TangiGuru: Tangible Learning Solution for Early Childhood Development: A Research

2022-287

Project Proposal Report

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B.Sc. (Hons) Degree in Information Technology
Specialized in Computer Systems and Network Engineering

Department of Computer Systems Engineering

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DECLARATION

I declare that this is our own work, and this proposal does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any other university or institute of higher learning, and to the best of our knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

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The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

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Signature of the supervisor Date

ABSTRACT

In the life span of a human, childhood is where the human brain will be developed. So, the activities carried out during childhood will develop the child's brain. The learning environment is crucial in a child's development life cycle, but unfortunately, their learning environment has been framed with mobiles. The learning environment significantly impacts a child's cognitive development and ability to work or play effectively. As there is a boundary between the physical and digital world, physical settings are needed to enhance children's everyday physical interactions. The research proposed through TangiGuru is a tangible, interactive learning kit for children supporting the development of their cognitive skills and critical thinking. The tangible kit enhances child to machine and child to environment connection through the real blocks. It offers various interactive activities for children to perform based on their age, which improves their cognitive skills by performing the activities with tangible blocks. TangiGuru research emphasizes deploying tangibles to enhance the children's active engagement. TangiGuru's research focuses on creating learning activities that make children more interactive with tangible cubes. We focus on the motivations for TangiGuru, its design, and the results of its study concerning 4 -7-year-old children. TangiGuru will consist of the central console and tangible cubes. These tangible cubes will be dynamic cubes that will change according to the child's activities. The user interface will be created considering the child's phycology. The central console will send the instructions to the cubes. After the activity is performed, the results will be sent back to the console. The activities will be aligned and created under the guidance of a child's psychologist.

Keywords – Tangible cubes, learning kit, Cognitive Development, Child’s Phycologist

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LIST OF ABBREVIATIONS

TUI	Tangible User Interface
PCB	Printed Circuit Board
GUI	Graphical User Interface
LKR	Lankan Rupees

1 INTRODUCTION

1.1 Background and Literature Survey

People's daily lives and children's education are both influenced by digital technologies. Inevitably, this will impact children's psychological development, such as creativity and cognitive skills. Creativity should not be overlooked in school or at home by memorizing or using digital devices because it is crucial for the twenty-first century[1]. The rapid advancement of technology in the twenty-first century has significantly impacted children's learning models, methods, and forms. Because they were born and reared in a technologically advanced society, today's children are digital natives since they are born[2]. As a result, several countries have acknowledged the value of incorporating technology into education and have updated primary school curricula for early childhood education[2]. Mobile phones, tablets, and laptops are "gateways" into the digital world. However, many of them are not necessarily appropriate for children, particularly young children, because they are typically intended by adults and for adults[2]. As a result, characteristics of a child's development that affect their ability to learn and engage with technology should be considered while designing and developing interactive technologies for children. Students' creative behaviors have been developed using graphical User Interfaces (GUIs), such as computer-assisted learning and Creativity Support Tools. However, this strategy has limitations because of its monotonous and automated interactive techniques. As a result, characteristics of a child's development that affect their ability to learn and engage with technology should be considered while designing and developing interactive technologies for children. In general, because they may blur the distinction between physical form and digital information, Tangible User Interfaces (TUIs) may be the best bridge between them[2]. As a result, TUIs are one of the most natural methods for children to interact with technology, particularly when it comes to learning. Because TUIs are a new field of study, the theoretical contributions of this study are twofold: it provides a critical overview of current research efforts in TUIs applications. Young children's learning and teaching process address knowledge gaps in the field that require further investigation. *Tangible learning* is defined as "emphasizing the use of the body in educational practice"[3] and includes gesture, motion, or full-body engagement. TUIs increased abstract idea learning by interaction with physical manipulatives and embodied metaphors. Technology becomes widespread by embedding it in regular activities and using natural acts like grasping to combine the physical and digital worlds.[4] In the past, physical engagement with digitally augmented interfaces has been investigated for learning in a variety of fields, including tangible programming [5], tangible music creation[6], storytelling[7]. TUIs are simple to use, and manipulating items require less cognitive effort[8]. Froebel and Montessori [[9], [10]] discovered the potential of manipulative tools and sensory experience for children more than a century ago. Perception and cognition are inextricably intertwined, and research has demonstrated that manipulating physical things while using haptic perception can help with constructive learning[11]. TUIs aid learning will allow children to engage in embodied engagement with physical motions, improving their thinking and learning [12]. According to Kazanidis etal is says that [3] "can offer a natural and immediate form of interaction that is accessible to learners, allow active and hands on engagement, allow for exploration, expression, discovery and reflection, and promote collaboration". TUIs help children's learning in the following ways, as summarized from prior studies (e.g. [13], [14]):

1) **Playfulness:** Play is a crucial part of a child's life since it fosters "social, emotional, physical, and cognitive growth" [15].

