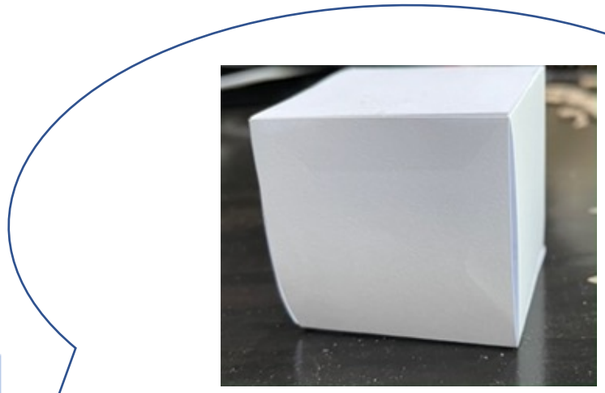
NET & APPLICATION ACTIVITY

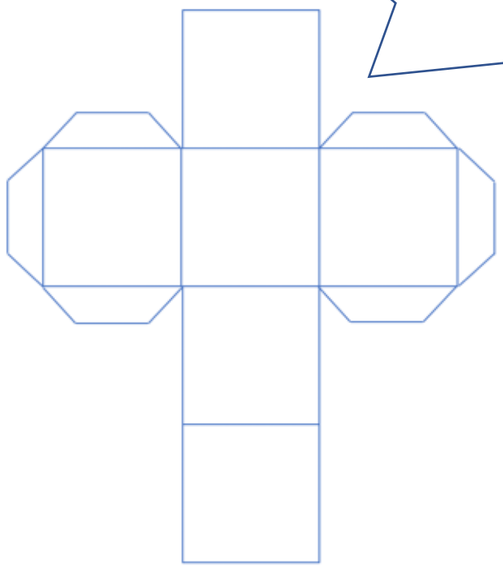


I think that the Net & Application Activity is a good idea to develop net skills and creativity. The use of nets, I believe, do not appear many times in the school syllabus, so I think this net exploration can develop logic. The connection of these two activities allows students to use their creative skills and have fun whilst also recycling paper.

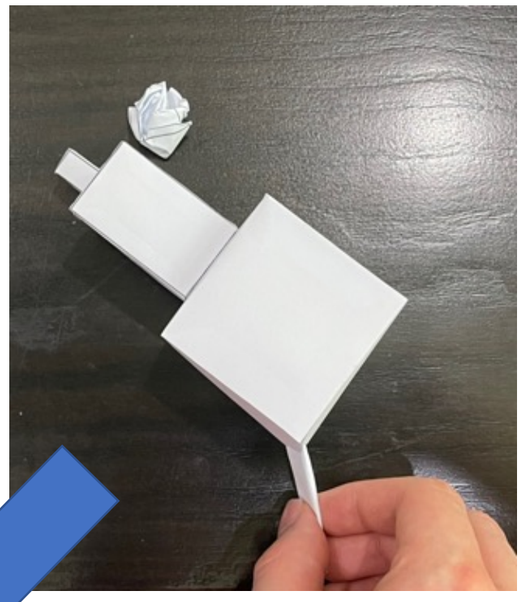
Problems I found in low fidelity prototype:

1) Paper is too weak to make complex structures.
2) Small pieces are hard to form.
3) A guide may be needed to help students as net forming may be complicated.

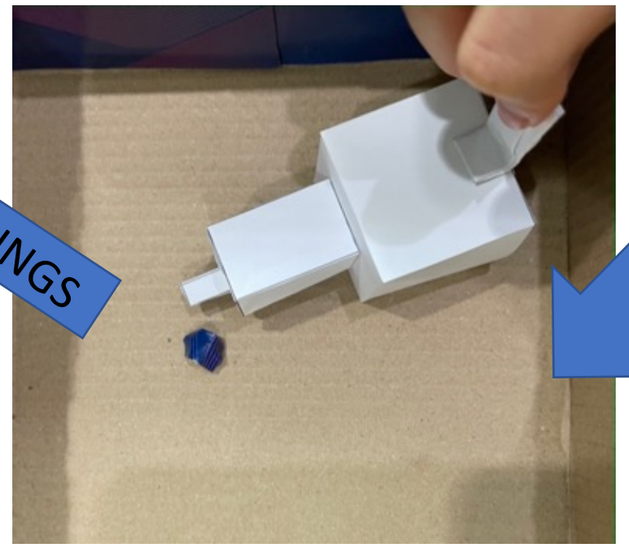




APPLICATION



FINDINGS

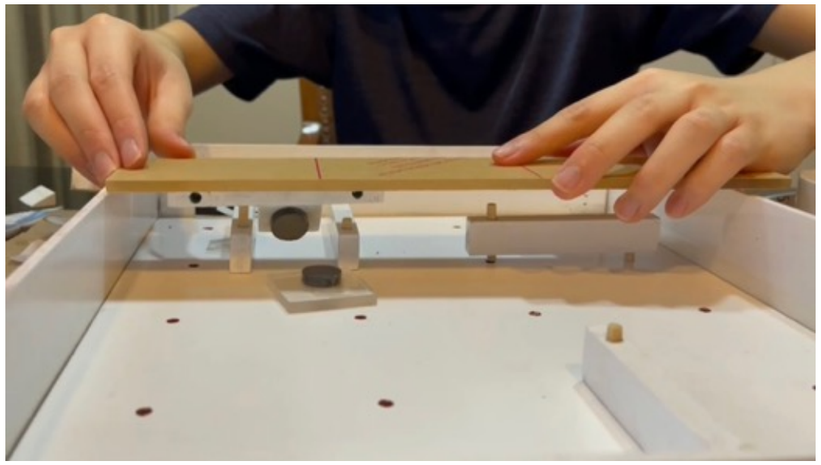


Efficiency

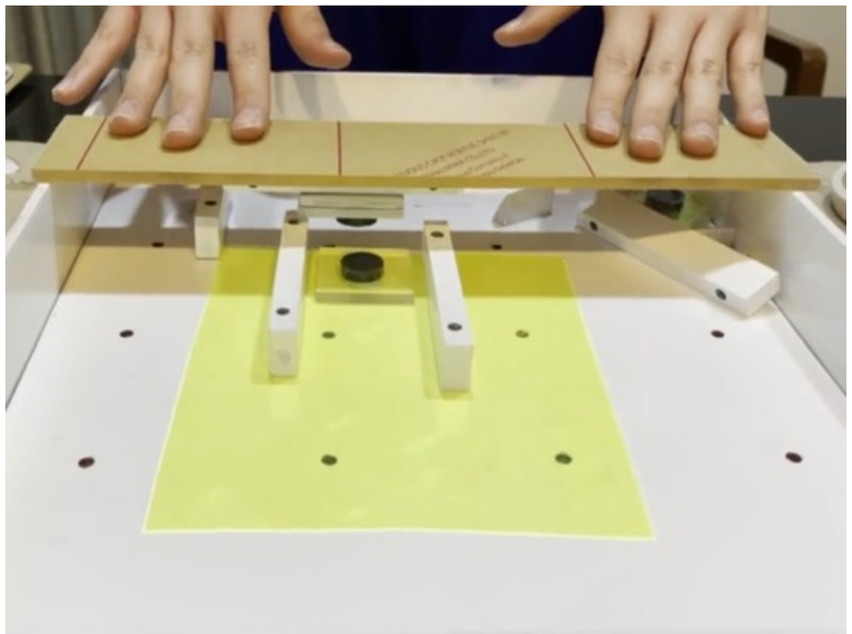
Budget-wise

MAGNET MAZE TESTING

Patent Pending



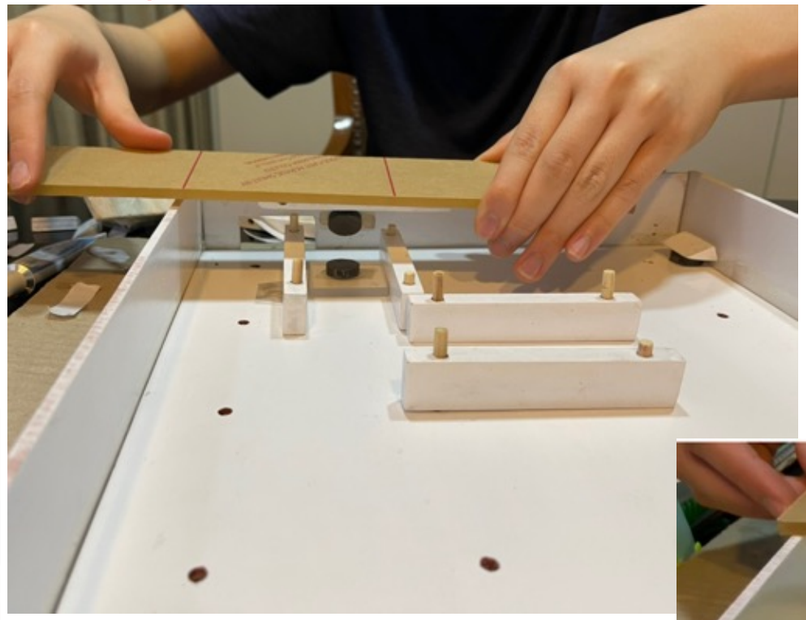
Efficiency



After testing the product, I found that a sliding mechanism of the instruction piece and magnet would be more efficient. This would allow students to learn the instructions and also get an idea of directions for the robot. For example, to turn right, they would have to slide the RIGHT instruction from left side to right side, like the rotation of the wheels in a robot, with only the left side rotating. This meant that the instruction and kit list will need to be redesigned.

Efficiency

After testing with the magnet repulsion method, I found that the repulsion force was too weak. This meant that the magnet would need to be closer. After moving the magnet closer, I found that there was a high chance that the magnet would flip as it attracted with the pole of the magnet above. I found that another material was required to prevent the magnet from flipping. This meant that a base would need to be designed. Also, I decided to change the instruction piece to transparent acrylic, to allow students to be able to see the magnet move.

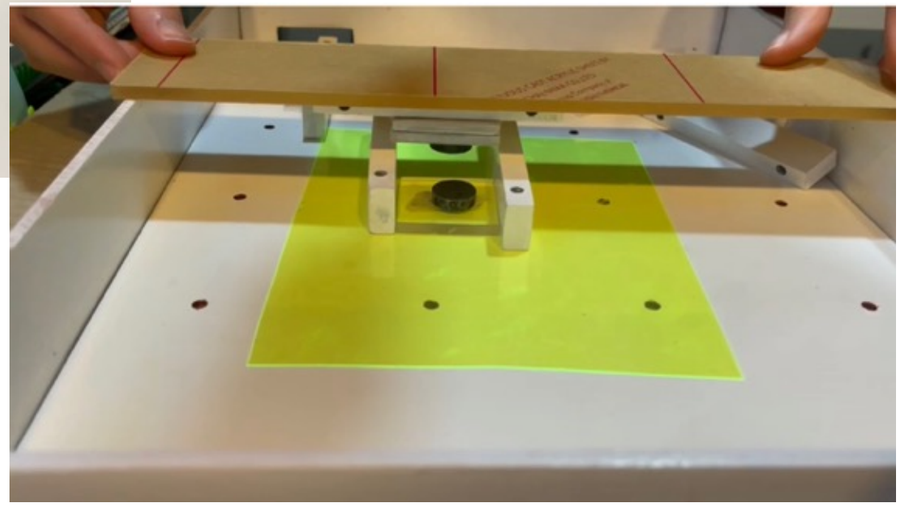


As I continued to test the magnet movement, I realized that the wooden base was causing friction. In order to minimize this, I tried placing a piece of plastic on top of the base. I found that this improved the magnet's movement. This meant that a material that reduces/has less friction should be used.

Efficiency

Furthermore, I found that the magnetic repulsion force was inconsistent and sometimes to weak. This meant that a repeated moving action of the instruction piece above would be required. I altered the course by moving the obstacle blocks closer to try and help the magnet. This meant the distance between the blocks would need to be exactly the size of the base and magnet. This allowed a more consistent movement from the magnet.

Efficiency



Finally, I found that the triangular piece may not be required as the magnet can be stuck in a parallel position instead. This would save costs and make it easier to produce as the piece was hard to cut. Also, I found that the obstacle blocks can simply be stuck on using Velcro straps as this reduces cost and may become more efficient.

Efficiency

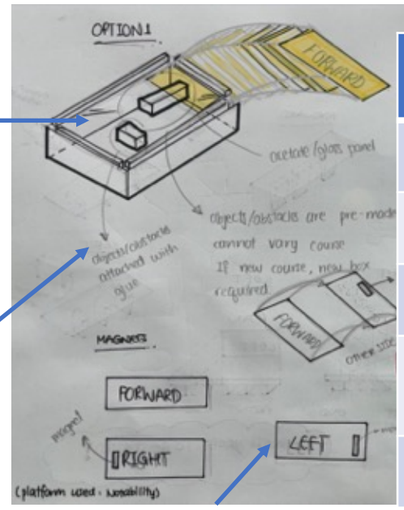
Budget-wise

DESIGN ANALYSIS

Design 1

Force of magnet may need to vary as glass panel may reduce the force.

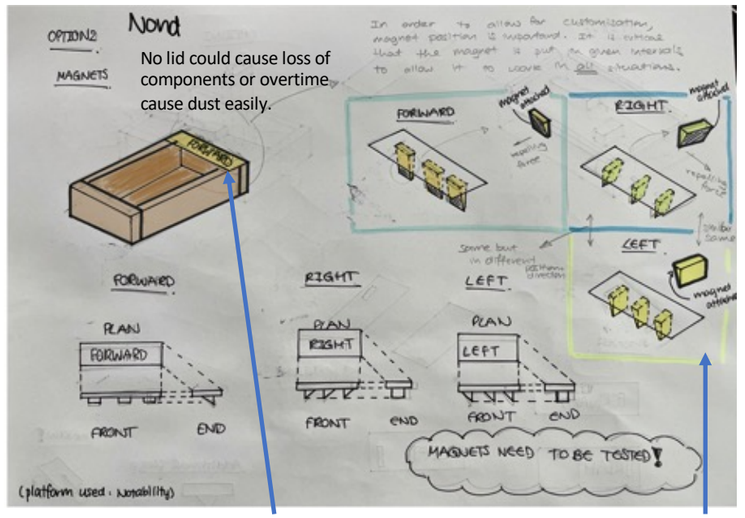
Standardized obstacles may mean a higher budget required to supply different difficulties/stages.



Position of magnet needs to be designed to allow effective usage.

Specification	
The product needs to appeal to user and work efficiently.	To an extent
The product needs to gain user's interest and interesting to use.	✓
The product needs to build logic and robotic skills.	✓
The product needs to be able to be used in a school environment and safe to use.	✓
The product needs to be at minimal cost.	To an extent

Design 2



The magnet may need a place to hook onto.

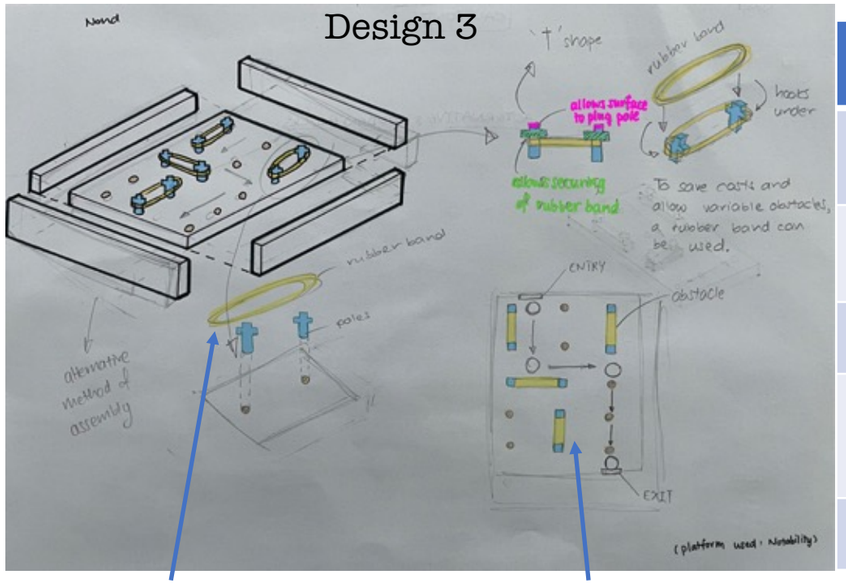
A customizable course should save costs and allow more variety in lessons.

Position of magnet should provide a suitable force to push the ball.

Sharp edges could be a problem.

Specification	
The product needs to appeal to user and work efficiently.	To an extent
The product needs to gain user's interest and interesting to use.	✓
The product needs to build logic and robotic skills.	✓
The product needs to be able to be used in a school environment and safe to use.	✓
The product needs to be at minimal cost.	To an extent

Design 3



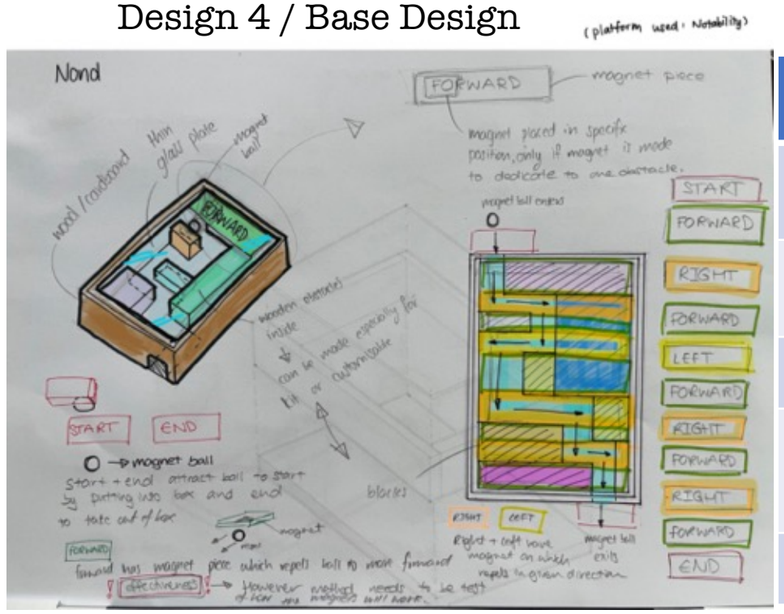
Use of rubber bands should save costs.

Customizable course should save costs and allow variable challenges.

Could rubber bands, which have less surface area, cause the ball to slide under?

