# Cognitive IoT Braille Game Design for Inclusive TVET in the Digital Era

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**Abstract:** The incorporation of blind and visually impaired students into Malaysia's conventional Technical and Vocational Education and Training is constrained by insufficient inclusive infrastructure, assistive technologies, and specialised educational resources. This paper intends to fill this gap by creating a Cognitive IoT-Enabled Braille Board Game designed to enhance cognitive development encompassing memory, spatial reasoning, and problem-solving via interactive and tactile learning experiences, especially for TVET students. The work aims to create a prototype of a cognitively stimulating IoT braille board game for blind and visually impaired individuals. It involves creating a concept sketch, integrating the game with microcontroller programming, locking system, and sensors, and evaluating its performance in real-time by analysing blind and visually impaired individuals' cognitive skills. Results indicate that the game could enhance cognitive abilities in visually impaired communities, potentially promoting cognitive development via physical education and science and technology. It shows that the game can evaluate the effectiveness of a particular set of working-memory training tasks in an ecologically valid setting in the context of brain games.

***Keywords: Keywords*** *Cognitive Learning, IoT, Braille Technology, Inclusive TVET, Digital Education*

## 1.0 INTRODUCTION

The fast development of digital technology has transformed Technical and Vocational Education and Training (TVET), providing novel opportunities for inclusive, accessible, and tailored learning experiences. Nonetheless, despite these technological advancements, individuals with visual impairments persistently have substantial obstacles in obtaining quality TVET programs. The digital divide has particular significance for this group, as conventional teaching methods and digital platforms frequently fail to provide the tactile and cognitive adaptations required to facilitate their learning preferences and necessities.

Incorporating Cognitive Internet of Things (Cognitive IoT) into assistive educational technologies addresses this significant deficiency and offers a transformative possibility. Cognitive IoT denotes intelligent systems that integrate sensory input, real-time data analysis, and adaptive learning processes to provide interactive and tailored user experiences. Cognitive IoT can significantly enhance engagement, accessibility, and skill acquisition for visually impaired learners in the TVET sector when utilized in the creation of educational games, especially through Braille-based interfaces. Based on rankings from Board game Geek (BBG), the board games that are accessible to the most visually impaired, as illustrated in Figure 1.

THE BEST BOARD GAMES FOR THE VISUALLY IMPAIRED

| BOARD GAME RANK | BGG RANK | BGG AVERAGE SCORE | PRICE |
|---|---|---|---|
| 1 Chess | 441st | 7.12 / 10 | £38 |
| 2 Cribbage | 608th | 7.06 / 10 | £15 |
| 3 Liar's Dice | 676th | 6.9 / 10 | £4 |
| 4 Quarto | 944th | 6.86 / 10 | £34 |
| 5 Quoridor | 1,200th | 6.67 / 10 | £29 |
| 6 Katamino | 3,711st | 6.42 / 10 | £30 |
| 7 Bananagrams | 1,738th | 6.37 / 10 | £28 |
| 8 Scrabble | 1,792nd | 6.28 / 10 | £33 |
| 9 Reversi | 2,733rd | 6.1 / 10 | £10 |
| 10 Connect 4 Advanced | 6,818th | 5.95 / 10 | £19 |

*BGG: BOARDGAMEGEEK

***Figure 1:*** *The Best Board Games for People Who Are Blind or Visually Impaired [1]*

This paper presents the design and development of a Cognitive IoT Braille Game, an innovative solution designed for inclusive Technical and Vocational Education and Training (TVET). The proposed system utilises tactile interfaces, real-time feedback, and intelligent content delivery to enhance cognitive learning in fundamental reading, coding logic, and occupational skills. This project seeks to integrate with Sustainable Development Goal 4 (Quality Education) and Malaysia's Digital TVET Transformation Framework to empower differently abled learners and guarantee inclusivity in the digital transition of vocational education.