2) **Trial and error:** TUIs encourage active play with trial and error to encourage discovery and experimentation. TUIs allow kids to attempt new things and readily undo their mistakes.[13]

3) **Sensory engagement:** TUIs appeal to a variety of senses, which can assist in the learning process [14]

4) **Spatial learning:** Tangible engagement improves spatial awareness by allowing for physically embodied interaction, such as twisting items with one's hands. Spatial abilities are critical for everyday tasks like tool usage and navigation, and they are also associated with more excellent STEAM (Science,

Technology, Engineering, Arts, and Mathematics) performance [16]. In addition, TUIs have also been shown to improve spatial memory [17].

5) **Social Connection:** TUIs may be utilized in groups to learn and allow for natural group interaction and conversation [14]. Children will be able to " get over their initial fears in the areas of mathematics and science and even begin to enjoy these subjects"[18]

6) **Feeling of Competence:** Children can acquire a sense of competence and autonomy while interacting with technology by actively controlling items with their hands [13].

Childhood is a vital stage in the development of creativity [19][20][21]. Children's nature is to be curious and carefree. In 1955, Barron [86] presented the first commonly recognized definition of creativity, emphasizing its originality and use to the public [87]. However, children's creative potential may be underestimated in this situation since their creative ideas are represented in daily activities without making a significant contribution. Kaufman's Four C model[58] added four more dimensions to the classic aspects of creativity as: "Big Creativity, Little Creativity, Pro Creativity, and Mini Creativity." According to this concept, children's creativity can be classified as "mini-c," which is embedded in the learning process. Furthermore, earlier research [42] indicated that individual creativity is influenced by the following five factors:

1) **Knowledge:** Vygotsky [21] characterized the mechanism of creative imagination as knowledge (also known as crystallized intelligence [17]): knowledge was the awareness of reality obtained from self-experience or gained from others' experience (e.g., historical, and social experience). This information nourishes a person's imagination. The ability to imagine, which is essential for children's creativity, can alter children's perceptions of reality. New ideas and conceptions must be embodied in materials to alter and transform the real world.

2) **Motivation [38]:** Initiative requirements, goals, and aspirations send additional external brain stimulation that supplies resources for imagination,

which are also essential elements for creativity [21]. The success and sustainability of creative growth are determined by motivation and readiness to participate in creative activities [22]. According to Keller's ARCS Model, attention and satisfaction were determined elements for motivation [23]. The ARCS attraction method proposed boosting concreteness and learners' interest and engagement to enhance motivation, while the satisfaction strategy supported providing natural consequences and positive feedback.

3) **Cognitive ability**(known as fluid intelligence [24])**:** In prior research, divergent thinking [25] and ideation [26] were viewed as critical foundations for creative growth. Although divergent thinking is regarded to impact idea creation directly in the early stages of issue solving [27], a solution resulting from divergent thinking indirectly impacts practical implementation in the later convergence phase. In addition, the ability to bring thoughts together is also necessary for the development of creativity [28].

4) **Personality:** The most significant elements influencing individuals' creativity, according to the Five-Factor Model (FFM) or Big 5 [27], are openness (both attitudinal and perceptual openness) and psychoticism. In addition, children's creativity in art and science is influenced by neuroticism and conscientiousness [29].

5) **Environment [30]:** The environment that parents, families, educational institutions, and society build together has a significant impact on nurturing children's creativity [20]. According to Torrance's developmental curve of creative abilities [20], the overall trend of children's creativity ability is gradually rising. However, there are periodical declines at certain ages, such as five-year-old or around fourth grade[20] [31]. The manifestations of young children's inventiveness, according to Urban [20], are:

    i. asking inquiries
    ii. Creating, manipulating, and experimenting with items
    iii. Expressing their emotions.