Specification	
The product needs to appeal to user and work efficiently.	To an extent
The product needs to gain user's interest and interesting to use.	✓
The product needs to build logic and robotic skills.	✓
The product needs to be able to be used in a school environment and safe to use.	✓
The product needs to be at minimal cost.	✓

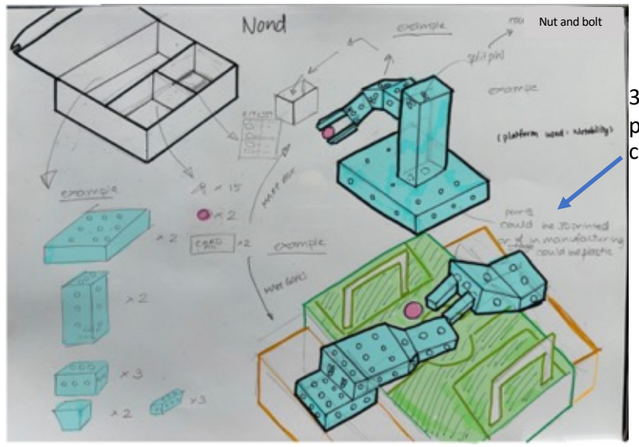
Design 4 / Base Design



Specification	
The product needs to appeal to user and work efficiently.	To an extent
The product needs to gain user's interest and interesting to use.	✓
The product needs to build logic and robotic skills.	✓
The product needs to be able to be used in a school environment and safe to use.	✓
The product needs to be at minimal cost.	To an extent

DESIGN ANALYSIS

Design 1



3D Printing and plastic manufacture could be expensive

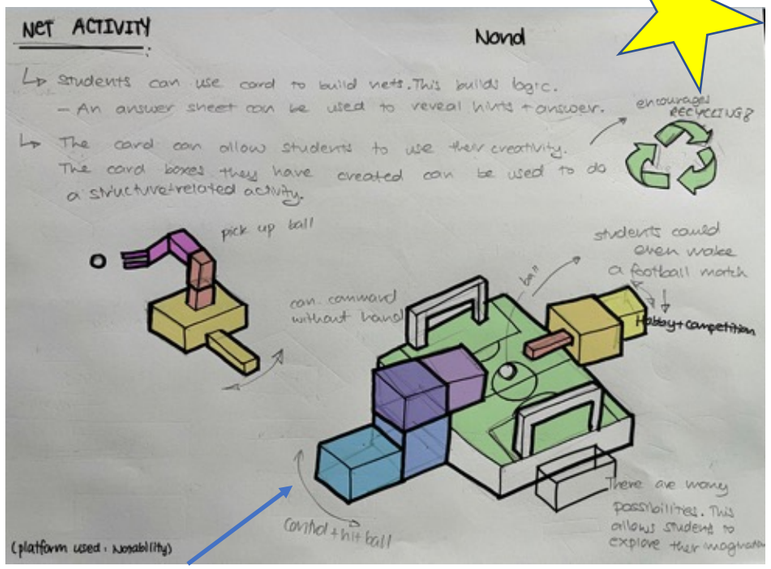
How effective would split pins and nut and bolt be?

There could be a problem (e.g. not strong enough, no space) in attachment/connection of parts with split pin and nut and bolt.

Allows freedom and creativity.

Specification	
The product needs to appeal to user and work efficiently.	To an extent
The product needs to gain user's interest and interesting to use.	✓
The product needs to build logic and robotic skills.	✓
The product needs to be able to be used in a school environment and safe to use.	✓
The product needs to be at minimal cost.	Kind of

Design 2



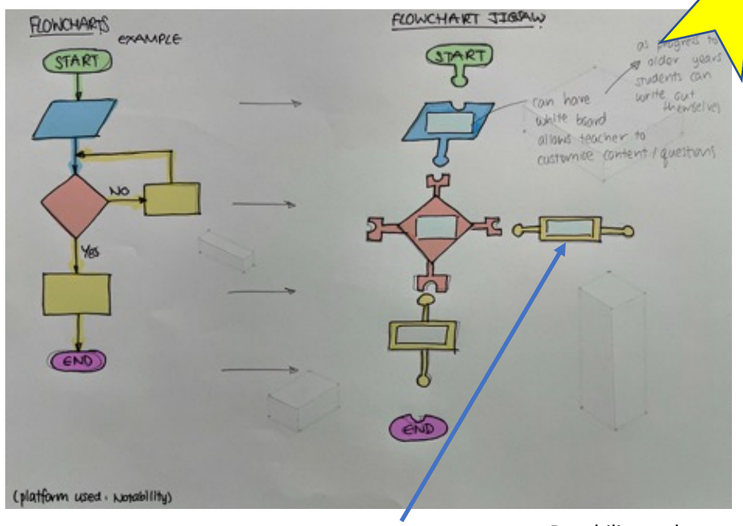
Use of card can lower budget and allow for recycling.

Strength of card my be an issue as this may limit the structures that can be built.

Creativity skills, logic and competition can be used in this task.

Specification	
The product needs to appeal to user and work efficiently.	✓
The product needs to gain user's interest and interesting to use.	✓
The product needs to build logic and robotic skills.	✓
The product needs to be able to be used in a school environment and safe to use.	✓
The product needs to be at minimal cost.	✓

Design 3



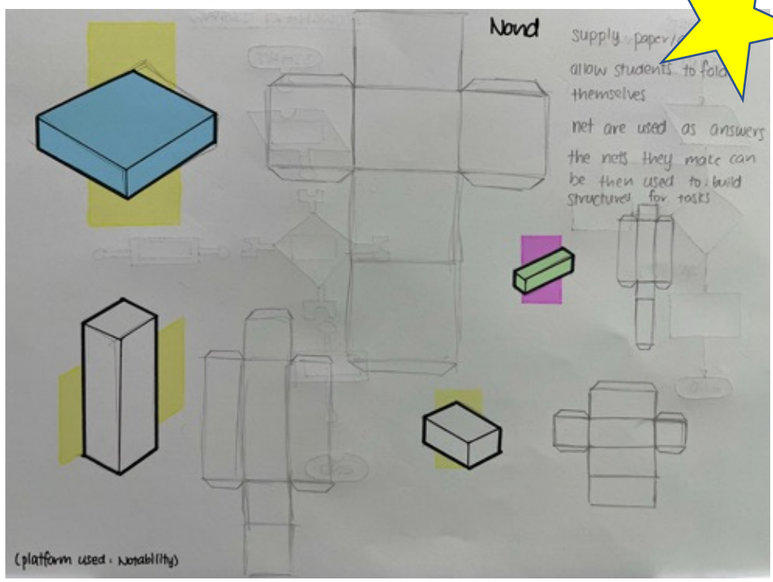
Effective integration of important concept of flowcharts with student interest.

Materials could vary such as cardboard or card. However, the whiteboard piece may be hard to find.

Durability and strength may be an issue.

Specification	
The product needs to appeal to user and work efficiently.	To an extent
The product needs to gain user's interest and interesting to use.	✓
The product needs to build logic and robotic skills.	✓
The product needs to be able to be used in a school environment and safe to use.	✓
The product needs to be at minimal cost.	✓

Design 4

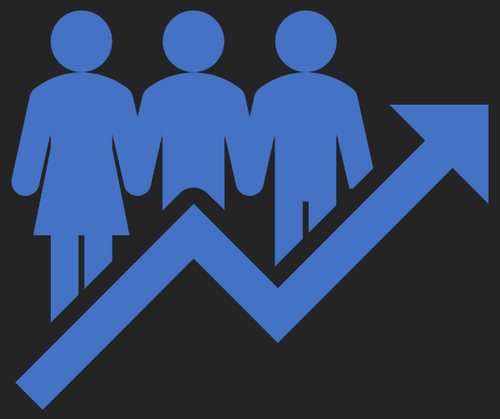


Simple, but effective building of logic.

Use of card can minimize costs, as well as link with other tasks/ideas.

This design idea is more of a sub-activity rather than a product, so it may not directly satisfy all specifications.

Specification	
The product needs to appeal to user and work efficiently.	✓
The product needs to gain user's interest and interesting to use.	✓
The product needs to build logic and robotic skills.	✓
The product needs to be able to be used in a school environment and safe to use.	✓
The product needs to be at minimal cost.	✓

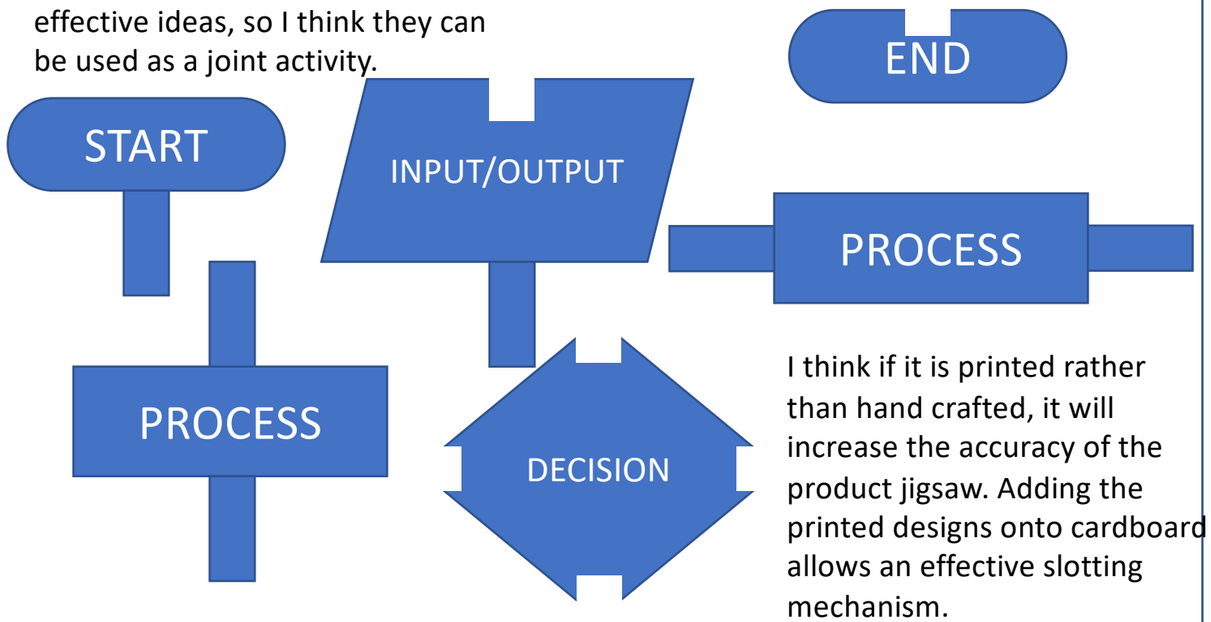


Development

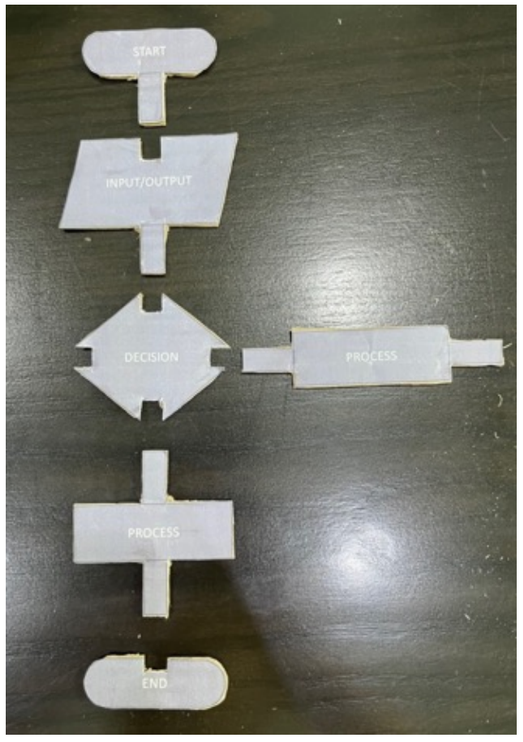
REDESIGN

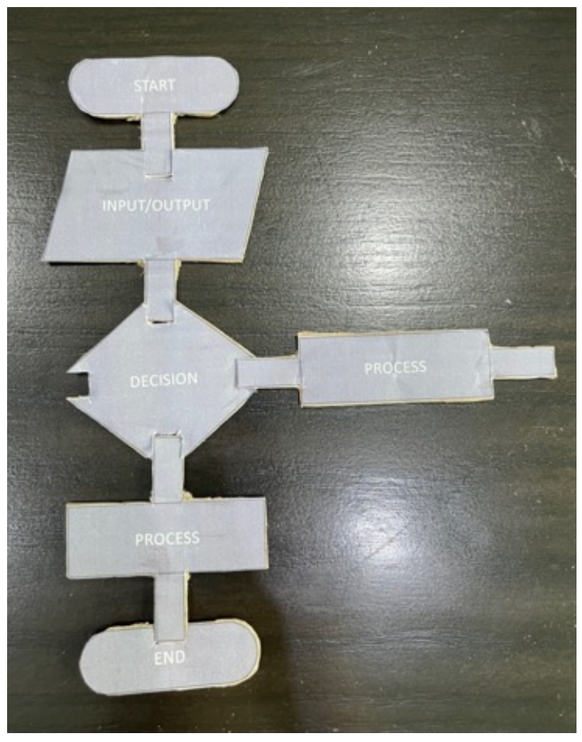
FLOWCHART ACTIVITY

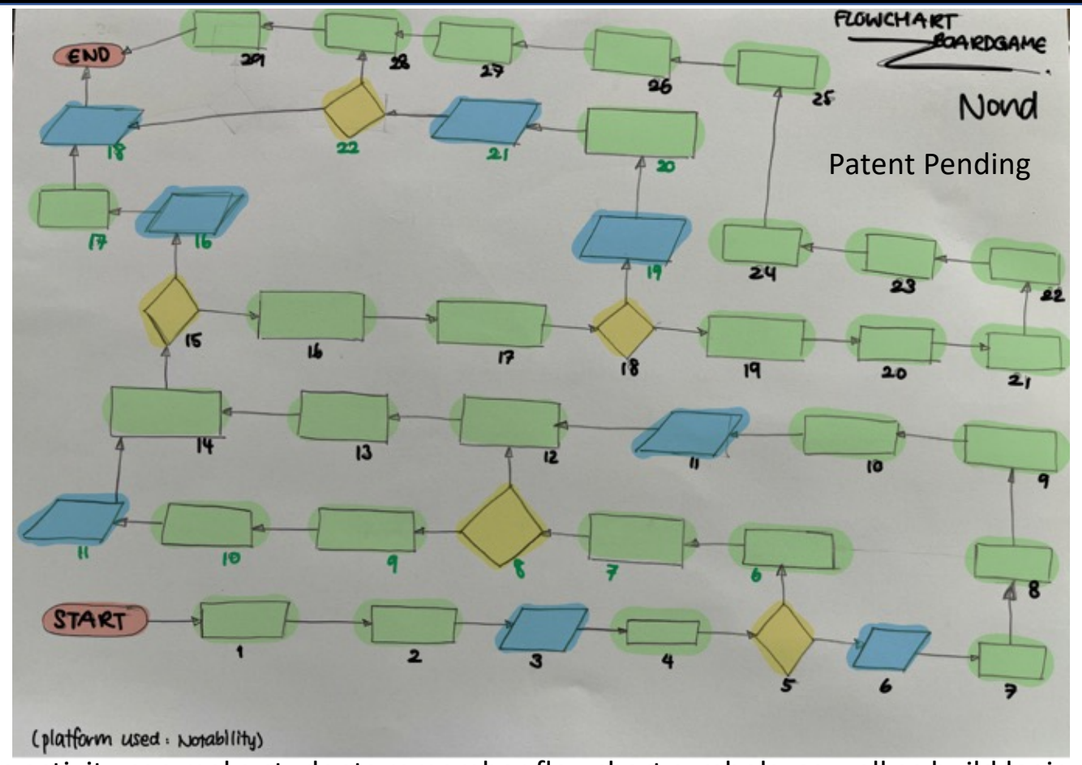
I think these two activities are effective ideas, so I think they can be used as a joint activity.



I think if it is printed rather than hand crafted, it will increase the accuracy of the product jigsaw. Adding the printed designs onto cardboard allows an effective slotting mechanism.

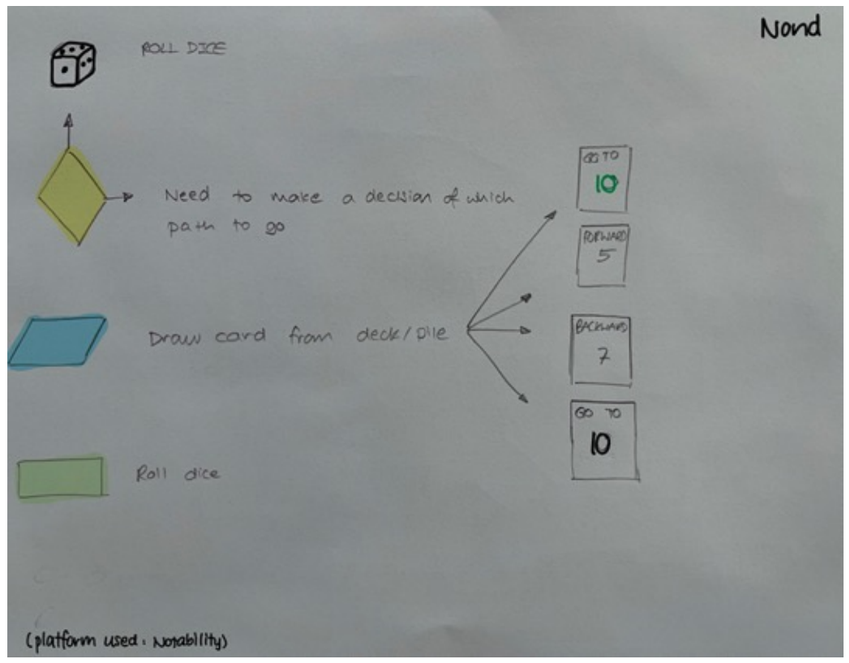




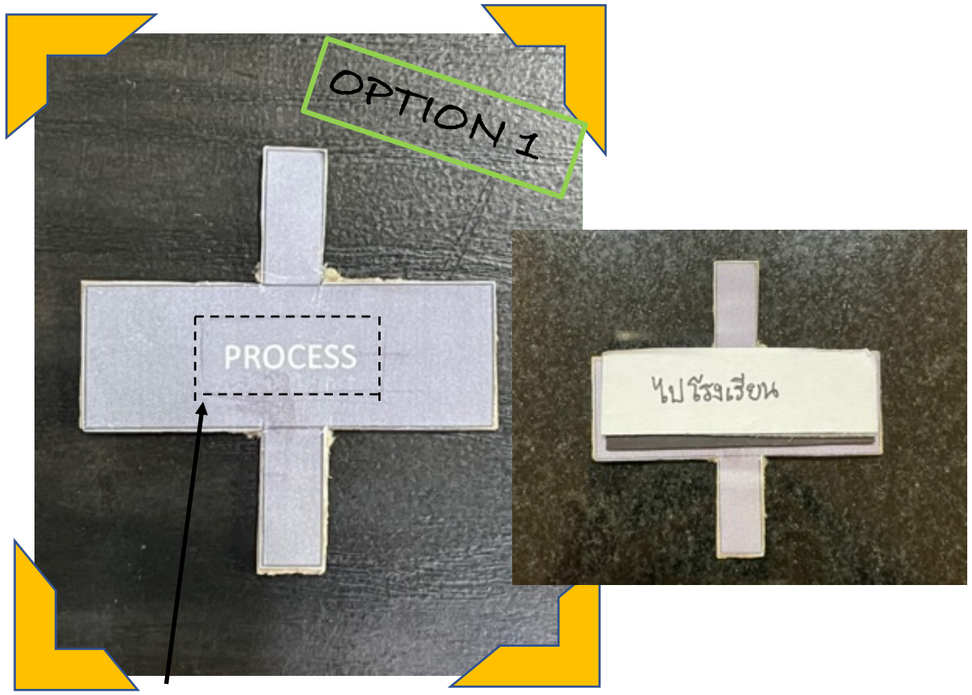


This activity can make students remember flowchart symbols, as well as build logic through decision making. For example, at the decision box, students have to choose whether to risk a 'draw card' or go with the safe route.

This new design is similar to typical board games, with the use of a dice to lead the game. Instead of using basic blocks, flowchart symbols are used to allow students to remember them. At different stages, students will have to perform a task, which can be found from the flowchart symbol, as shown on the right. ---------->



FLOWCHART ACTIVITY COMPONENTS



Magnet can be placed on the block to allow easier attraction and increased efficiency. A magnet sheet can be used or a simple magnet. This will allow customization.