The following sections of this paper will examine the related works, the theoretical foundations of inclusive design, the technical framework of the Braille IoT gaming system, user interaction methods, and preliminary results from prototype implementation. This effort aims to enhance the debate on inclusive innovation in TVET and demonstrate how cognitive IoT technologies may address equity gaps in education and workforce preparedness.

## 2.0 LITERATURE REVIEWS

Previous studies show that games in learning can enhance human thinking skills as games can develop cognitive skills [2-8]. People who participate in Higher-Order-Thinking (HOT) skills can go further than the fundamental level of understanding. They can analyse, synthesise, evaluate, and interpret the text they are reading at complex levels. These skills emphasise individual capacity and create competent individuals. Critical thinking is an essential quality in solutions to complex problems. Board games also play a significant role in the learning process. They significantly increase early

learning, brain vibrating, fluency and communication skills, and teamwork, among other cognitive skills. These skills emphasise individual capacity and create competent individuals.

According to research, playing board games has been shown to stimulate brain areas involved in complex thought and memory formation in children and adults. [9-11]. Previous research has also shown that using games in the classroom can improve students' thinking skills by helping them develop cognitive skills [12]. New neurons aid in maintaining cognitive abilities such as learning and attention. Several studies have found a link between playing certain video games and improved decision-making abilities and cognitive flexibility [13].

One of the most important criteria for academic success today is thinking independently while remaining logical. Education is one of the main factors under 10 of SOCIO-ECONOMIC DRIVERS for 2021 as the continuing education spans from pre-school to post-doctoral. Today, education is aimed at nurturing a creative society and qualified employees. According to Linda Elder et al., students who can analyse and critique ideas can better connect disciplines, perceive knowledge as relevant in everyday life, and understand the content on a broader and extra-sustained level [14]. In solutions to complex problems, critical thinking is an essential quality. Higher-Order-Thinking (HOT) participants go above and beyond the basics.

Visual impairment is a risk factor for visual-sensory and overall development [15]. The education sector generates income and focuses on individual capacity, enhancing decision-making, evaluation, and problem-solving. The new economy demands flexible intellectual skills, and critical thinking enhances academic performance and gives employees an edge in the market, enabling independent thinking. Studies have been conducted through tests that would ultimately show the difference between children and their cognitive abilities at different ages [16]. Based on Piaget's theory of cognition, visual impairment is defined as the loss of vision that ranges from partial vision loss to the disability to see. The range of vision impairment is divided into several categories listed in Table 1.

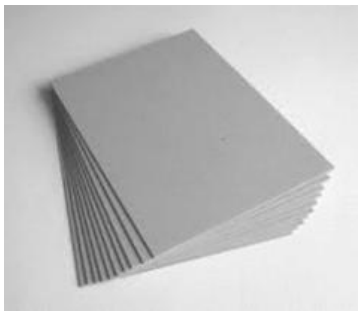
The experience of visual impairment is different for each individual, it varies depending on various factors such as the availability of prevention and treatment interventions, access to vision rehabilitation (including assistive products such as glasses or white canes), and whether the individual experiences problems with inaccessible buildings, transport and information [17].

**Table 1**
Level of Impairment

| Level of Impairment | Value of Visual Acuity |
|---|---|
| Mild | Worse than 6/12 to 6/18 |
| Moderate | Worse than 6/18 to 6/60 |
| Severe | Worse than 6/60 to 3/60 |
| Blindness | Worse than 3/60 |

### *2.1 Material Used for Board Game*

There are several different types of materials commonly used for the outer part of a board game. The most common material is the binding board as illustrated in Figure 2a. A binding board is made from the same material as a hardback book cover. They are also made from chipboard or very thin wood. The thickness of the board, the density of the fibres and the type of materials used all affect the rigidity, humidity resistance and durability of the board. A binding board is commonly layered with a textured paper wrap, printed paper, and a coating layer [18]. Besides that, a 2 to 2.5mm thick grey board is also commonly used to make the exterior component for a board game. Figure 2b shows a greyboard is a stronger version of cardboard. It is one of the easiest components to be used when making a prototype, as it can be found at local bookstores. Grey boards are quite durable but require a layer of coating for protection [19].