Inside [32] [33] [34] [35] and outside the school [36] [37], studies from many angles have investigated how to increase students' creative learning. However, they mainly were undertaken from five perspectives, as stated in Table 3, as follows:

Table 1.1:TUIs' Benefits or Influence on Children's Creative Learning

Creativity Dimensions	**Advantages of TUI's**	**Examples of Design Concepts**
Knowledge	Scaffold novice	flexible tinkering[37][38] , iterative [38] [39][40], risk-taking[33] [32] [28], no worry to failure[39], low-cost [39][40][41], familiar [28][42], feel of easiness [43], "low floors" [43][44], affordance [45], Accessibility[46]
Environment	Engage collaboration and communication.	inspiration [36], co-creating [47], insight/ exchange expertise/ share ideas [39] , Joint engagement/ joint collaborative activity [47], social interaction [47], shared working space/ space for spatial interaction [48], common ground[49]
	Return to reality	overcoming time and size scales [37], authentic context[43], Meaningful [37][43], reality/ real world context/ problem/ application [37] [43], practical issue[50], intuitive [37]
Personality	Ability to think beyond the boundaries	Open/open-end development/ play/ inquiry/ problem solving[33][37][43][51][1], free/ freedom [32][37][51] [1], think outside box [32], explore beyond instruction [32], original , unintended interpretations [36]
Cognitive ability	Develop the cognitive skills	creative cognition [52], spatial cognition [52][53], Free cognitive bandwidth , reduce cognitive burden [46], complement cognitive process [50], hand-eye coordination[54],give/assign/make meaning [36], epistemic actions.
Motivation	Encourage the development of new ideas	Sensory engagement, exploration [32][36] [43], self-expression/ physical expression [32] [38] [42], arouse scientific curiosity [co-design/ co-designer [38], self-directed/ self-driven[51], sense of agency/ control, active imagination/ development [43] [43],

		enhance confidence/ confidence to cultivate interest [39] [43]

The school (6 studies), workshop (6), and museum were the most prevalent venues in which TUIs were used for creative learning (3). In addition, two investigations were conducted at kindergarten and home. As a result, TUIs have aided eight various tasks, as illustrated in Table 1.2.

Table 1.2:TUI-supported activities

Activities	**Viewed Studies**
Storytelling	8
Music composition	3
Real-world problem solving	3
Play	2
3D Modelling	1
Paper Mechatronics	1
Design anti-boredom machine	1

pupils participating in three-dimensional modeling [33], multi-dimensional games [32], and musical storytelling [34] [35]. However, most research focused on fun and recreational activities, with only a minority integrating with the academic curriculum. Students utilized technology to build and execute paper Mechatronics [39], music composition, write stories [42] and construct programs to address real-world issues[28]throughout the session in the workshop. Children utilized TUIs at the museum to learn about history and culture through storytelling [36], and to engage with physical tokens for bio-design [37]. Furthermore, studies revealed that engaging with robots improved kindergarten children's computational thinking abilities and nourished and enlightened them in art, music, and culture.

The findings show that older children have been the subjects of more research than younger children in terms of age distribution. There are 10 about of studies from 3 to 6 years old age group. In the age group of (7 to 9 years) there are 10 studies. There were 12 or 13 studies every year over the previous three years (i.e., 10-12 years old). The age of a child has an impact on how they comprehend and apply rules [55][56].

Visual feedback and meaningful sound are preferred by younger children (ages 4 to 6). On the other hand, older children (ages 10 to 12) are more likely to incorporate more complicated and abstract interactive tactics in their games[56]. Children aged 10 to 11 years old, for example, prefer more complicated rules with more adjustable details. Children in the MagicBuns [56] research shows different relationships and how they designed their play area. Furthermore, TUIs were employed in various ways by children of various ages.

Furthermore, TUIs were employed in various ways by children of various ages. When comparison to virtual interfaces, several comparative studies indicated that physical interfaces might dramatically enhance the pace with which younger children completed tasks. On the other hand, TUIs did not appear to benefit the older student, which might be because they preferred to spend more time exploring the interface [57].

Aside from age, gender made a difference in how youngsters behaved. For example, Rogers [104] discovered that males were better at putting toys together and more confident participating in STEM activities. Gender equality can be promoted by combining activities that are familiar to both male and female pupils.

Childhood is a crucial time for the development of creativity. It indicated that most typical venues to employ TUI for children's creative learning was through school, workshop, and museum. A more significant number of studies were created for older children than younger children.TUIs benefited children's creative learning by providing novice-friendly interaction, supporting the cognitive process, promoting their initiatives, encouraging them to think outside the box, and facilitating communication and collaboration in an authentic context, all of which correspond to five dimensions of creativity: knowledge, cognitive ability, motivation, personality (openness), and environment. Designing and implementing TUI for children's creative learning has three significant challenges:

1. Balancing abstractness, openness, and complexity in TUI design and creating a smooth experience for young children;
2. Collaborating with teachers in TUI design so that tangible interactive learning can be integrated into school education;
3. Increasing the number of sample sizes and long-term experiments and providing more objective evaluation.