OPTION 1 PROFILE

CHARACTERISTICS:

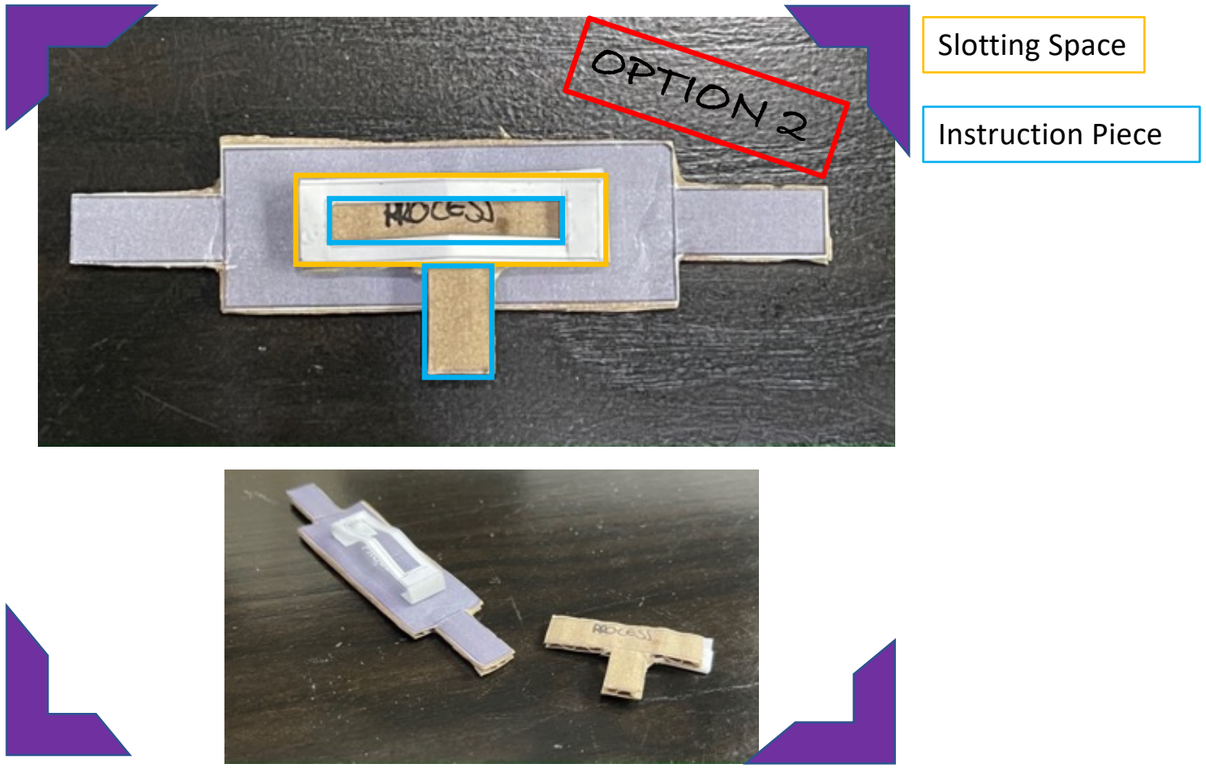
- Use of magnets; attraction force

ADVANTAGES:

- High efficiency with use of magnets
- Can write directly onto magnet sheet

DISADVANTAGES:

- Cost
- Requires a more complicated design and manufacture.



Slotting Space

Instruction Piece

Here, a simple sliding mechanism can be used. There can be a slotting space and gap to allow the instruction piece to be put inside. This will allow customization.

OPTION 2 PROFILE

CHARACTERISTICS:

- Use of sliding mechanism between slotting space and instruction piece.

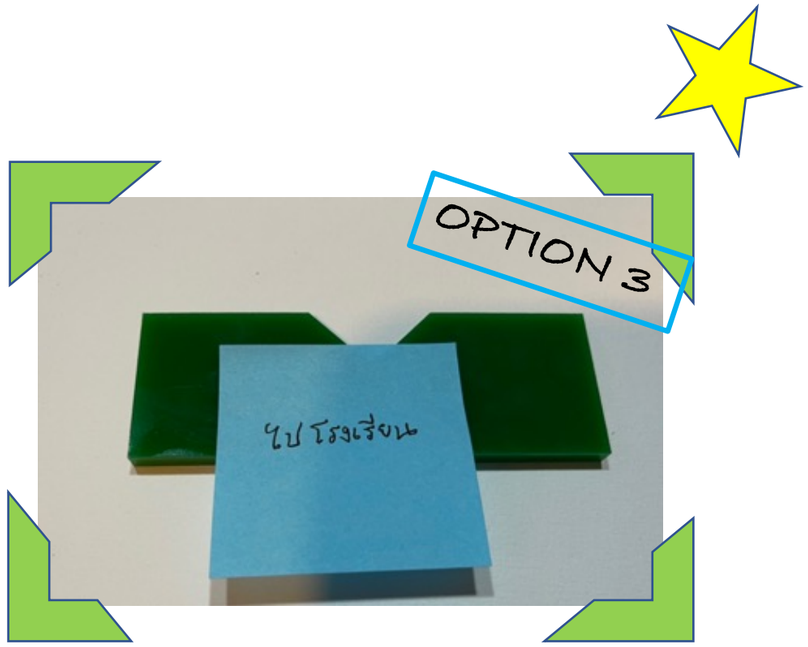
ADVANTAGES:

- Simple design
- Low cost
- Functional despite lower cost

DISADVANTAGES:

- May break easily
- Many pieces required

FLOWCHART ACTIVITY COMPONENTS



OPTION 3 PROFILE

CHARACTERISTICS:

- Use of a Post-It to stick onto each piece.

ADVANTAGES:

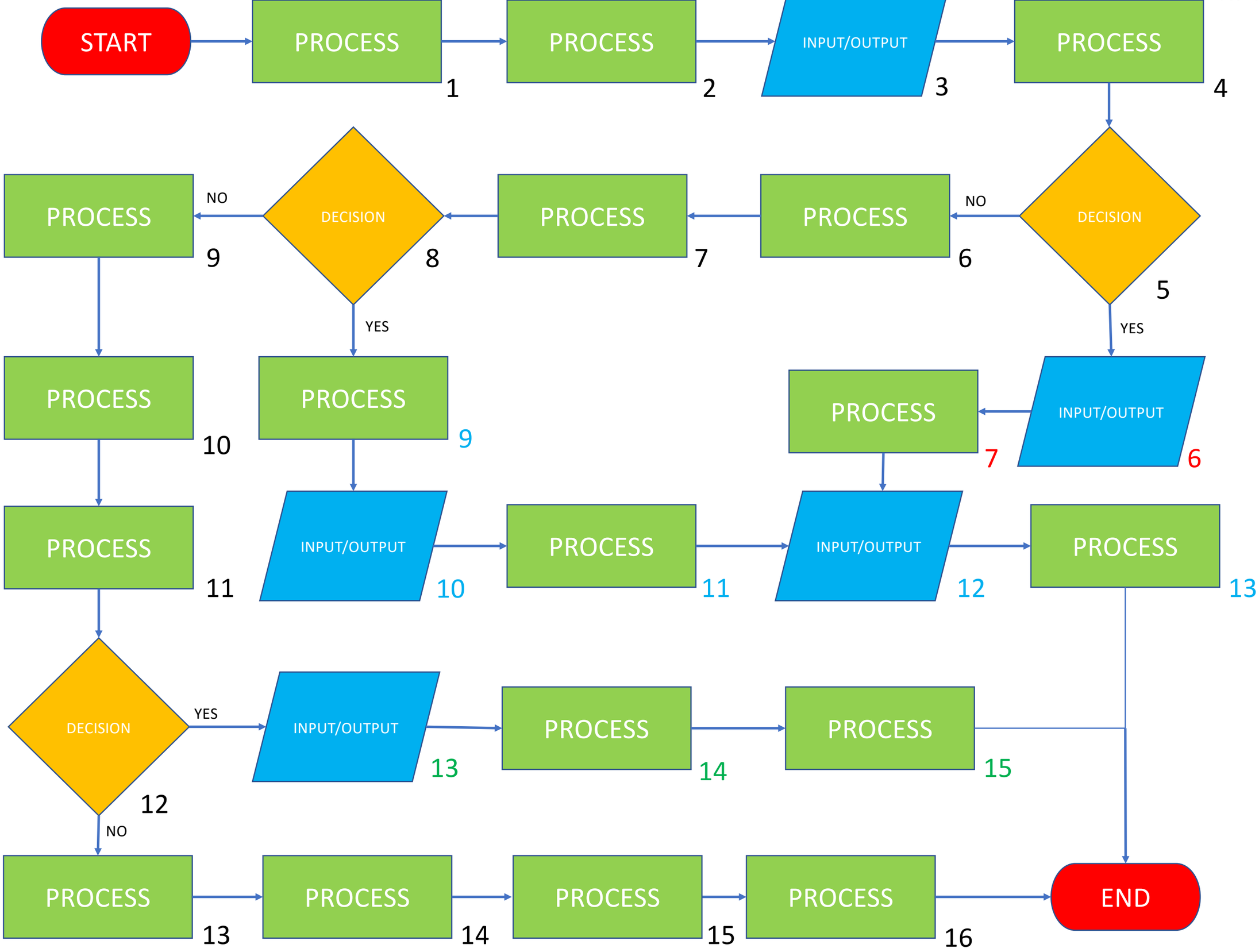
- Simple but effective
- Low cost

DISADVANTAGES:

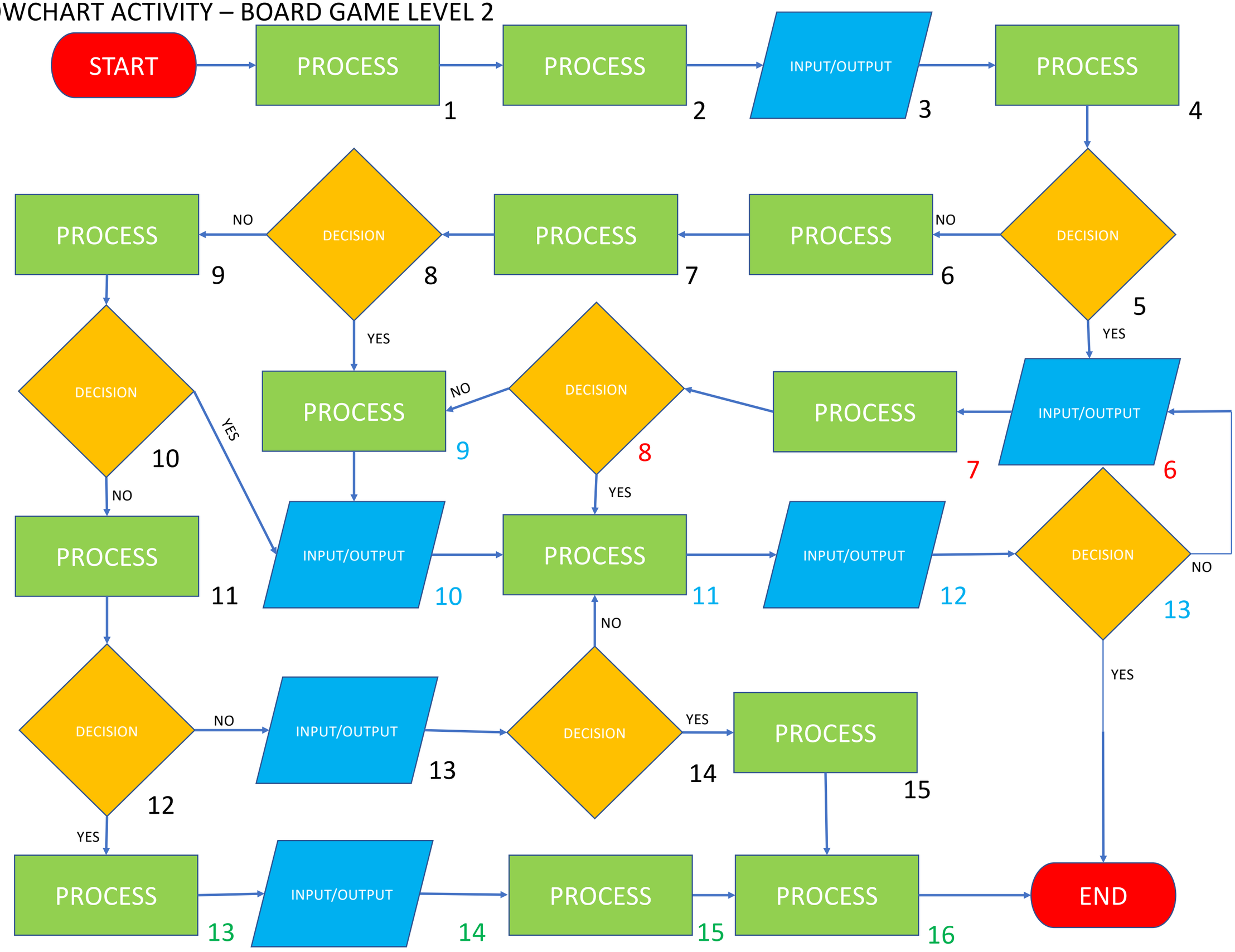
- May tear easily as it is made from paper.

FLOWCHART ACTIVITY – BOARD GAME LEVEL 1

Patent Pending



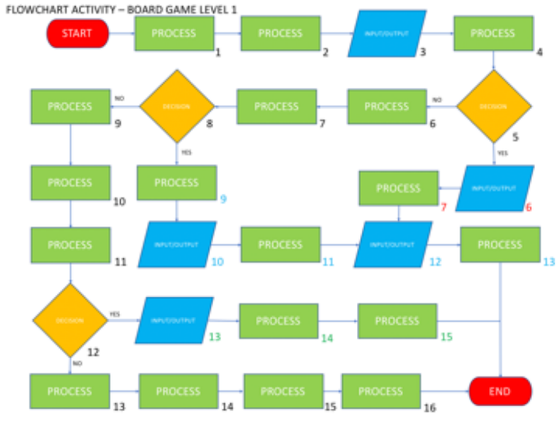
FLOWCHART ACTIVITY – BOARD GAME LEVEL 2

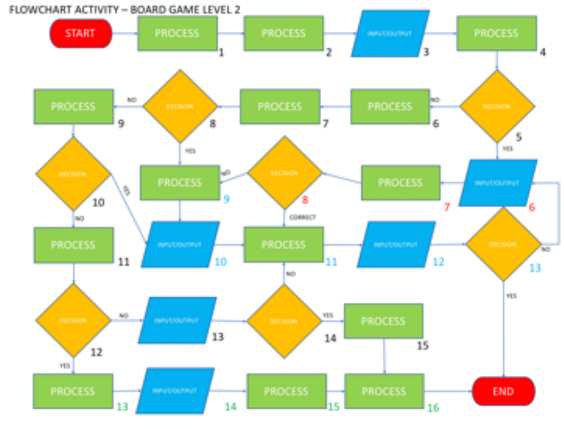


FLOWCHART BOARDGAME COMPONENTS

Patent Pending

BOARDGAME x2





DICE x1

COUNTERS x4

These can also be made by students, following on from net skills. This can also save costs.

INPUT/OUTPUT DECK OF CARDS x1

FORWARD 2	FORWARD 2	FORWARD 3	FORWARD 5	FORWARD 5	BACKWARD 3	BACKWARD 2	BACKWARD 2
GO TO 7	GO TO 10	GO TO 10	GO TO 14	GO TO 7		BACKWARD 5	BACKWARD 5

FLOWCHART BOARDGAME COMPONENTS

DECISION DECK

Q1	Q2	Q3	Q4	Q5
Q6	Q7	Q8	Q9	Q10
Q11	Q12	Q13	Q14	Q15

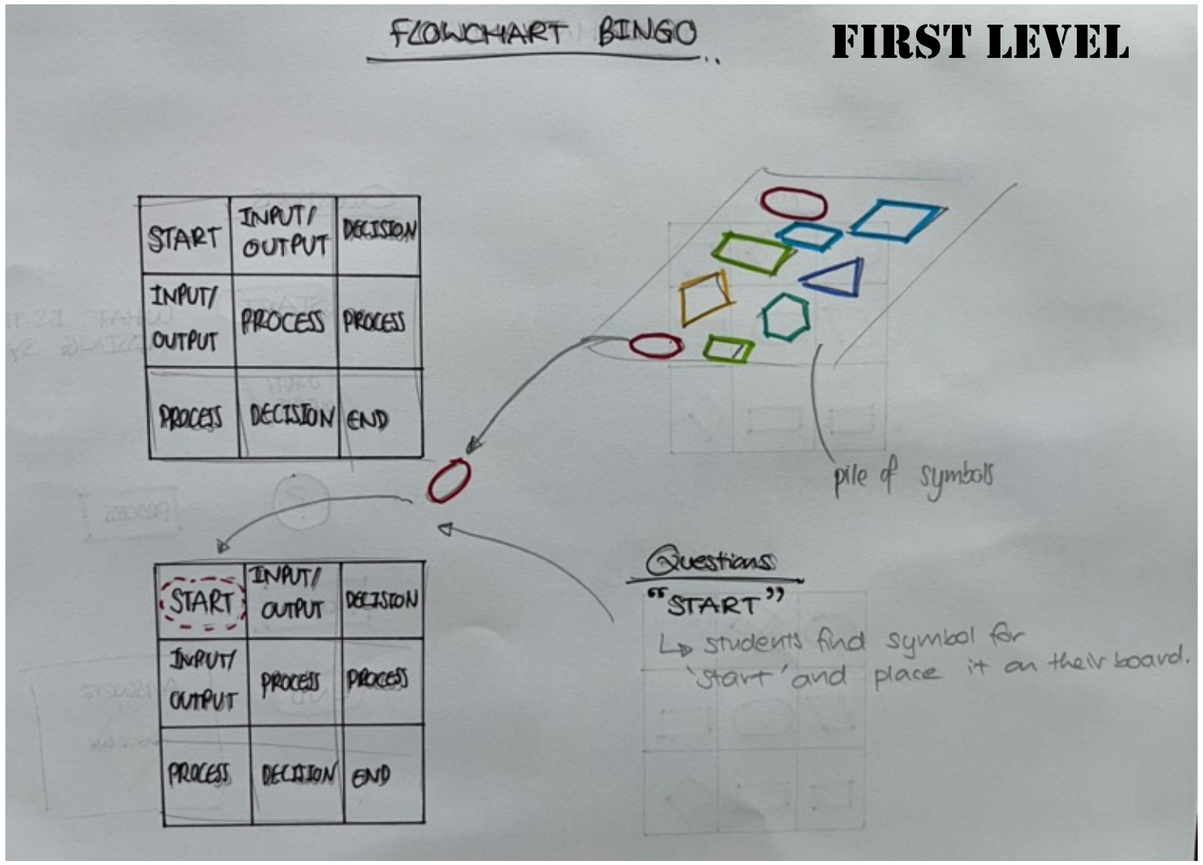
After testing, I found that the cards from the deck were too small, especially for younger students. Also, I wanted to add an additional detail of having ‘DECISION DECK’ and ‘INPUT/OUTPUT DECK’ on the back of the card to allow the cards to be sorted into correct piles.