*a) Binding Board* *b) Grey Board*

***Figure 2:*** *Material used for board games from previous work.*

### *2.2 Adjusted Board Games Available*

Figure 3a illustrates the Braille Monopoly, an adapted board game tailored for players with visual impairments. This version includes oversized cards featuring braille, a 20-inch layout with a unique overlay, as well as brailled dice, cards, and currency. Nonetheless, it necessitates considerable memory and effort to execute accurately [20]. In addition, Scrabble, a family favourite, was made more accessible to the visually handicapped. Figure 3b shows Braille Scrabble with Braille-marked plastic tiles that have been adjusted for the visually impaired, featuring tactile and Braille markings, layered surfaces, and a built-in base for easy accessibility [21].



a) Brailled Monopoly b) Brailled Scrabble

***Figure 3:*** *Example of adjusted board games available*

To approach this gap, this paper presents the development of a prototype for a cognitively stimulating IoT braille board game designed for those who are blind or visually impaired. The process entails creating a conceptual sketch with AutoCAD to provide a digital illustration of the idea and utilising a 3D printer for the hardware system. The proposed Cognitive IoT Braille Game prototype enhances previous board games for the visually impaired, which mainly emphasised tactile accessibility and entertainment, by incorporating educational elements through intelligent feedback and adaptive learning mechanisms, thus filling a significant void in inclusive digital TVET content for visually impaired learners.

## 3.0 METHODOLOGY

### *3.1 Conceptual Framework of the Project*

Figure 4 shows the experimental setup of the prototype. This project emphasises the implementation of hardware, software, and human cognitive impact performance via alpha and beta testing. It is categorised into three different phases. Phase 2 emphasises hardware and software implementation, whereas the Alpha and Betha testing is carried out in Phase 3. The board is created using a 3D printer based on the design. The second part involves the interface between the board with the IoT (the electronics and sensor integration) to give the user interaction with the team members. In phase 3 for data sampling, the human cognitive impact performance via alpha and beta testing involves 30 blind or visually impaired game participants. In this phase, the influence of the Cognitive IoT Braille Board Game on brain neuron stimulation in visually impaired people is unraveled.