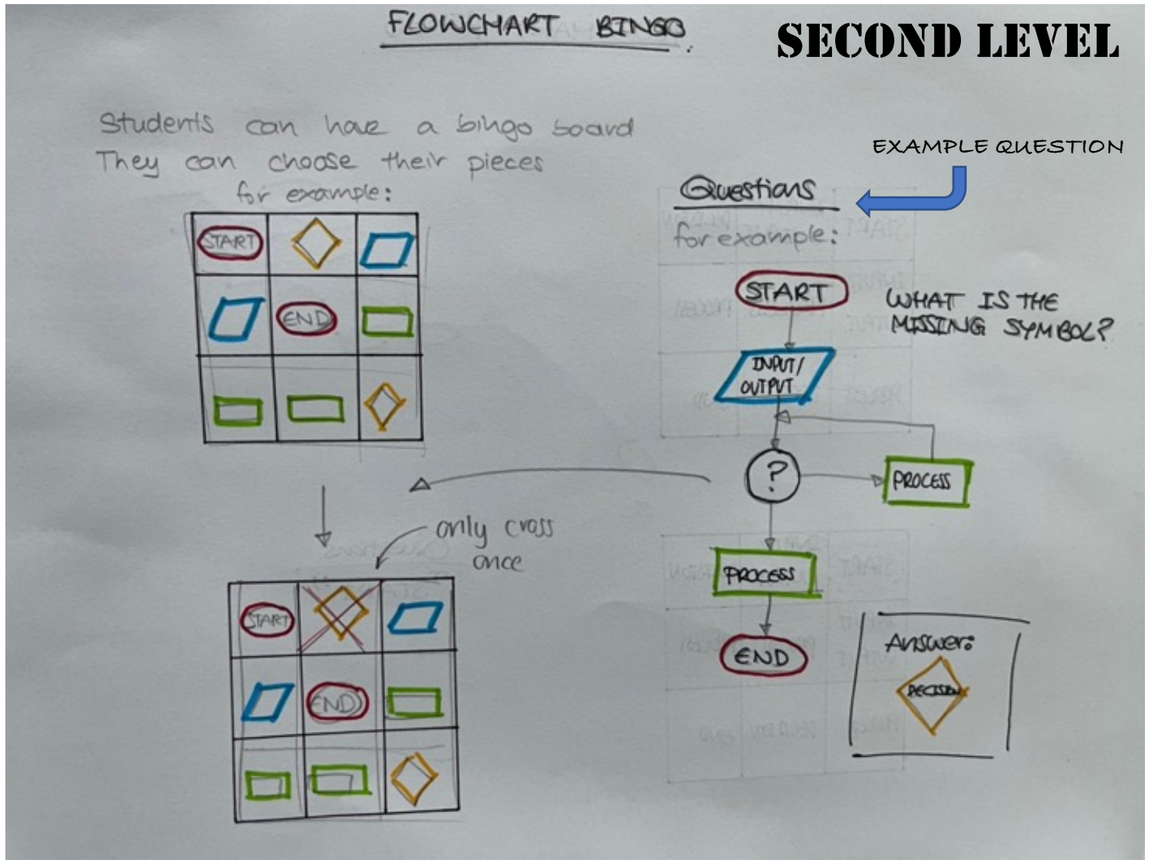
คำถามในการ์ดคำถาม

1. คำถาม: การเขียนผังงาน เราเรียกว่าอะไร
   คำตอบ: Flowchart
2. คำถาม: การเขียนผังงานจะต้องเริ่มด้วยสัญลักษณ์อะไรเสมอ
   คำตอบ: Start/ เริ่มต้น
3. คำถาม: การเขียนผังงานจะต้องสิ้นสุดหรือจบด้วยสัญลักษณ์อะไรเสมอ
   คำตอบ: End/ จบ
4. คำถาม: สัญลักษณ์ที่แปลว่าการมีทางเลือกในการตัดสินใจ (decision) มีลักษณะอย่างไร
   คำตอบ: สี่เหลี่ยมขนมเปียกปูน
5. คำถาม: การเขียนผังงาน แต่ละสัญลักษณ์จะถูกเชื่อมต่อด้วยอะไร
   คำตอบ: Arrow/ ลูกศร
6. คำถาม: ให้เขียนโฟล์ชาร์ทการต้มบะหมี่กึ่งสำเร็จรูป
   คำตอบ:
7. คำถาม: 12 x 5 =?
   คำตอบ: 60
8. คำถาม: 4 + (10/2) =?
   คำตอบ: 9
9. คำถาม: ให้เขียนตัวอย่าง code ในภาษาที่เรียน
   คำตอบ:
10. คำถาม: สัญลักษณ์ที่แปลว่าการปฏิบัติงานหรือประมวลผล (process) มีลักษณะอย่างไร
    คำตอบ: สี่เหลี่ยมผืนผ้า
11. คำถาม: สัญลักษณ์ที่แปลว่าการรับข้อมูล (input) มีลักษณะอย่างไร
    คำตอบ: สี่เหลี่ยมด้านขนาน
12. คำถาม: วันวิทยาศาสตร์ของไทยตรงกับวันที่เท่าไร
    คำตอบ: วันที่ 18 สิงหาคม ของทุกปี
13. คำถาม: สัญลักษณ์ที่แปลว่าการแสดงข้อมูล (output) มีลักษณะอย่างไร
    คำตอบ: สี่เหลี่ยมด้านขนาน
14. คำถาม: อุปกรณ์ที่ใช้ในหุ่นยนต์มีอะไรบ้าง
    คำตอบ: เหล็ก, program code, น็อตและโบลท์
15. คำถาม: ให้ยกตัวอย่างข้อมูลส่วนบุคคลที่เราไม่ควรเปิดเผยกับคนอื่น
    คำตอบ: พาสเวิร์ด/ รหัสผ่าน, เลขประจำตัวประชาชน, รหัส ATM, ฯลฯ

    15 คำถามนี้เป็นเพียงตัวอย่าง คุณครูสามารถปรับคำถามและคำตอบได้

FLOWCHART BINGO



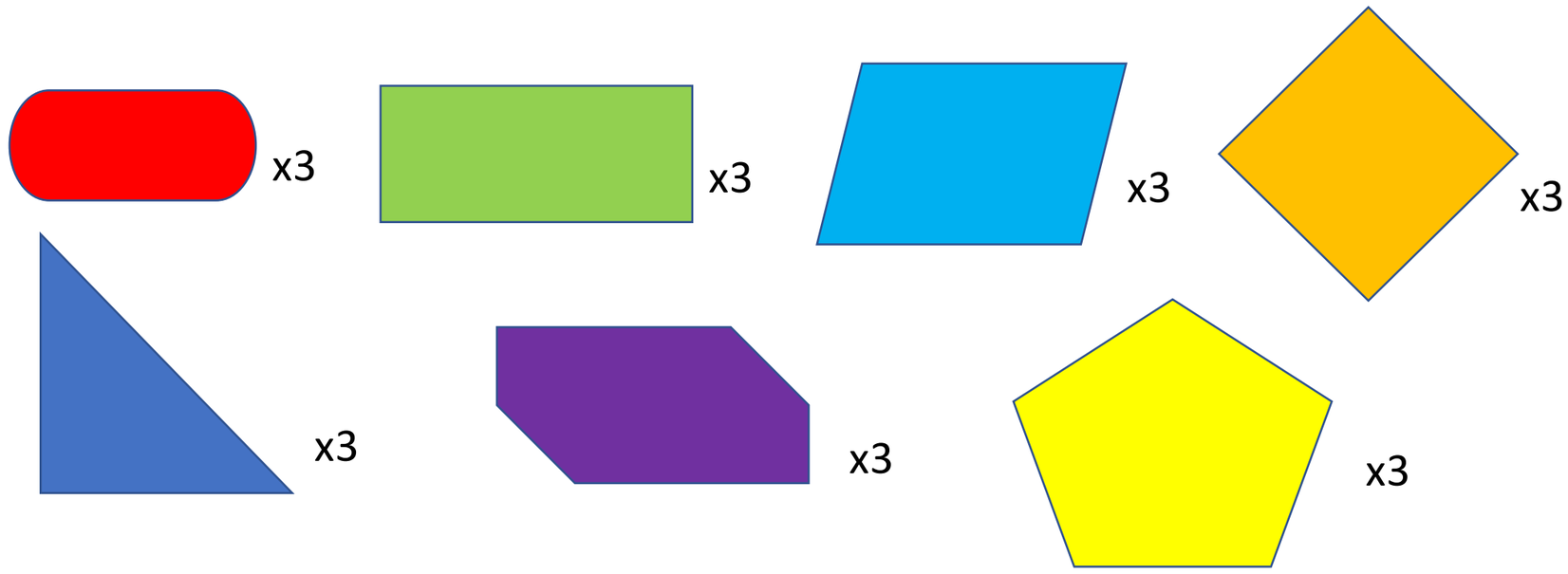


This activity can be useful for online lessons as there are not many materials required.

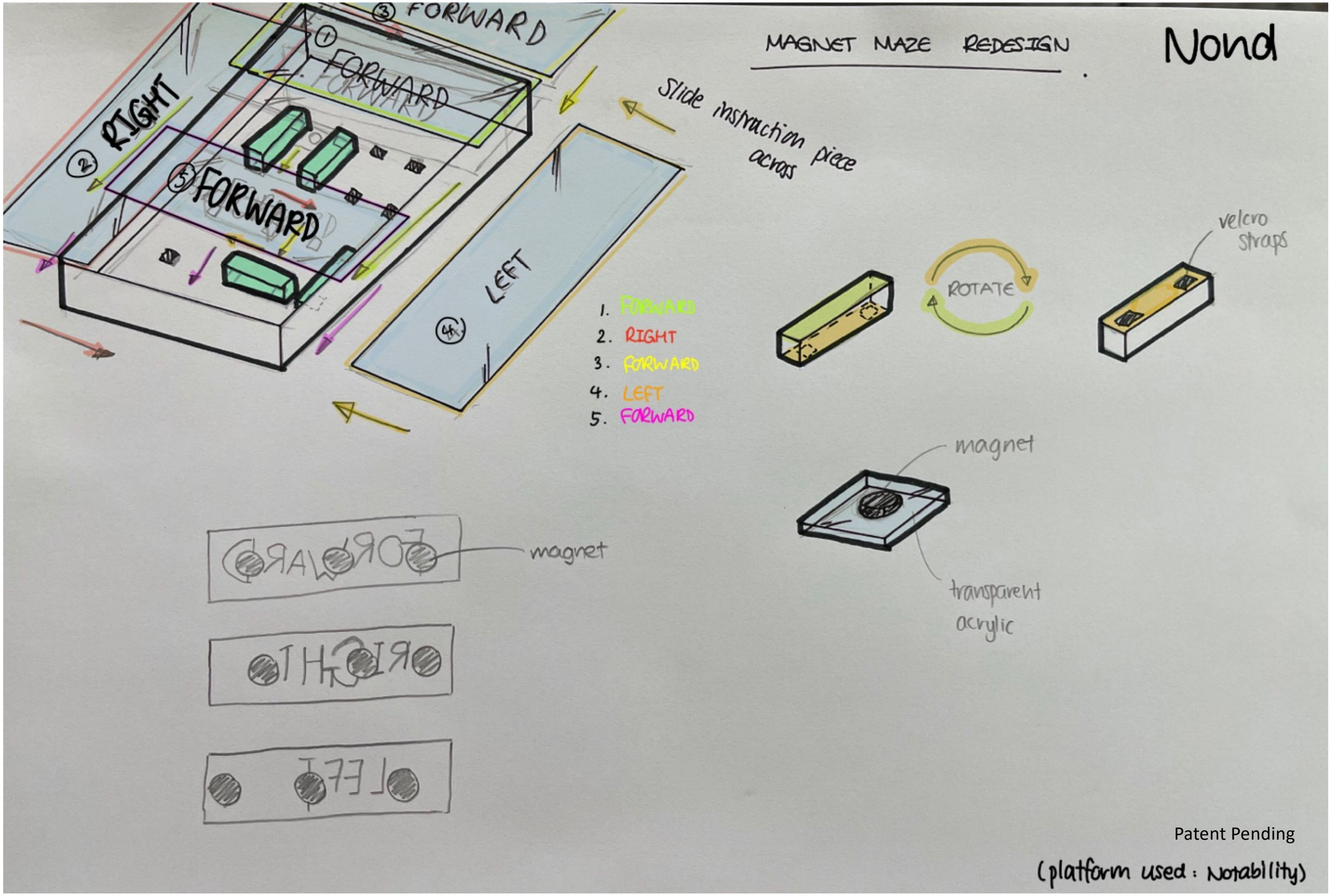
FLOWCHART BINGO

- There will be two levels to this activity.
  - The first level is shown in the photo on the left.
    - Students will play a game of BINGO. However, there are different rules.
    - Students will start with a 3x3 square, and they will write the names for different flowchart symbols.
    - The teacher will read out a name for a symbol, and students will need to find the symbol in the pile and place it in their square.
    - First to obtain 3 in a row is the winner. Teachers can check the winner's board.
  - The second level is shown on the photo in the right.
    - This is similar to the first level of BINGO.
    - Students will start with a 3x3 square, and they will draw different flowchart symbols.
    - The teacher will show the students a question (example shown in photo on the right) and the students will need to find the answer. If they have the symbol, which is the answer to the question, they can cross it out.
    - First to obtain 3 in a row is the winner.

FLOWCHART BINGO COMPONENTS

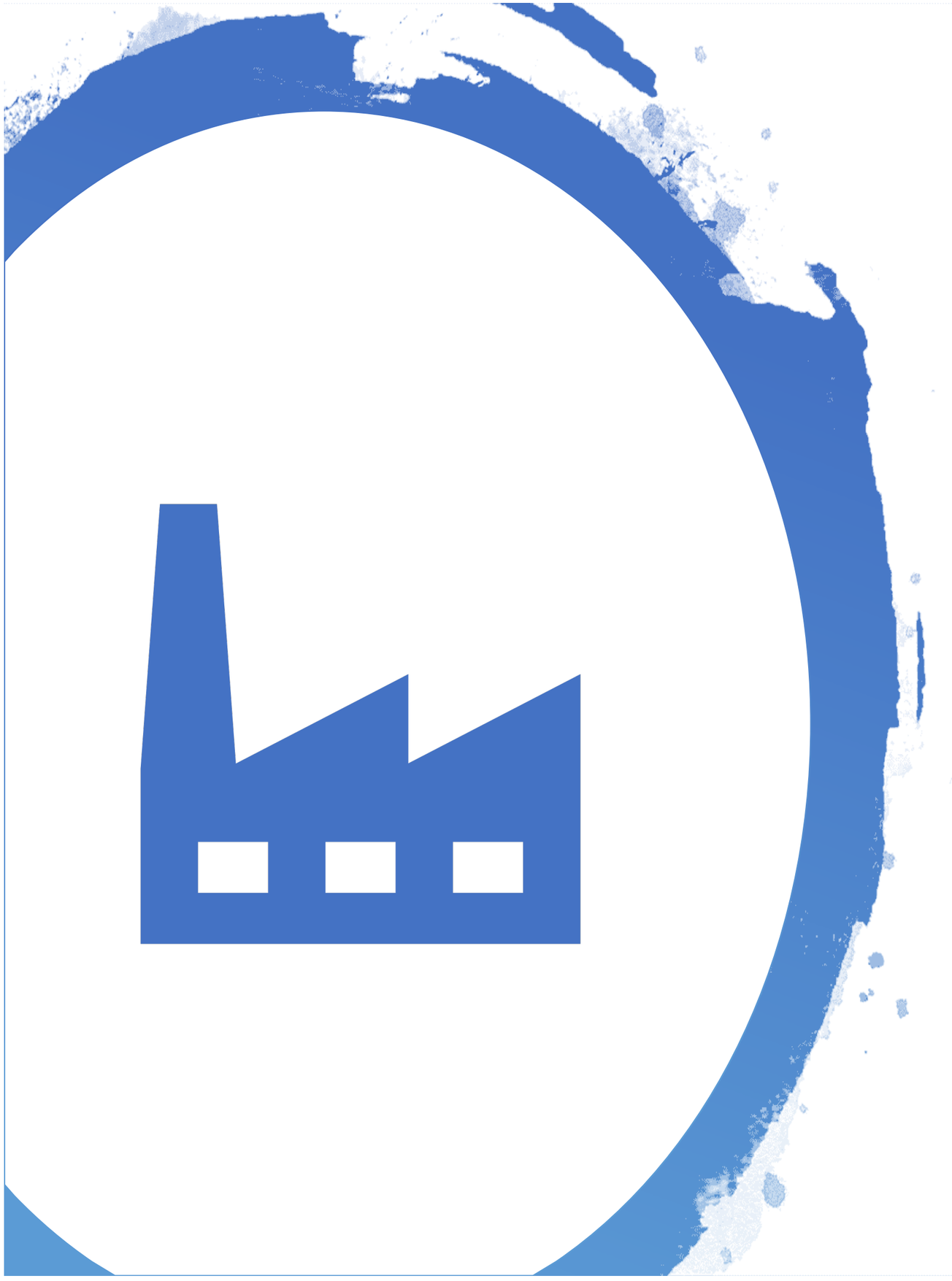


MAGNET MAZE REDESIGN



Patent Pending

(platform used : Notability)



Manufacturing

RESEARCH INTO MATERIALS

NET & APPLICATION ACTIVITY

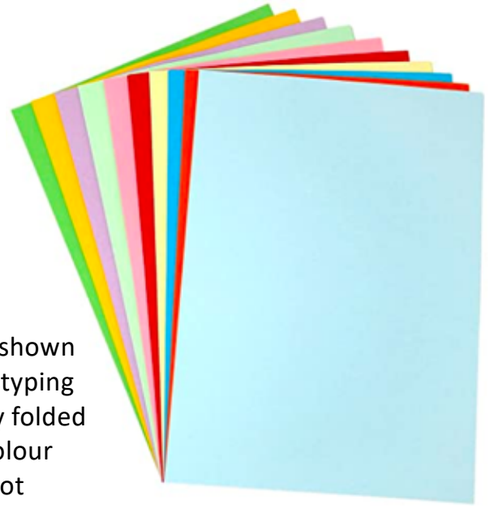
I think card is the best material as it can be folded into blocks and then used for net skills and application task, promoting recycling. Also, card is strong and can be folded easily into shapes, as well as it is easy to supply and not expensive.

(platform used: Notability)

Important Characteristics of Material used:
- Strong as it will need to be able to balance and glued together
- Flexible to an extent as it needs to be folded
- Not thick as this will make folding hard
- Optional: can include colour
- Easy to find and supply, not expensive

Possible Materials that can be used:
- Card
- Paper
- Corrugated cardboard
- Corrugated plastic
- Filament (for 3D Printing)

Card
- Strong to an extent
- Can be folded easily
- Can include colour
- Easy to find, not expensive



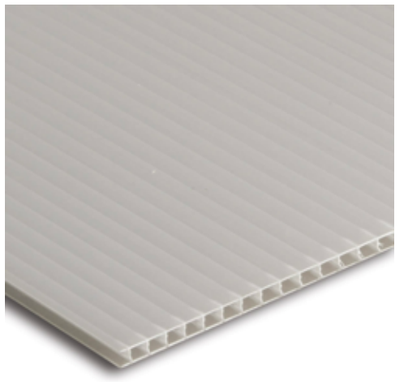
Paper
- Not strong as shown through prototyping
- Flexible, easily folded
- Can include colour
- Easy to find, not expensive

https://www.officemate.co.th/en/one-%E0%B8%81%E0%B8%A3%E0%B8%B0%E0%B8%94%E0%B8%B2%E0%B8%A9%E0%B8%81%E0%B8%B2%E0%B8%A3%E0%B9%8C%E0%B8%94%E0%B8%AA%E0%B8%B5-a4-180-%E0%B9%81%E0%B8%81%E0%B8%A3%E0%B8%A1-%E0%B8%82%E0%B8%B2%E0%B8%A7-50%E0%B9%81%E0%B8%9C%E0%B9%88%E0%B8%99-one-ofm5005051

https://www.amazon.com/Sheets-Construction-Colors-Stationery-Printers/dp/B089LR8NKQ

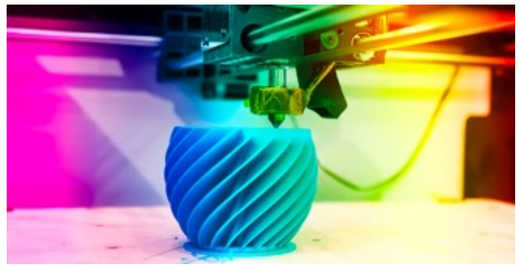
Corrugated Cardboard
- Strong
- Not really flexible but can be folded
- Thick
- Hard to apply colour
- Easy to find, not expensive

https://www.packaginginnovation.com/packaging-materials/cardboard-packaging-2/3-benefits-corrugated-cardboard-packaging/



Corrugated Plastic
- Strong
- Not really flexible but can be folded sometimes
- Thick
- Can be found in colour
- Easy to find, not expensive

https://www.amazon.com/Falken-Design-COR-WT-6MM-2436-Corrugated/dp/B07BCVCLN2

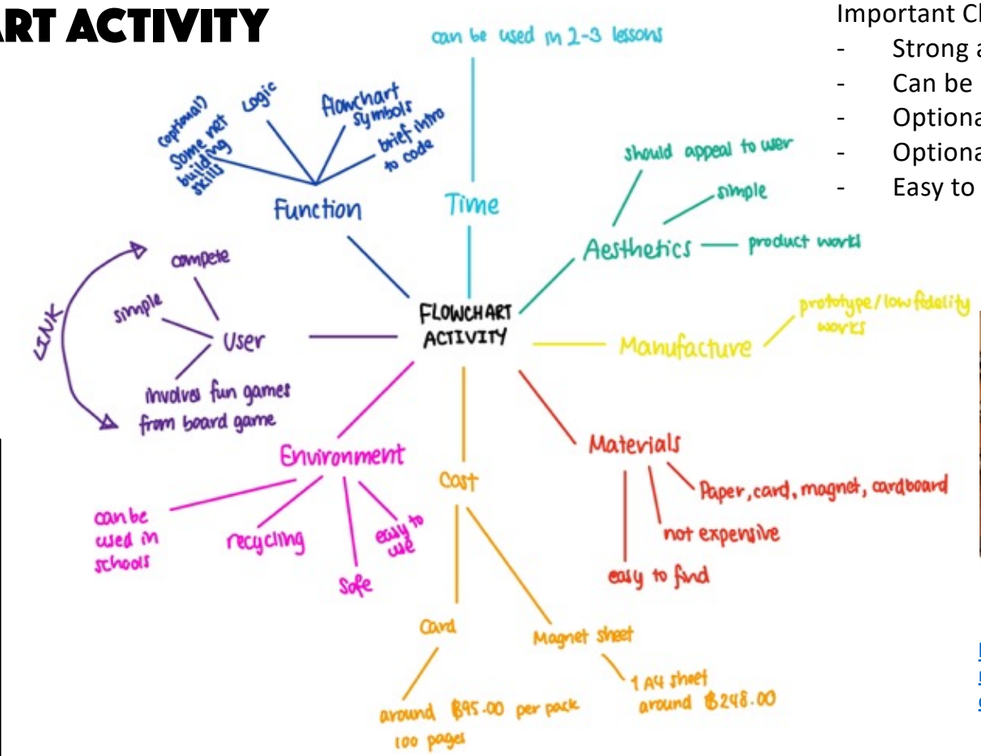


3D Printing
- Allows easy and fast manufacturing of blocks
- Strong
- Can involve use of nut and bolt, good introduction to robotic structure building
- Not expensive to print
- Expensive to buy 3D printer

https://dynamicwork.net/wp/3d-printing-2019/

RESEARCH INTO MATERIALS

FLOWCHART ACTIVITY



(platform used : Notability)

I think paper is best for the flowchart and board game to be printed on, as it is most convenient. This can be glued onto corrugated cardboard, which is easy to find and encourages recycling, to make the product more strong. An alternative to corrugated cardboard can be corrugated plastic as this can be used in A3.

Important Characteristics of Material used:
- Strong as will be needed in jigsaw mechanism
- Can be cut out and crafted easily
- Optional: can fold easily
- Optional: can include colour
- Easy to find and supply, not expensive

Possible Materials that can be used:
- Card
- Paper
- Corrugated cardboard
- Corrugated plastic
- Filament (for 3D Printing)
- Additional: Magnet

https://www.packaginginnovation.com/packaging-materials/cardboard-packaging-2/3-benefits-corrugated-cardboard-packaging/

Corrugated Cardboard
- Strong
- Sometimes hard to cut
- Not really flexible but can be folded
- Thick
- Hard to apply colour
- Easy to find, not expensive

สินค้าที่จำหน่ายจริงเป็นสีเหลือง

https://www.officemate.co.th/en/magx-%E0%B9%81%E0%B8%9C%E0%B9%88%E0%B8%99%E0%B8%A2%E0%B8%B2%E0%B8%87%E0%B9%81%E0%B8%A1%E0%B9%88%E0%B9%80%E0%B8%AB%E0%B8%A5%E0%B9%87%E0%B8%81-%E0%B9%80%E0%B8%AB%E0%B8%A5%E0%B8%B7%E0%B8%AD%E0%B8%87-%E0%B9%81%E0%B8%A1%E0%B9%8A%E0%B8%81%E0%B9%80%E0%B8%AD%E0%B9%8A%E0%B8%81%E0%B8%8B%E0%B9%8C-mvc-a4y-ofm7002482

https://www.amazon.com/Falken-Design-COR-WT-6MM-2436-Corrugated/dp/B07BCVCLN2

Corrugated Plastic
- Strong
- Sometimes can be hard to cut
- Not really flexible but can be folded sometimes
- Thick
- Can be found in colour
- Easy to find, not expensive

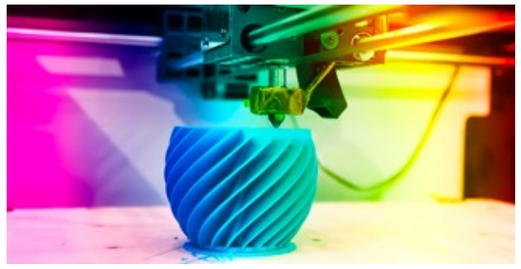
Magnet
- Allows easy attachment
- More efficient than sliding card mechanism
- More expensive

Card
- Strong to an extent
- Can be cut out easily
- Can be folded easily
- Can include colour
- Easy to find, not expensive

https://www.officemate.co.th/en/one-%E0%B8%81%E0%B8%A3%E0%B8%B0%E0%B8%94%E0%B8%B2%E0%B8%A9%E0%B8%81%E0%B8%B2%E0%B8%A3%E0%B9%8C%E0%B8%94%E0%B8%AA%E0%B8%B5-a4-180-%E0%B9%81%E0%B8%81%E0%B8%A3%E0%B8%A1-%E0%B8%82%E0%B8%B2%E0%B8%A7-50%E0%B9%81%E0%B8%9C%E0%B9%88%E0%B8%99-one-ofm5005051

Paper
- Not strong as shown through prototyping
- Can be cut out easily
- Flexible, easily folded
- Can include colour
- Easy to find, not expensive

https://www.amazon.com/Sheets-Construction-Colors-Stationery-Printers/dp/B089LR8NKQ



https://dynamicwork.net/wp/3d-printing-2019/

3D Printing
- Allows easy and fast manufacturing of blocks
- High accuracy
- Strong
- Not expensive to print
- Expensive to buy 3D printer

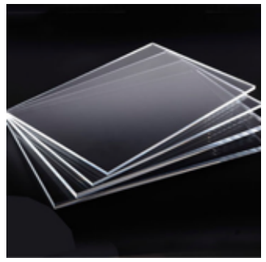
RESEARCH INTO MATERIALS

MAGNET MAZE ACTIVITY

I think wood is the best material to make the maze as it is strong and can include temporary and permanent fixings. As wood is a materials used in a range of products and toys, this should mean that it is a suitable material. Magnets are the main gimmick of this product, so it is a suitable material. Acrylic is useful as it is see-through to allow the user to see the magnet moving through the maze.

Important Characteristics of Material used:
- Strong
- Optional: See-through
- Can include temporary fixing
- Easy to find and supply, not expensive

Possible Materials that can be used:
- Card
- Wood
- Corrugated Cardboard
- Acrylic
- Corrugated plastic
- Filament (for 3D Printing)
- Magnet



Acrylic
- Strong
- See-through
- Suitable for instruction pieces (FORWARD pieces)
- Easy to find, not expensive

https://shopee.com.my/Acrylic-Perspex-Sheet-Clear-A2-A3-A4-%282mm%29-i.156706123.4619014357

Corrugated Cardboard
- Strong
- Can be glued together
- Easy to find, not expensive

https://www.packaginginnovation.com/packaging-materials/cardboard-packaging-2/3-benefits-corrugated-cardboard-packaging/

สินค้าที่จำหน่ายจริงเป็นสีเหลือง

https://www.officemate.co.th/en/magx-%E0%B9%81%E0%B8%9C%E0%B9%88%E0%B8%99%E0%B8%A2%E0%B8%B2%E0%B8%87%E0%B9%81%E0%B8%A1%E0%B9%88%E0%B9%80%E0%B8%AB%E0%B8%A5%E0%B9%87%E0%B8%81-%E0%B9%80%E0%B8%AB%E0%B8%A5%E0%B8%B7%E0%B8%AD%E0%B8%87-%E0%B9%81%E0%B8%A1%E0%B9%8A%E0%B8%81%E0%B9%80%E0%B8%AD%E0%B9%8A%E0%B8%81%E0%B8%8B%E0%B9%8C-mvc-a4y-ofm7002482

Magnet
- Allows repulsion for movement
- Efficient, unique
- More expensive

Card
- Strong to an extent
- May be too weak for a maze
- Can be glued together
- Easy to find, not expensive

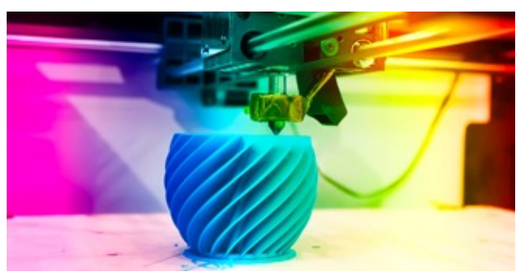
https://www.officemate.co.th/en/one-%E0%B8%81%E0%B8%A3%E0%B8%B0%E0%B8%94%E0%B8%B2%E0%B8%A9%E0%B8%81%E0%B8%B2%E0%B8%A3%E0%B9%8C%E0%B8%94%E0%B8%AA%E0%B8%B5-a4-180-%E0%B9%81%E0%B8%81%E0%B8%A3%E0%B8%A1-%E0%B8%82%E0%B8%B2%E0%B8%A7-50%E0%B9%81%E0%B8%9C%E0%B9%88%E0%B8%99-one-ofm5005051

Wood
- Strong
- Can include temporary fixing
- Used in many products, so should work
- Easy to find, not expensive

https://en.wikipedia.org/wiki/Wood

Corrugated Plastic
- Strong
- Sometimes can be hard to cut
- Can be glued together
- Easy to find, not expensive

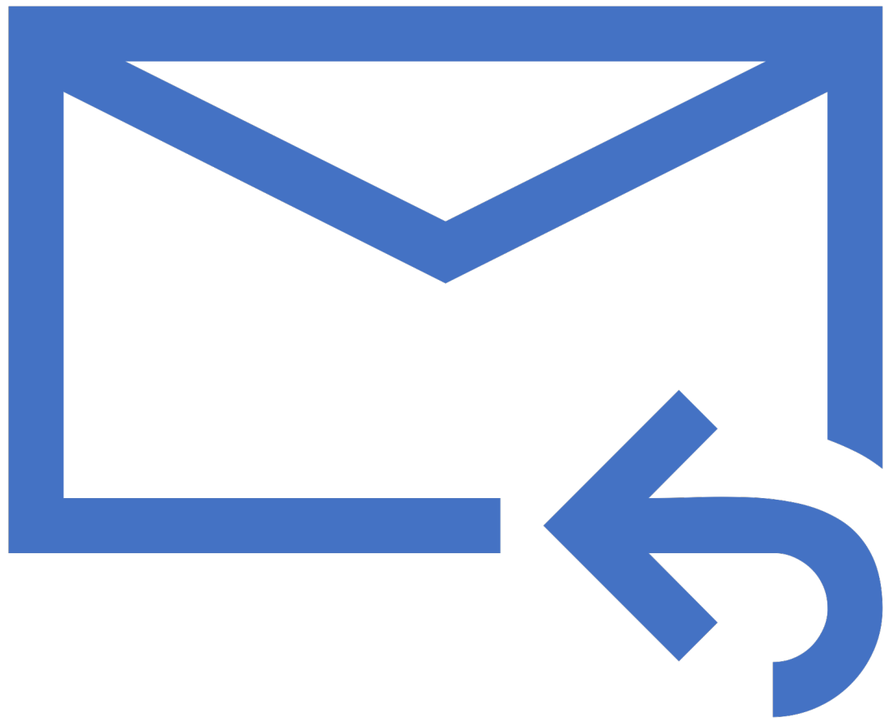
https://www.amazon.com/Falken-Design-COR-WT-6MM-2436-Corrugated/dp/B07BCVCLN2



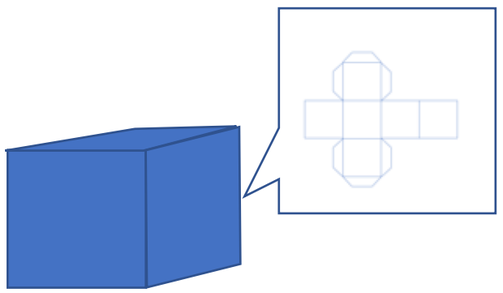
3D Printing
- Allows easy and fast manufacturing of blocks
- High accuracy
- Strong
- Not expensive to print
- Expensive to buy 3D printer

https://dynamicwork.net/wp/3d-printing-2019/

Client Feedback



FEEDBACK



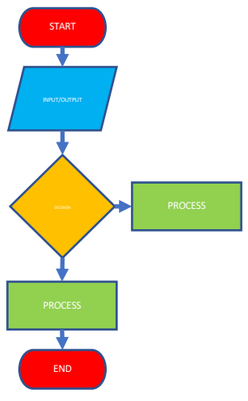
NET & APPLICATION ACTIVITY

Feedback from clients for this activity include:
+ Clients said that this was an effective hand-eye co-ordination activity.
+ This activity can be used in a larger scale, ranging from the basic tasks (for ages 8-9) to complicated tasks (for age 13-14).

- For age group 8-9 years, some aspects of this activity may be too complicated as folding and forming nets can become challenging.
- Target group may be too young for this task so some aspects may need to be adjusted to make it easier.

Overall, this activity had positive feedback with its effectiveness, but in order to satisfy the younger audience, some aspects may need to be simplified.

Overall, I received positive feedback for the three activities, meaning that I am heading into the right direction. I think the improvements will allow an increase in efficiency and effectiveness and they will be implemented to the prototype.



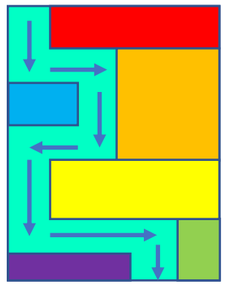
FLOWCHART ACTIVITY

Feedback from clients for this activity include:
+ Clients said that this activity was effective in introducing the flowchart symbols to students and in an interesting way.
+ This activity is simple but effectively attracts attention and interest.

- However, in order to maximize the effectiveness, the sequence of activities may need to be re-ordered, starting with BINGO then BOARD GAME.

Overall, this activity received positive feedback as its simplicity and game-related aspect intrigues the younger audience.

MAGNET MAZE ACTIVITY



Feedback from clients for this activity include:
+ Clients said that this was an engaging method of introducing code language to students in robotics.
+ If this activity is introduced to schools, it will be an effective material to lead to robotics.

- Concerns of budget
- Size of the product.

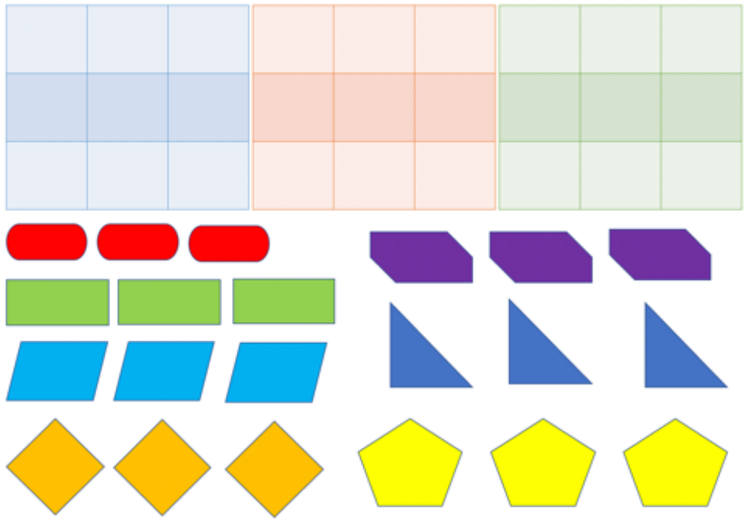
Overall, clients believed that this activity will be efficient and effective for school if it works. However, its cost and size could turn to become an issue if it exceeds a specific number.

Special thanks to teachers from Lasalle and Satit PIM for feedback.

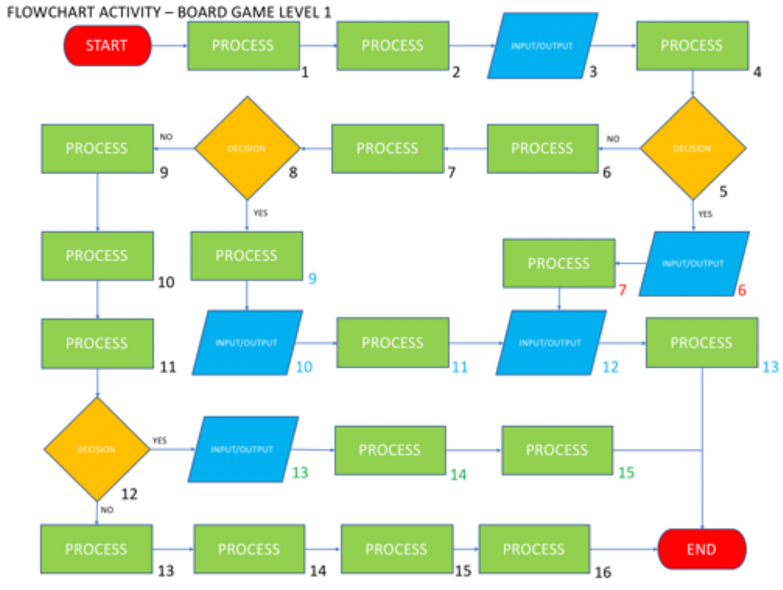
Implementing the Improvements

IMPROVING THE FLOWCHART ACTIVITY

BINGO GAME



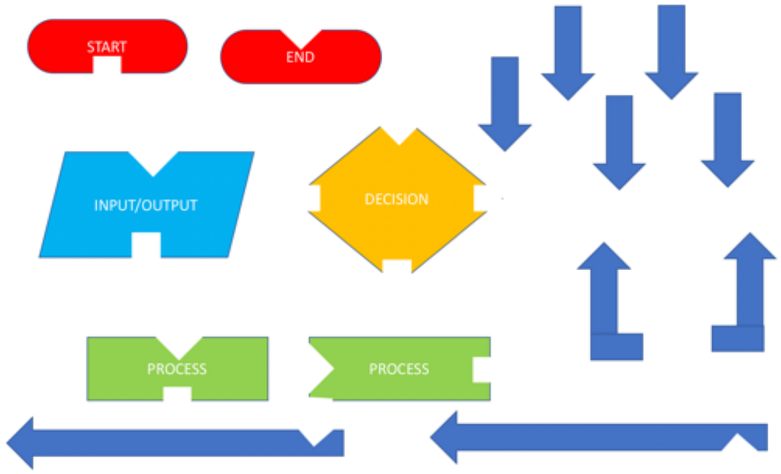
BOARD GAME

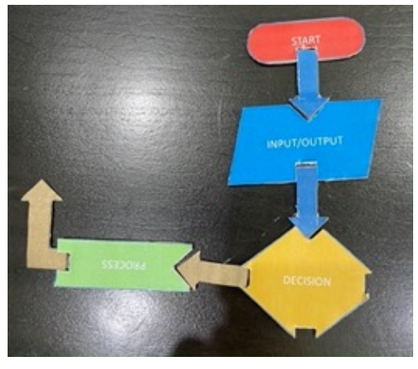


Patent Pending

My clients suggested a re-order of the sequence for this activity.