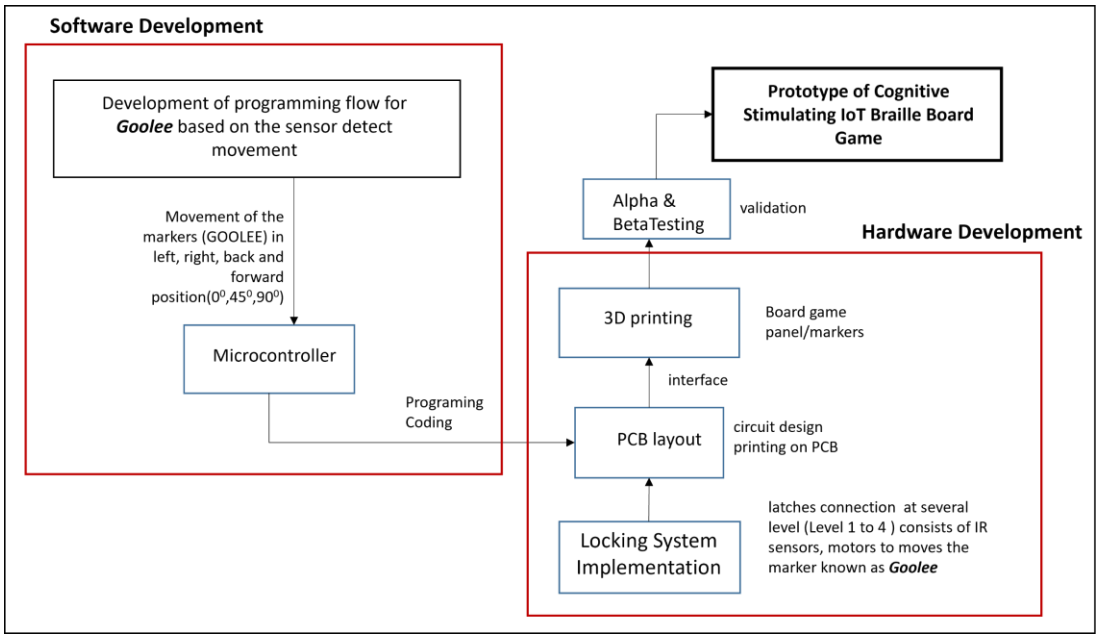



***Figure 4:*** *Experimental Setup*

This paper focuses on achieving set objectives, including the use of suitable materials to reduce weight, improve product durability, and reduce production costs. The system used on each level is carefully selected to avoid unnecessary parts and reduce production costs. The language used on the board is crucial for players to understand the game's components and achieve goals, ensuring they can fully enjoy the experience.

### *3.2 Conceptual Framework of the Project*

The overall flowchart in Figure 17 resembles the general input and output of the development of this prototype.

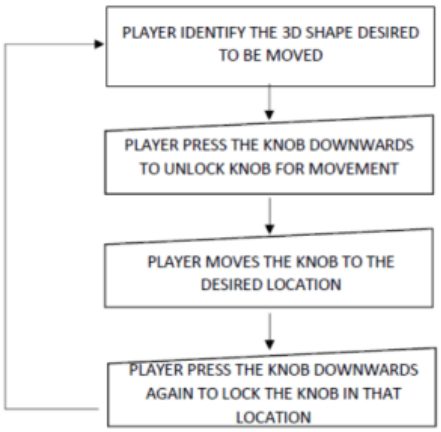



***Figure 5:*** *Overall flowchart for input and output*

The flow chart illustrates how players set the board game according to the game card design, using four different shapes resembling Goolee knobs. The design and language are created to communicate with visually impaired individuals, using shapes to recognize and differentiate each Goolee from the others. This approach is accessible to people with total visual impairment and good eye-sight. The game design focuses on preventing accidental board game breakage by limiting player movement to one Goolee at a time, ensuring movement within game lines, and preventing lifting the Goolee away. The game features a locking system on the fourth level and a path-away design on the second level.

### *3.3 Prototype Process Development*

This research encompasses various processes, including sketches, designs, colour schemes for moving components, materials, an instruction manual, and integrated IoT.

**i. Sketches**

The initial sketches for components and board game serve as the foundation for exploring creative options, enhancing game mechanics, and creating a visually engaging gaming

experience. Physical pieces are set up aligned with the project's vision and objectives, as illustrated in Figure 6 and Figure 7.