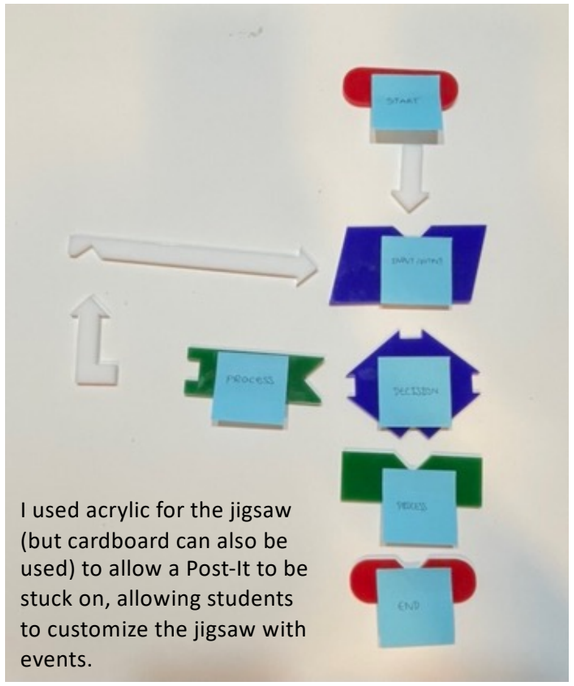
1) BINGO
2) JIGSAW
3) DAILY LIFE FLOWCHART
4) BOARD GAME
5) IMPLEMENT TO ROBOTICS

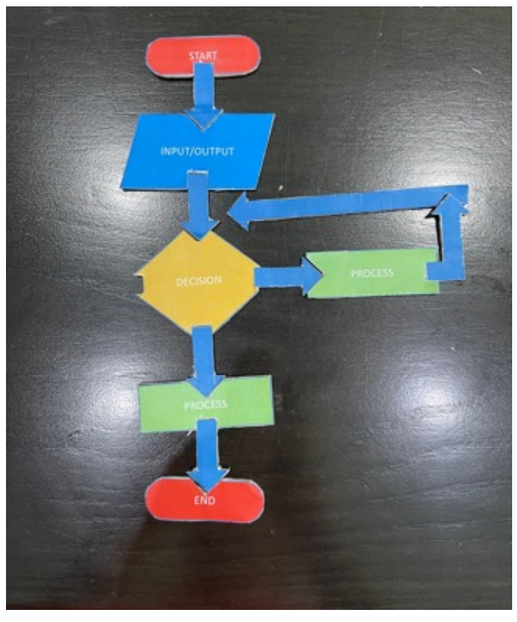




However, I found that the flowchart may be limited to variations as students may want to vary the direction of symbols.

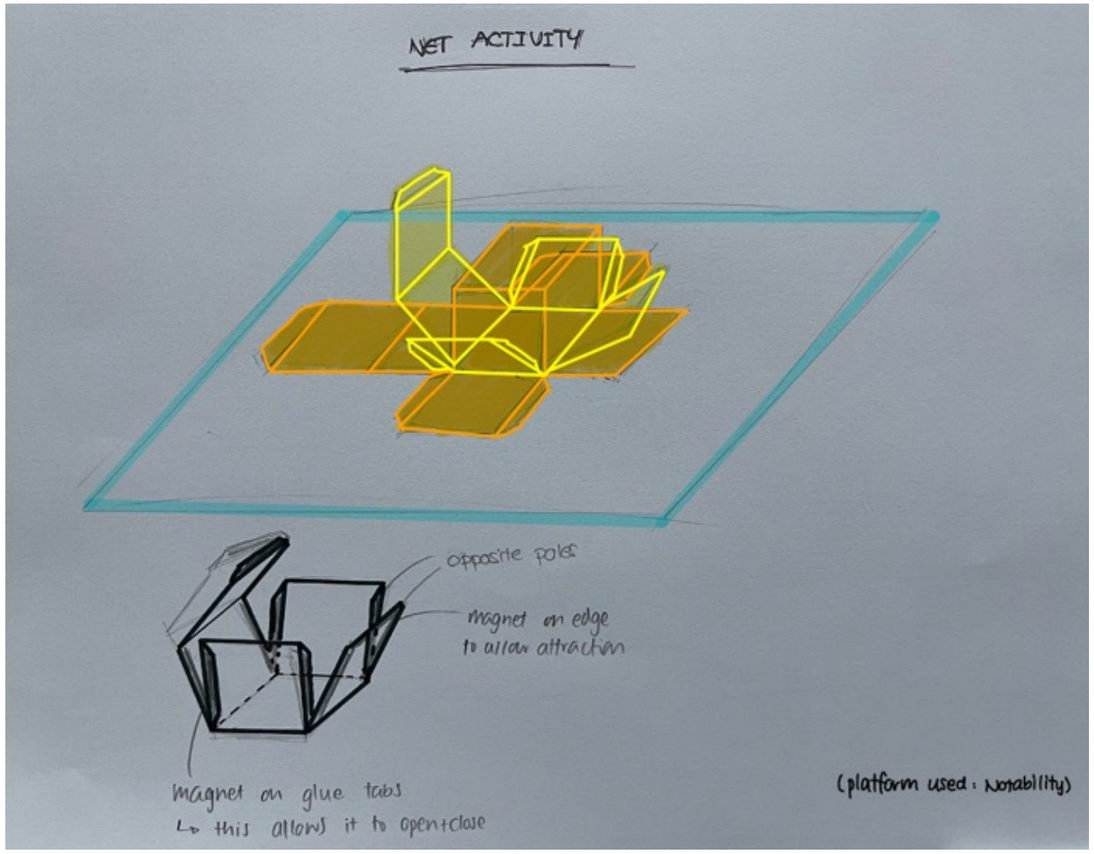
JIGSAW





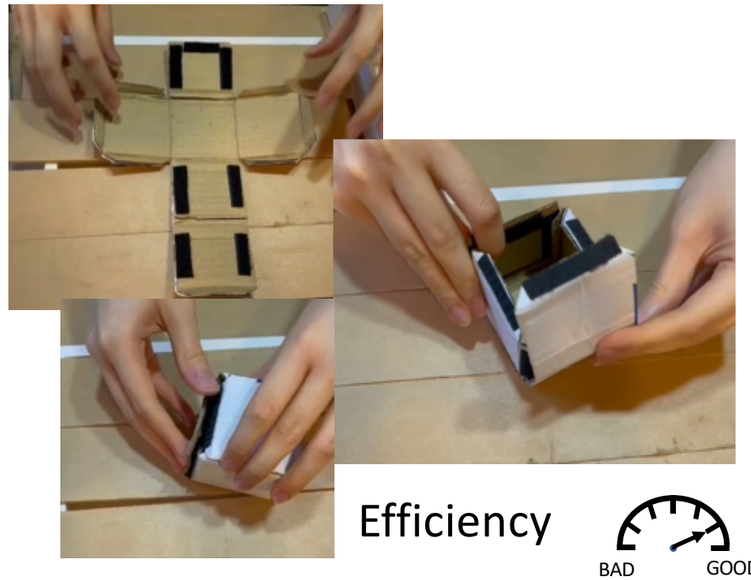
I added colour to the flowchart jigsaw and changed the connections to arrows to allow a clearer picture.

IMPROVING THE NET & APPLICATION ACTIVITY



Since imagining the net of a cube may be challenging for younger students, I think a physical imagination would prove useful to them. The drawing on the left illustrates a net of a cube with a function of attraction from magnets to allow the closing and opening of the cube. This will allow a basic and interactive introduction to nets.

I tested this idea out using corrugated cardboard and Velcro straps. The Velcro straps were very efficient and the corrugated cardboard was strong enough to be folded repeatedly.



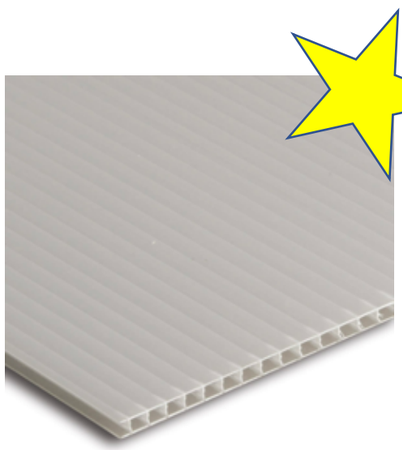
Efficiency

BAD GOOD

Budget-wise

BAD GOOD

MATERIALS THAT COULD BE USED:



Corrugated Plastic
- Strong
- Not really flexible but can be folded sometimes
- Thick
- Can be found in colour
- Easy to find, not expensive

https://www.amazon.com/Falken-Design-COR-WT-6MM-2436-Corrugated/dp/B07BCVCLN2

สินค้าที่จำหน่ายจริงเป็นสีเหลือง

Magnet
- Allows easy attachment
- Efficient
- More expensive

https://www.officemate.co.th/en/magx-%E0%B9%81%E0%B8%9C%E0%B9%88%E0%B8%99%E0%B8%A2%E0%B8%B2%E0%B8%87%E0%B9%81%E0%B8%A1%E0%B9%88%E0%B9%80%E0%B8%AB%E0%B8%A5%E0%B9%87%E0%B8%81-%E0%B9%80%E0%B8%AB%E0%B8%A5%E0%B8%B7%E0%B8%AD%E0%B8%87-%E0%B9%81%E0%B8%A1%E0%B9%8A%E0%B8%81%E0%B9%80%E0%B8%AD%E0%B9%8A%E0%B8%81%E0%B8%8B%E0%B9%8C-mvc-a4y-ofm7002482

Corrugated Cardboard
- Strong
- Can be folded
- Easy to find, not expensive

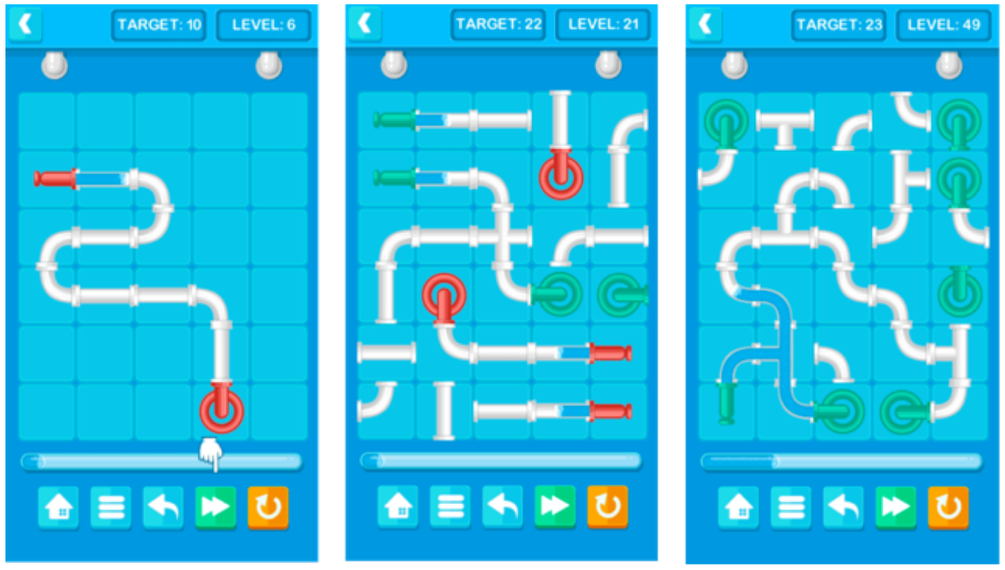
https://www.packaginginnovation.com/packaging-materials/cardboard-packaging-2/3-benefits-corrugated-cardboard-packaging/

Velcro Straps
- Allows easy attachment
- Easy to find, not expensive

https://shopee.co.th/เทปตีนตุ๊กแก-เมจิกเทป-เวลโก้เทป-มีกาว-เทปตีนตุ๊กแกแบบมีกาว-Hook-And-Loop-Tape-i.111213494.2268390214

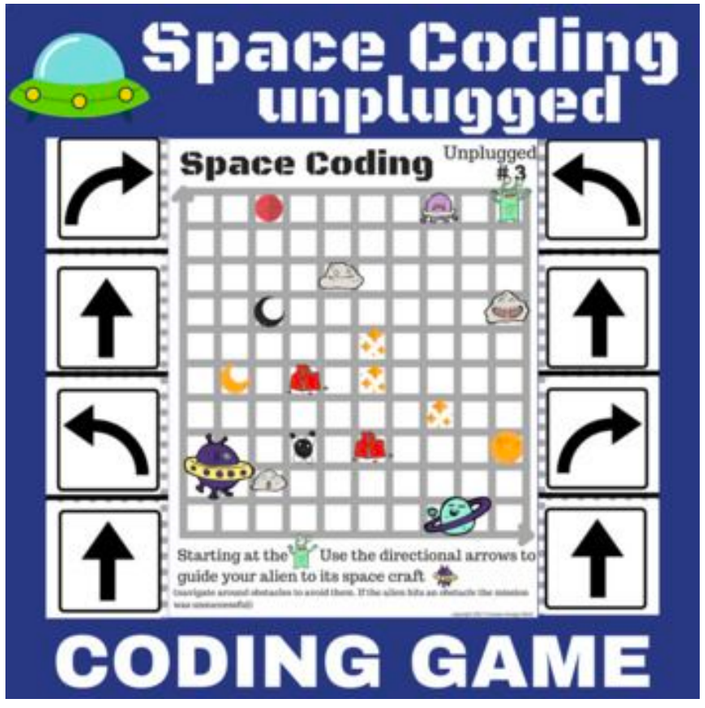
I think for the box, either corrugated plastic or corrugated cardboard can be used. In terms of the attaching mechanism, I think Velcro straps would be best as it is at a lower cost.

IMPROVING THE MAGNET MAZE ACTIVITY

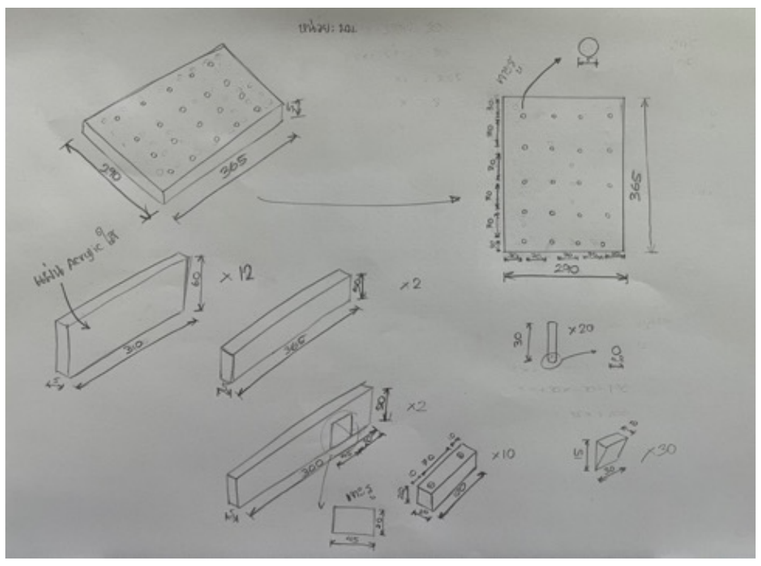


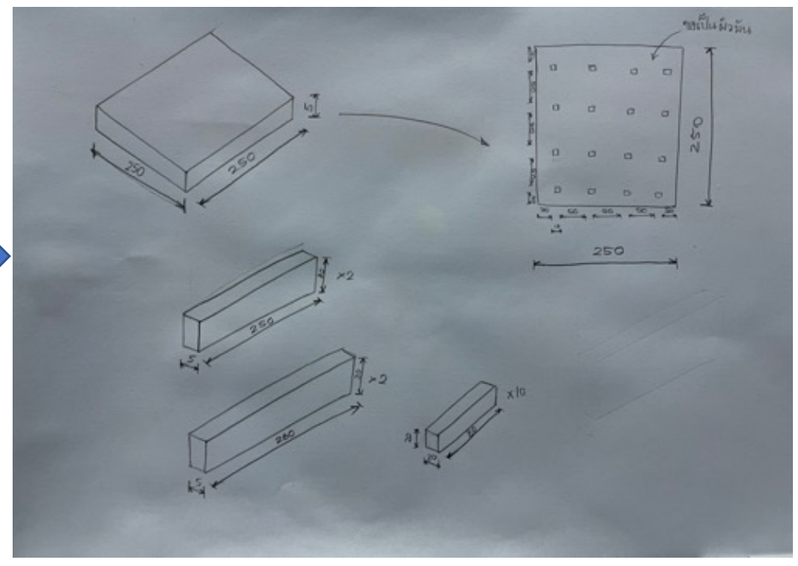
https://codecanyon.net/item/pipe-mania-html5-puzzle-game-construct-23/22791706

My clients referred to a ‘Pipe game’, which allows students to use simple commands to navigate the ball around. It was suggested to use the pipes. Another suggestion included the use of blocks with arrows or FORWARD directions to navigate around a playing board. Also, students may be assigned special tasks to earn more points such as collecting items on the board or limiting the number of directions they can move. For the second idea, students may need to write the commands they want before placing the blocks to mimic the idea of writing code and testing.



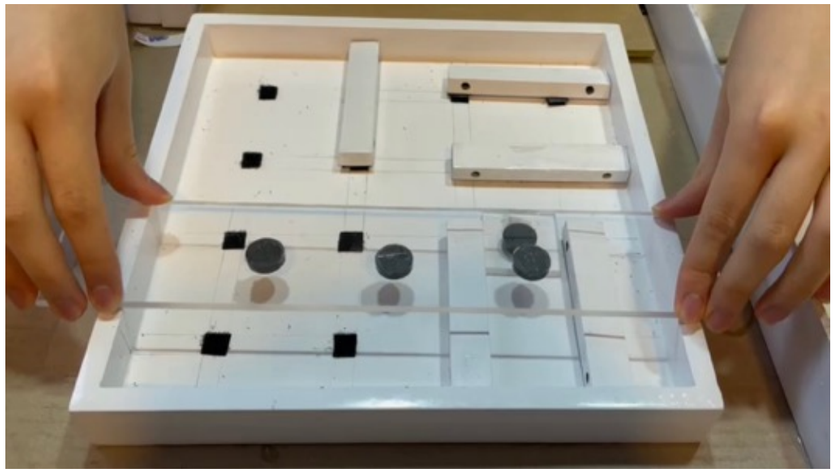
https://www.pinterest.com/pin/32440059805256779/



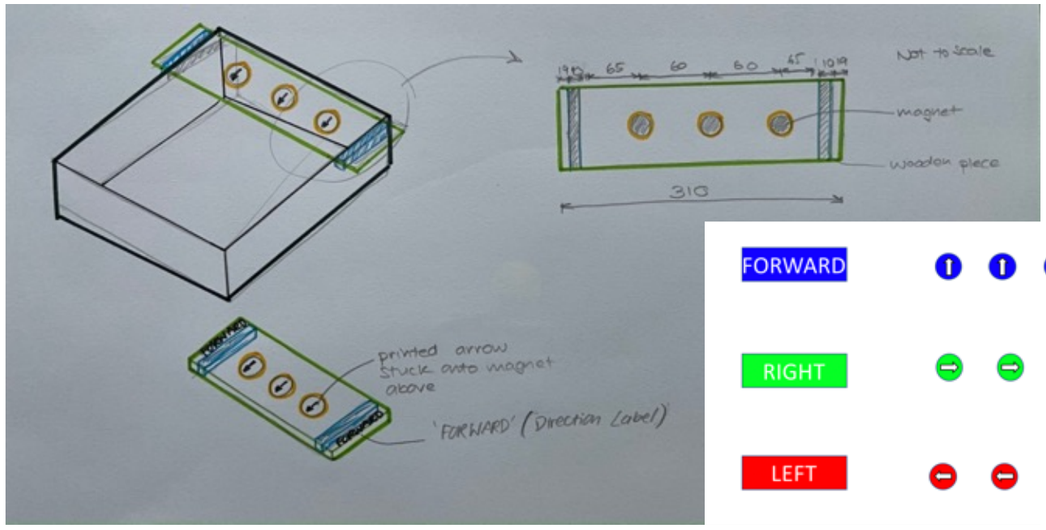


This image highlights the aspects of the product that are going to be changed. So aspects such as acrylic instruction set are kept the same, with the addition of Velcro straps.

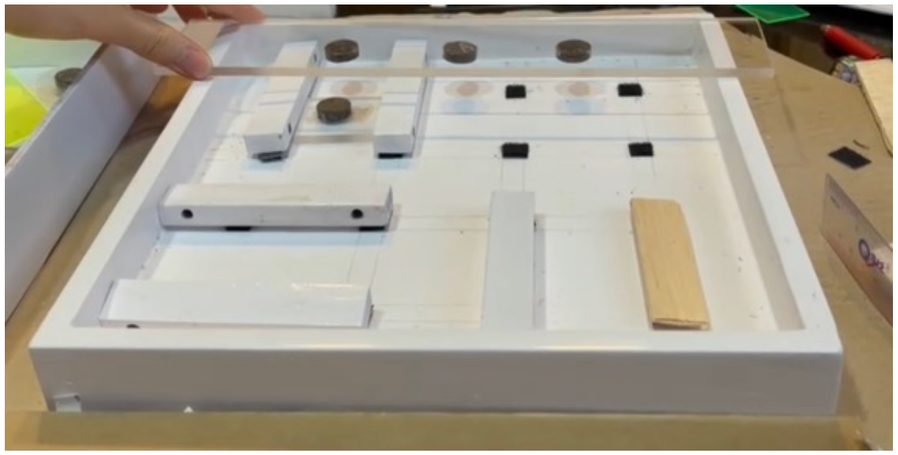
MAGNET MAZE IMPROVEMENTS

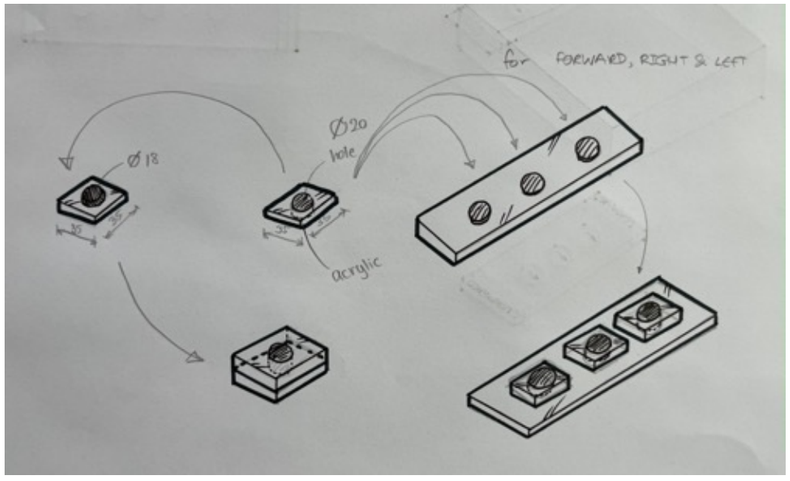


I re-designed the instruction piece by adding a small block on either end of the piece. This would allow a more efficient sliding movement and also ensure that the magnets will always be in the correct place. The addition of the direction (e.g. FORWARD) and an arrow in the direction of the sliding will allow each piece to be identifiable.



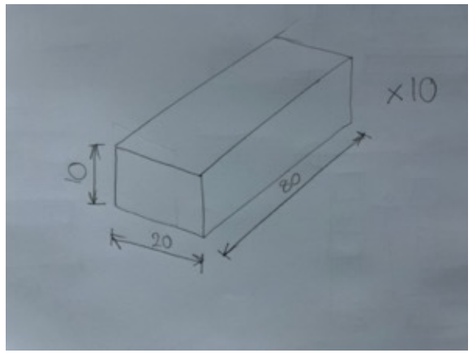
After implementing the improvements, the magnet maze became more efficient. The blocks were easier to attach and attached more easily, whilst the magnet was more effective.





Furthermore, I found that sometimes the magnet movement was unreliable and may flip to attract to the magnets above. I decided to implement the improvement above. The acrylic casing around the magnet would provide more weight to prevent the magnet flipping and prevent the magnet from trying to attract the magnet above as the acrylic thickness reduces this force. So, the casing would need to be added.

However, the use of the 20mm by 20mm by 80mm was too tall and would interfere with the magnet mechanism. So, I tested with smaller blocks and found that a better size would be 10mm by 20mm by 80mm.



In addition, the size of the acrylic, which the magnet is placed on, was made smaller to 35mm by 35mm to prevent the magnet from getting stuck between obstacles.

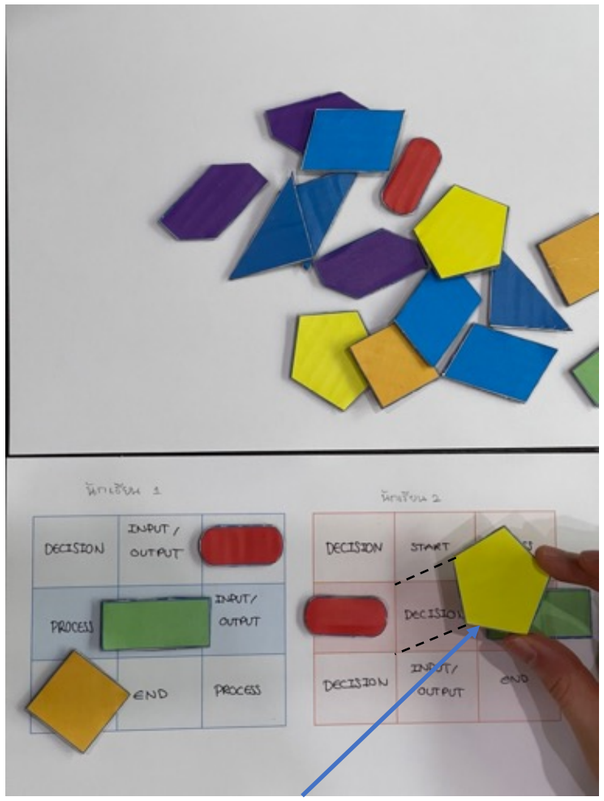
Prototyping

FLOWCHART

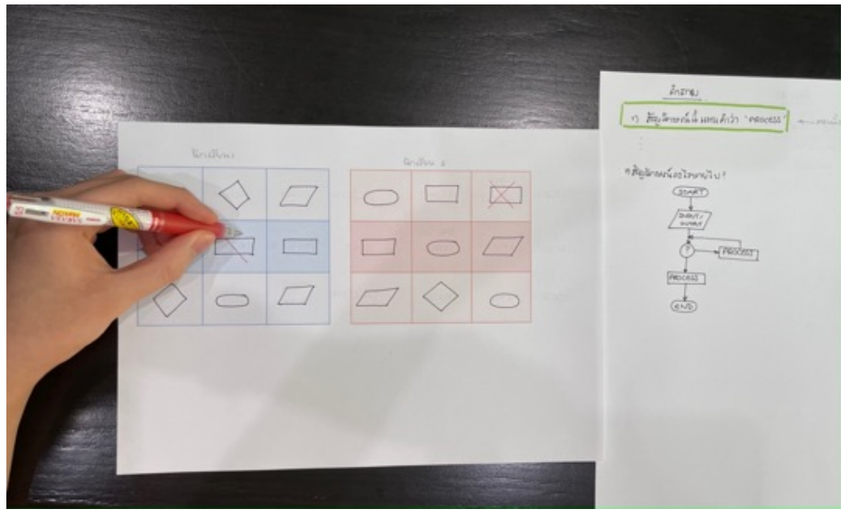
MATCH THE SYMBOL

1 set for 3 students.

Students will start with a 3x3 square, which they draw on paper. Once the teacher reads out the question, the students will need to find the symbol that represents that word. Students can only take 1 symbol per question. First to get 3 in a row wins.



For example, if the students was to put the pentagon at the decision box, this would be incorrect and they would not get the point.



This is the second level, in which students will start with a 3x3 square. Symbols from a flowchart will be written in each box. The teacher will read out a question and the students would need to cross out the symbol they think is the answer. Students can only cross out 1 symbol per question.

Materials used:
- Recycled Cardboard
- Paper (using printer to print)

Cost:
- ฿0
- ฿1 (around for 1 printed page) and around ฿0.26 per page

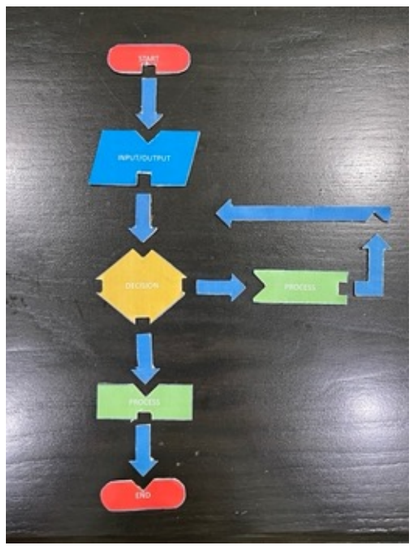
Total Cost for 1 year group (around 300 students):
฿1.26 * 100 = ฿126

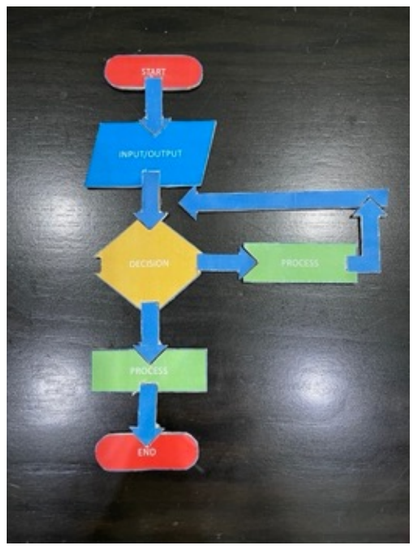
Efficiency

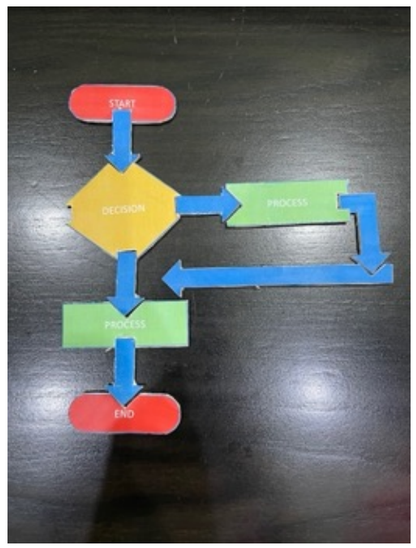
Budget-wise

FLOWCHART JIGSAW

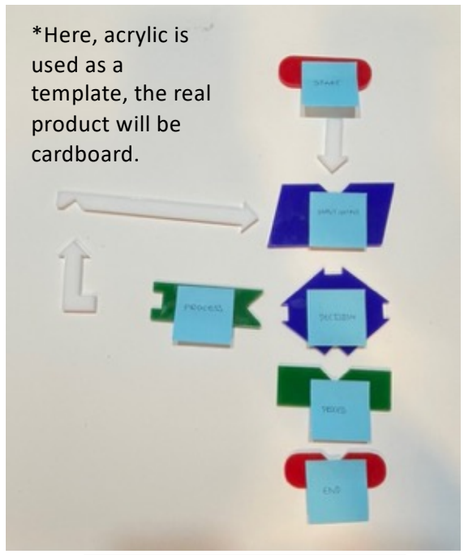
1 set for 3 students.







Students can play around with a physical version of a flowchart to allow interactive learning. They can use the jigsaw to explore different variations of the flowchart.



*Here, acrylic is used as a template, the real product will be cardboard.

Total Cost for 1 year group (around 300 students):
(฿1.26) * 100 = ฿126

Materials used:
- Recycled Cardboard
- Paper (using printer to print)

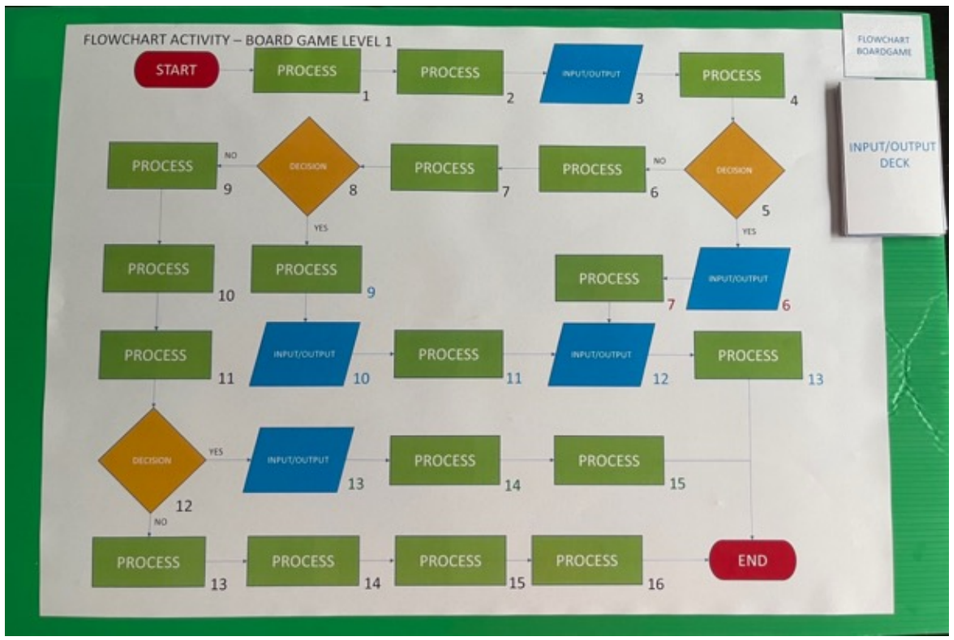
Cost:
- ฿0
- ฿1 (around for 1 printed page) and around ฿0.26 per page

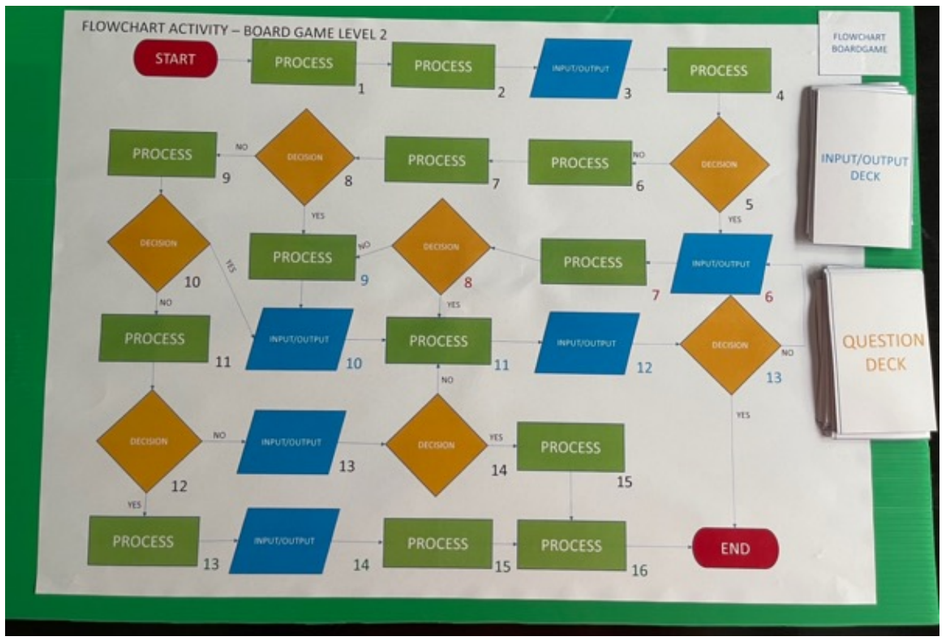
Efficiency

Budget-wise

FLOWCHART

BOARD GAME





PLAYING THE BOARD GAME

1 set for 4 students.

Total Cost for 1 year group (around 300 students):
(฿4.68 + ฿3.02 + ฿35) * 75 = ฿3,202.5

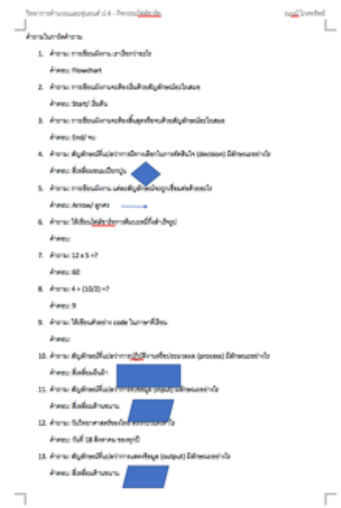
Patent Pending

Efficiency

Budget-wise

Materials used:
- Card or Paper
- Paper (using printer to print)
- Corrugated Plastic (Future Board); or any type of board that is strong.

Cost:
- ฿4.68 around 3 pages of card (around ฿1.3 per page and around ฿1 for 1 printed page)
- ฿1 (around for 1 printed page) and around ฿0.26 per page
- ฿3.02 (฿0.51 per A3 page) and around ฿1 for 1 printed page
- ฿35 for corrugated plastic (around A3 size).

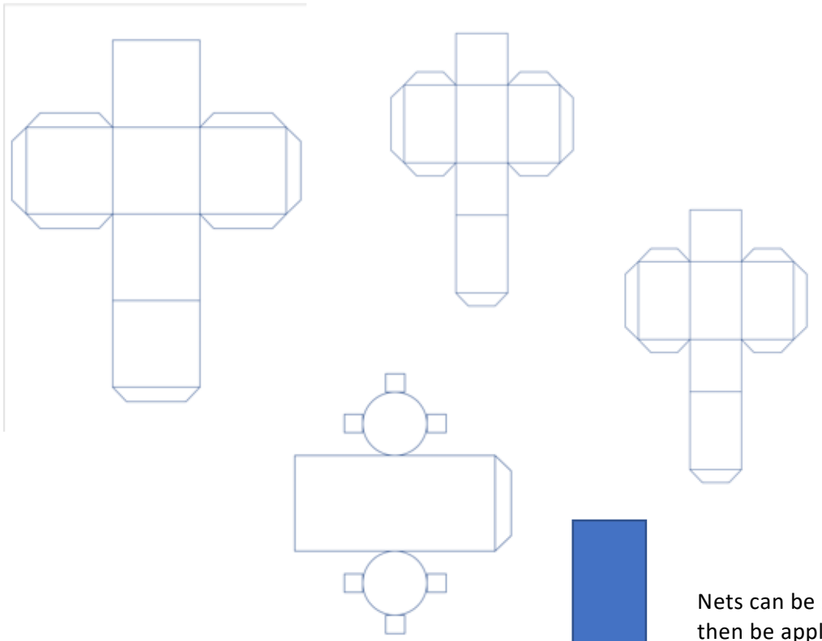


14. คำถาม: อุปกรณ์ที่ใช้ในหุ่นยนต์มีอะไรบ้าง
    คำตอบ: เหล็ก, program code, มู่เตอและใบพัด
15. คำถาม: ให้ยกตัวอย่างข้อมูลส่วนบุคคลที่เราไม่ควรเปิดเผยกับคนอื่น
    คำตอบ: พาสเวิร์ด/ รหัสผ่าน, เลขประจำตัวประชาชน, รหัส ATM, ฯลฯ
    15 คำถามนี้เป็นเพียงตัวอย่าง คุณครูสามารถปรับคำถามและคำตอบได้

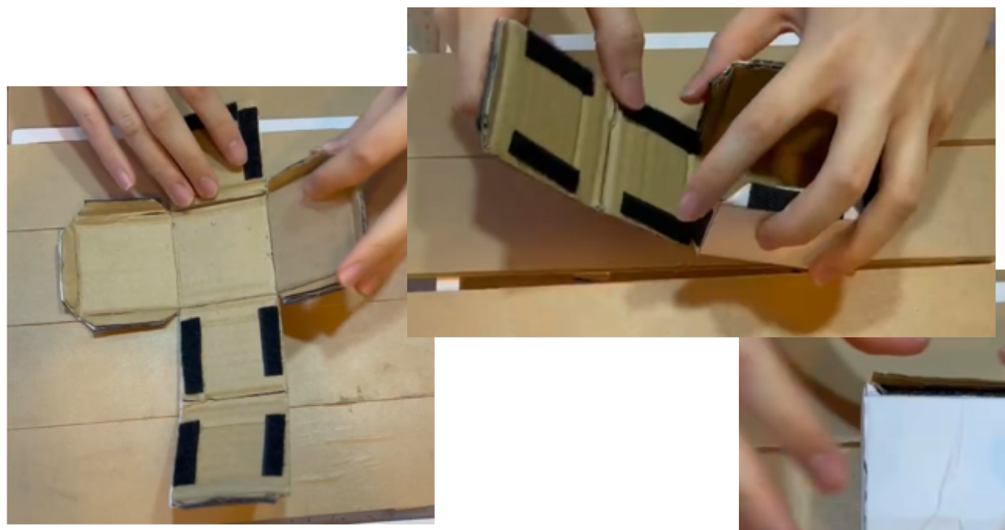
NET & APPLICATION

1 set for 2 students.