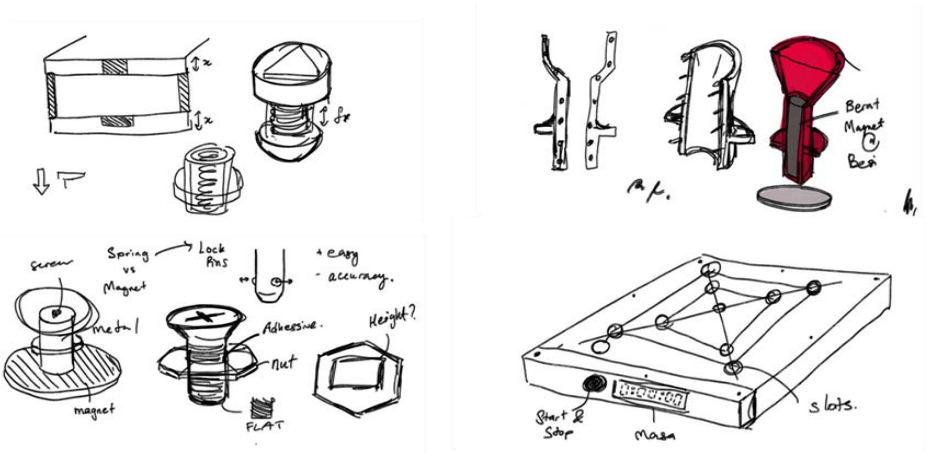



***Figure 6**: Initial Sketches for Components and Boardgame*

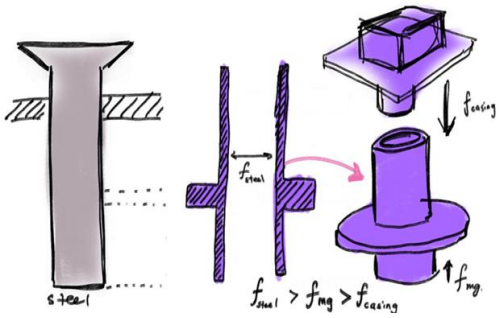



***Figure 7**: Friction Locking system.*

## ii. Manual Dimension

The manual dimension to aid the visually impaired and blind user is shown in Figure 8. This work includes the development of a hardware prototype, a board game, and a set of instructions (level 1: pink, level 2: dark blue, and reset: orange color). The prototype's findings are shown in Figure 8.

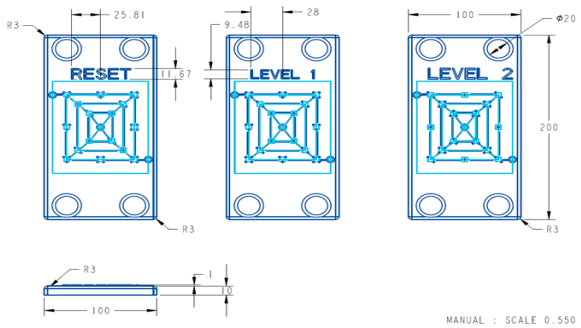



***Figure 8**: The manual dimension of the prototype.*

### iii. Instruction Manual

The instruction manual is designed to assist participants in utilising the prototype, particularly for individuals with visual impairments. In this project, the instruction manual directs the user to read in the correct orientation. The explanation is detailed as follows:

a. Orientation markings: These markings may be embossed or printed in ink and assist the reader in identifying the top of the page. This study employs a symmetrical manual design.
b. Reading techniques: individuals may utilise the placement of their hands or fingers on the page to assist in locating the top of the page or the commencement of a new line. The engraved lines and braille markings indicate the designated position.

Figures 9 and Figure 10 illustrate the symmetrical design employed in this work, which is contingent upon orientation; the manual design is symmetrical, indicating that no orientation markings are necessary for the user.