NETS

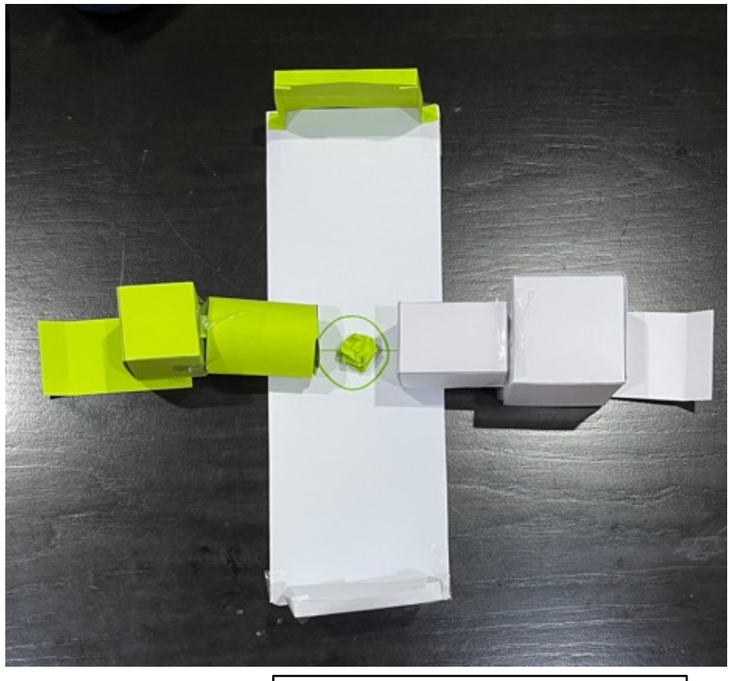


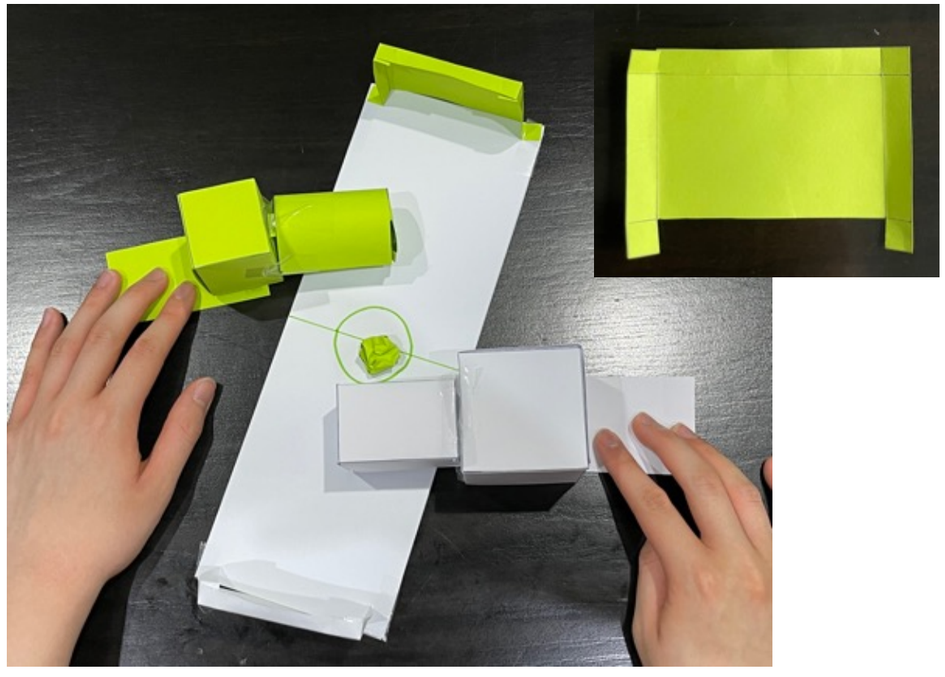
NET MODEL



Nets can be drawn and then folded into 3-Dimensional objects. These can then be applied to make different tasks.

EXAMPLE: FOOTBALL GAME





Total Cost for 1 year group (around 300 students):
(฿6.5 + ฿14) * 150 = ฿3,075

Efficiency

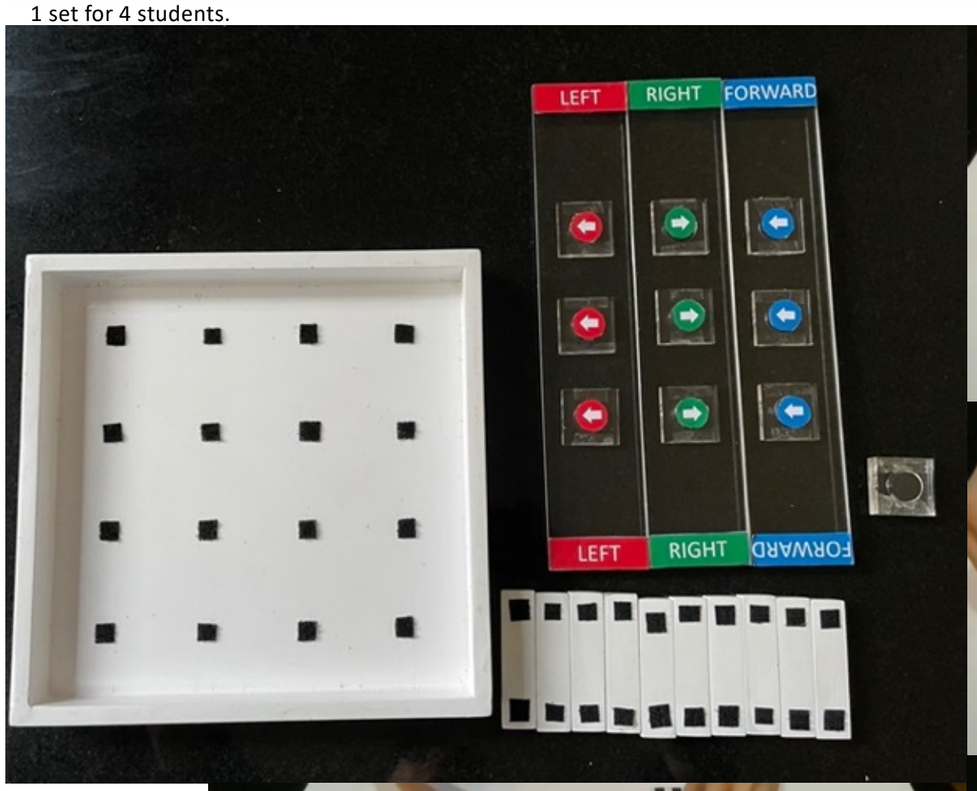
Budget-wise

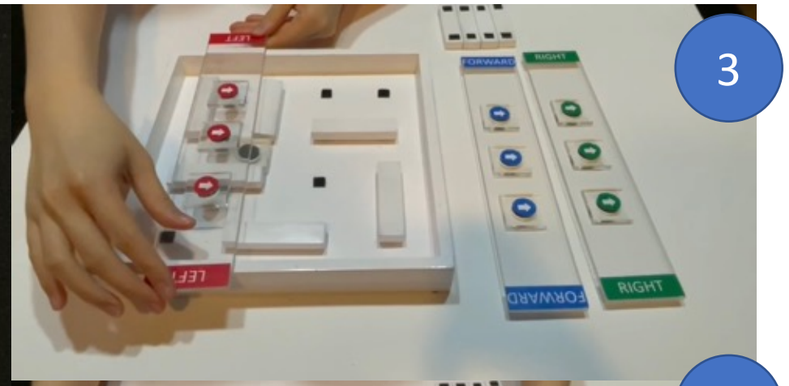
Materials used:
- Card
- Recycled Cardboard
- Velcro straps

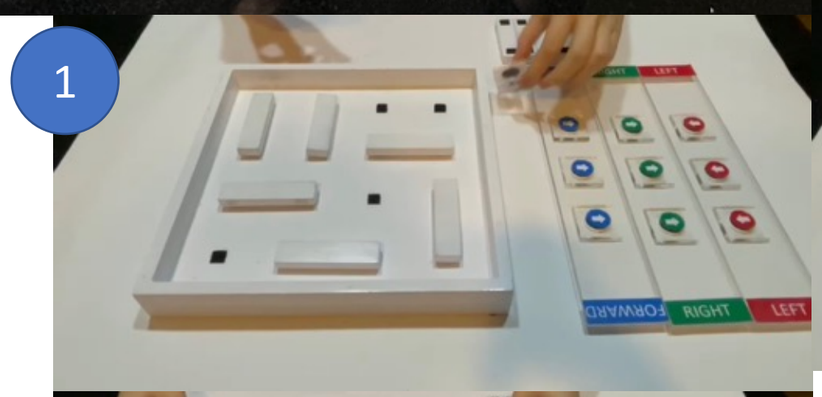
Cost:
- ฿1.3 per page
- ฿0
- Around ฿14 for 14 pieces required

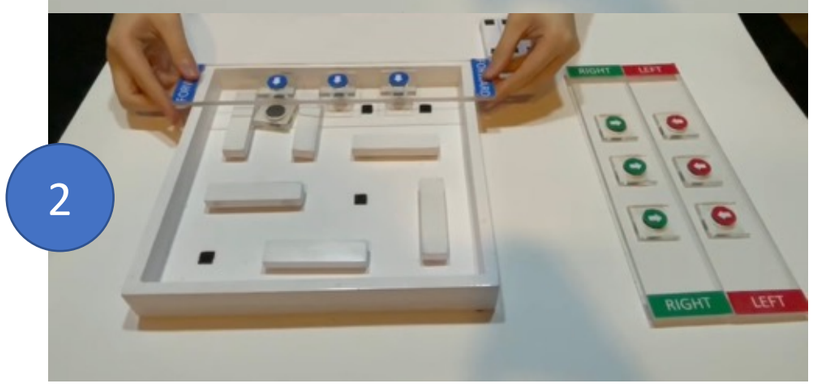
MAGNET MAZE

1 set for 4 students.









Patent Pending

Efficiency

Budget-wise

Materials used:
- Viva Board/Wood
- Magnet
- Acrylic
- Velcro straps
- Paper (using printer to print)
- Laser cutting

Cost:
- ฿10 (around for pieces required)
- ฿70 (for 10 magnets required)
- ฿67.35 (around for pieces required)
- ฿18.9 (around for 36 1cmx1cm pieces)
- ฿1 (around for 1 printed page) and around ฿0.26 per page
- ฿200 (around for pieces required)

Total Cost for 1 year group (around 300 students):
(฿10 + ฿70 + ฿67.35 + ฿18.9 + ฿1.26+฿200) * 75 = ฿27,563.25

KIT LIST

It is important that the products contain a kit list. This allows the user to know how to use the product and teachers understand how they can use this product to teach their students. A kit list ensures that all components of the product is present, the product is used correctly and efficiently and safely.

NET & APPLICATION ACTIVITY

Materials required:

- Paper Card pack (approximately 100 sheets)
- Net Model
- Kit List and Instructions

Other equipment required:

- Scissors
- Glue

Paper Card pack can be used for a whole class. Several kit lists may be needed for each table and the teacher.

FLOWCHART ACTIVITY

Materials required:

- Flowchart Jigsaw
- Flowchart Board Game
- Flowchart Match the Symbol
- Kit List and Instructions

Other equipment required:

- Paper Card
- Scissors
- Glue

OR

- Dice
- Counters

Other equipment choice may depend on the school of which they prefer. Paper Card Option allows students to use net skills to build dice and counters.

KIT LIST & PRICE

MAGNET MAZE ACTIVITY

Materials required

- Maze Board
- Magnet Pieces for instruction
- Obstacles for board
- Magnet
- Kit List and Instructions

Board can be supplied constructed or supplied with each component. Smaller components will be stored in zip-lock bags and larger pieces will be stored in the main box.

PRICE

FLOWCHART		NET & APPILICATION		MAGNET MAZE		TOTAL COST	
300 STUDENTS	฿3,454.5	**300 STUDENTS**	฿3,075	**300 STUDENTS**	฿27,563.25	**300 STUDENTS**	฿34,092.75
AVERAGE PER STUDENT	฿11.52	AVERAGE PER STUDENT	฿10.25	AVERAGE PER STUDENT	฿91.88	**AVERAGE PER STUDENT**	฿114

BIBLIOGRAPHY

Reference list

iRobot Education. (n.d.). *Coding Robots, Learning Library & STEM Outreach*. [online] Available at: https://edu.irobot.com/ [Accessed 20 Feb. 2022].

mblock.makeblock.com. (n.d.). *mBlock*. [online] Available at: https://mblock.makeblock.com/.

microbit.org. (2020). *micro:bit at home - activity picker*. [online] Available at: https://microbit.org/news/2020-05-09/microbit-at-home-activity-picker/ [Accessed 20 Feb. 2022].

น้ำครู (2018). *รวมบทความเกี่ยวกับวิชา วิทยาการคำนวณ*. [online] Dek-D's School. Available at: https://school.dek-d.com/blog/kidcoding/computationalthinking/.

Nattapon's Blog. (2019). *กรกฎาคม 2019*. [online] Available at: http://www.nattapon.com/2019/07/ [Accessed 20 Feb. 2022].

Packaging Innovation. (2014). *3 benefits of corrugated cardboard packaging*. [online] Available at: https://www.packaginginnovation.com/packaging-materials/cardboard-packaging-2/3-benefits-corrugated-cardboard-packaging/.

Powers, M. (2018). *Code.org*. [online] Common Sense Education. Available at: https://www.commonsense.org/education/website/codeorg.

Pratchatorn School. (n.d.). *Robot – โรงเรียนปรัชชาธร*. [online] Available at: https://www.pratchatorn.ac.th/news/robot/.

redfoc (n.d.). *Pipe Mania - HTML5 Puzzle Game (Construct 2/3)*. [online] CodeCanyon. Available at: https://codecanyon.net/item/pipe-mania-html5-puzzle-game-construct-23/22791706 [Accessed 28 Mar. 2022].

Shopee.co.th. (2021). [online] Available at: https://shopee.co.th/.

Shopee.com.my. (2022). [online] Available at: https://shopee.com.my/Acrylic-Perspex-Sheet-Clear-A2-A3-A4-%282mm%29-i.156706123.4619014357 [Accessed 28 Mar. 2022].

teacherspayteachers (n.d.). *Space Coding Unplugged | Coding lessons, Unplugged coding activities, Teaching coding*. [online] Pinterest. Available at: https://www.pinterest.com/pin/324400598052567 79/ [Accessed 28 Mar. 2022].

Torsakuln (2020). *เกิดอะไรขึ้นกับเทคโนโลยี 3D printing ทั่วโลกในปี 2019 นี้บ้าง ? | Dynamicwork.co.,ltd*. [online] dynamicwork. Available at: https://dynamicwork.net/wp/3d-printing-2019/ [Accessed 28 Mar. 2022].

Wikipedia Contributors (2019a). *Flowchart*. [online] Wikipedia. Available at: https://en.wikipedia.org/wiki/Flowchart.

Wikipedia Contributors (2019b). *Scratch (programming language)*. [online] Wikipedia. Available at: https://en.wikipedia.org/wiki/Scratch_(programming_language).

Wikipedia Contributors (2019c). *Wood*. [online] Wikipedia. Available at: https://en.wikipedia.org/wiki/Wood.

www.amazon.com. (n.d.). *Amazon.com: A4 Color Paper,100 Sheets Construction Paper,10 Colors Stationery Paper,100GSM Inkjet and Laser Printers Paper for Home School Office,8.3 x 11.7 Inches : Office Products*. [online] Available at: https://www.amazon.com/Sheets-Construction-Colors-Stationery-Printers/dp/B089LR8NKQ [Accessed 28 Mar. 2022].

www.amazon.com. (n.d.). *Amazon.com: Falken Design COR-WT-6MM/2436 Coroplast Sign Board, Corrugated Fluted Plastic Sheet 6mm (0.236") 24" x 36" - White, Plastic : Industrial & Scientific*. [online] Available at: https://www.amazon.com/Falken-Design-COR-WT-6MM-2436-Corrugated/dp/B07BCVCLN2 [Accessed 28 Mar. 2022].

www.officemate.co.th. (n.d.). *Colour Card Paper A4 180 gsm. White (50/Pack) ONE | OfficeMate*. [online] Available at: https://www.officemate.co.th/en/one-%E0%B8%81%E0%B8%A3%E0%B8%B0%E0%B8%94%E0%B8%B2%E0%B8%A9%E0%B8%81%E0%B8%B2%E0%B8%A3%E0%B9%8C%E0%B8%94%E0%B8%AA%E0%B8%B5-a4-180-%E0%B9%81%E0%B8%81%E0%B8%A3%E0%B8%A1-%E0%B8%82%E0%B8%B2%E0%B8%A7-50%E0%B9%81%E0%B8%9C%E0%B9%88%E0%B8%99-one-ofm5005051 [Accessed 28 Mar. 2022].

www.officemate.co.th. (n.d.). *ออฟฟิศเมท (OfficeMate) ที่เดียวครบ ตอบโจทย์ทุกธุรกิจ*. [online] Available at: https://www.officemate.co.th/ [Accessed 28 Mar. 2022].

www.robomindacademy.com. (n.d.). *Course overview*. [online] Available at: https://www.robomindacademy.com/navigator/courses [Accessed 20 Feb. 2022].

www.robotsiam.com. (n.d.). *micro:bit Smart Robot Car V2.0*. [online] Available at: https://www.robotsiam.com/product/198/microbit-smart-robot-car-v2-0 [Accessed 20 Feb. 2022].

www.vexrobotics.com. (n.d.). *VEXcode VR - VEX Robotics*. [online] Available at: https://www.vexrobotics.com/vexcode-vr.

www.youtube.com. (2014). *CodeCombat Multiplayer Tutorial*. [online] Available at: https://www.youtube.com/watch?v=IFvfZiJGDsw [Accessed 20 Feb. 2022].