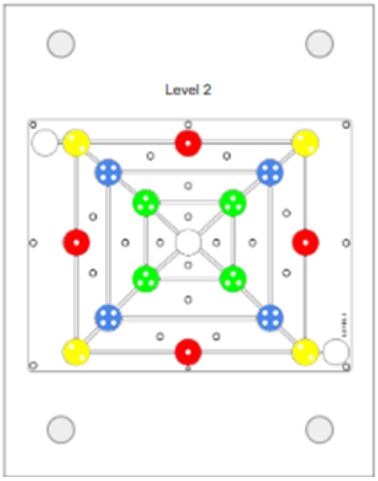



***Figure 9:*** *The Instruction Symmetrical Design*

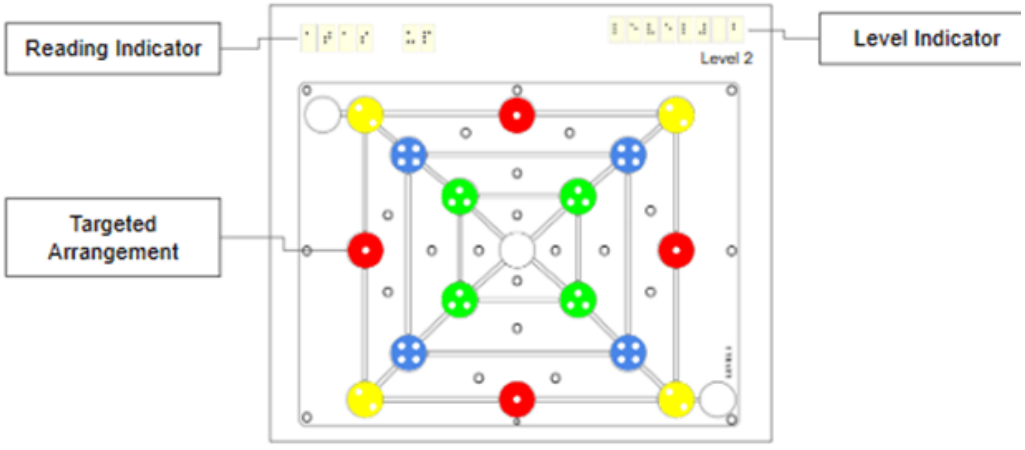



***Figure 10****: Prototype Instruction Levels*

### iv. IoT Integration System

The Internet of Things (IoT) is transforming board games by enhancing interactivity and immersion. The ESP32 microcontroller, with its wireless connectivity, processing capabilities, sensor integration, and low power consumption, is an excellent choice for IoT projects. Its dual-core CPU and built-in sensors make it easy to integrate with other devices. The ESP32 is ideal for IoT gadgets with limited power sources and is a cheap and flexible platform for creating Internet of Things applications. Figures 11 illustrates the comprehensive block diagram for the IoT integration.

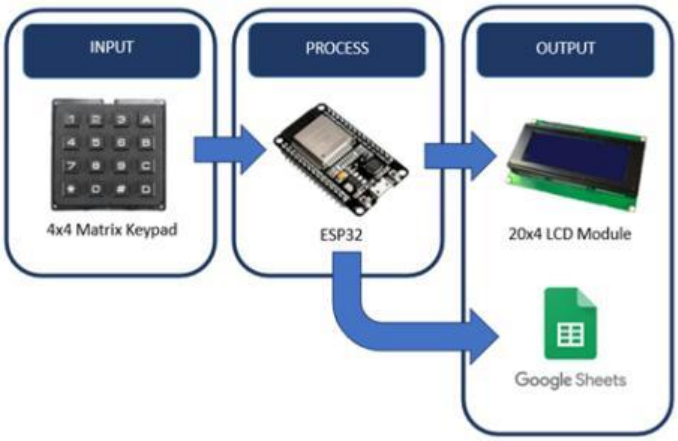



***Figure 11**: The overall block diagram for the IoT integration*

## 4.0 DATA ANALYSIS AND FINDINGS

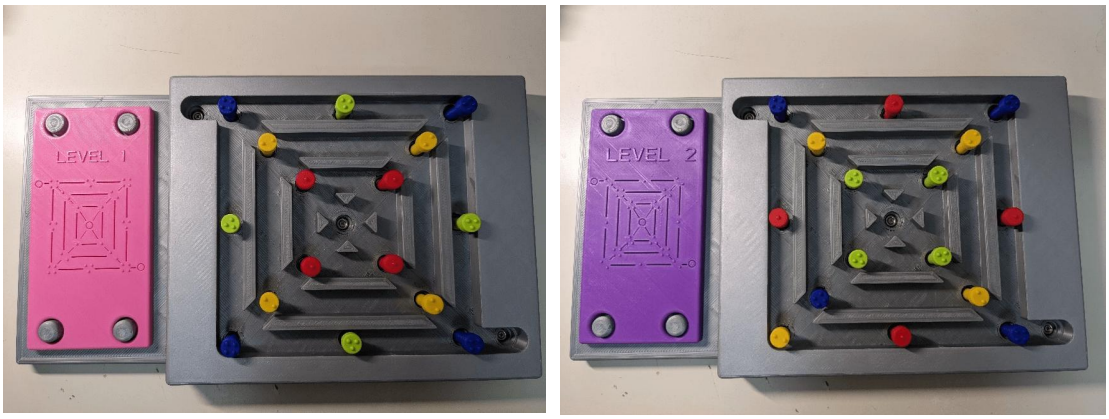
### *4.1 Prototype*

This paper presents the development of a hardware prototype, a board game, and instructional manual (level 1: pink, level 2: dark blue, and reset: orange) designed to assist visually impaired and blind users in gameplay. Figure 12 displays the results of the prototype.


*a) Manual Instruction Board Level Formation b) IoT Braille Board Game with Braille Dots*

***Figure 12**: Manual Instruction Board Level Formation*

In addition, the complete prototype of cognitively stimulating IoT braille board game development for the blind and visually impaired prototype is developed with the component fitting in designation space, as shown in Figure 13. Moreover, the prototype with component fitting in designation space and with four colour and Braille elements.

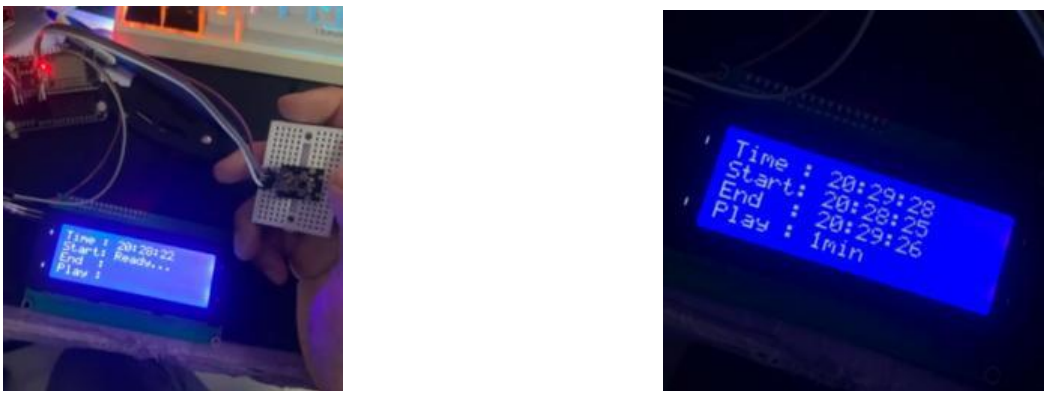



*a) Reference Board Level 1* *b) Reference Board Level 2*

***Figure 13**: Complete Prototype of Cognitive IoT Braille Game Design*

### *4.2 Development of Software and Microcontroller Connection*

Each push latch is equipped with two components with two wires. One wire is connected to the electromagnet and switch, while another is connected to the side of the switch. The wire attached to the electromagnet is connected to other electromagnets in parallel and to the ground. In contrast, the other wire is connected to two pins for each push latch to the Arduino Mega. The wire is branched out into two wires. One wire is connected to the analog pin, while the other is connected to the digital pin. Figure 14 below shows the wires connected to the Arduino Mega and the Software Development.




a) Test the screen testing and IoT connection's availability. b) LCD screen

***Figure 14**: Development of Software and Microcontroller Connection*

## 5.0 CONCLUSIONS

The paper aims to address the lack of inclusive infrastructure and assistive technologies in Malaysia's Technical and Vocational Education and Training (TVET) for blind and visually impaired students. It proposes a Cognitive IoT-Enabled Braille Board Game to enhance cognitive development, including memory, spatial reasoning, and problem-solving, particularly for TVET students. The project involves developing a prototype, incorporating microcontroller programming, a locking system, and sensors, and assessing its effectiveness in real-time. The findings suggest the game may improve cognitive skills, potentially fostering growth through physical education and advancements in science and technology.

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