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1.2 Research Gap

So as mentioned above, there are various solutions provided to improve early childhood with tangible learning, but most of them depend on a tablet or mobile device. TUIs, in general, can be thought of as physical objects where interaction can result in a variety of digital consequences, allowing children to engage in inventive play and learning. Even though tangibles are thought to be more efficient than GUIs, a little study compares the cognitive and social benefits of TUIs to GUIs.[58] Moreover, the activities are separated. There is no complete solution to offer several different activities based on their age aligned to develop children's early childhood. In addition to that, there are no specific solutions focused on the age group 4-7 of children. Majority of the tangible research was carried out for children within the year more than 7 years or older[59]. The research that was already carried out does not provide an evaluation system after performing the activity. In addition to that, the tangibles research that was carried out will frame the child to specific activities. There are various activities to develop children's skills with tangible user interfaces. Furthermore, there are pain points when using a digitally developed solutions. To address these innovative solutions, need to be proposed.

Table 1.3: Comparison of former research

Research	Dynamic	Age Range	Multiple Activities	Automated Evaluation	Aligned with Early Childhood Development	Interaction
Magic Buns	✗	Junior(7-12)	✗	✗	✗	Color, Vibrate, and Sound
Story Blocks	✗	Junior(7-12)	✗	✗	✗	Audio, Blocks
Cyberplace	✗	Junior(7-12)	✗	✗	✗	Color, Sound
Superbleeper	✗	Primary(4-6)	✗	✗	✗	Blocks, Music
TangiGuru	✓	Primary(4-7)	✓	✓	✓	Color, Vibration, Sound, Blocks, Visual, Touch

The proposing solution will contain the dynamic feature of the tangible user interfaces which was not offered from the previous work that was reviewed. This will offer various activities aligned to develop the early childhood of the children and it will have the automated evaluation. This proposed solution offers color, vibration, sound, visual, and touch as the interaction methods to children .

1.3 Research Problem

Innovative ideas and solutions are required to fill out this gap. So, to fill out these gaps more research work needs to do considering the young children. Majority of the developed research will focus on improving a particular skill which can be applied for a specific domain. Developed solutions are static which means the activities will be limited. When the research questions focus on filling this gap, a specific methodology will be followed to address this research problem. The main research problem will be **How to create a tangible learning kit that will help them develop children's early childhood, which offers various activities with the help of dynamic tangible cubes?** Several research questions will arise when focusing on the main research problem.

1. Do children perform significantly better with tangible cubes when task-solving time is considered?
2. Do children perform significantly better with tangible cubes when the number of errors is considered?
3. Will children use GUI or Tangible cubes? Do they engage more with a specific interface?
4. When children use Tangible cubes will they engage with the activity well compared to GUI?

2 OBJECTIVES

2.1 Main Objective

TangiGuru project proposes a complete solution to develop children's skills based on their age from 4-7 years. This solution will not offer a simple solution to develop early childhood. However, this will offer a complete solution that will perform certain activities based on the child's age group and where the child can grow with the kit. It will consist of various activities to develop children's cognitive skills, knowledge, personality, motivation, and environmental interaction. Tangigruru proposes making the learning experience valuable and engaging with a dedicated console and dynamic tangible cubes. So, with the dynamic tangible cubes, children will be able to experience different activities with a new aspect of learning compared to traditional methods of learning. This solution will contain software that will guide the children to perform the activities and evaluate them, evaluate them, and provide feedback. This will give a full summary report about child’s performance.

This whole proposed solution will be applied to a set of dynamic cubes. Children will use those cubes to perform the defined activities in many different methods. Moreover, the tangible block will display the outputs related to the activities, give haptic feedback, and calculate the cubes' movements and orientation, and color outputs. This will improve the interaction with the child compared to traditional teaching methods. These cubes will interact with the main console and get the data to the cube before the child starts performing an activity. In addition to that, this system proposes a main console, which will be capable of getting the user inputs. After getting the user inputs, it will undergo processing. After processing the data, it will send it to the tangible cubes. This proposal document will mainly focus in building the tangible cubes, and the main console of the learning kit.

2.2 Specific Objectives

These three objectives must be met to fulfil the above-mentioned main goal.

2.2.1 Development of the tangible cube and communication between blocks

This is the most vital part of this proposed solution. Because this is the part

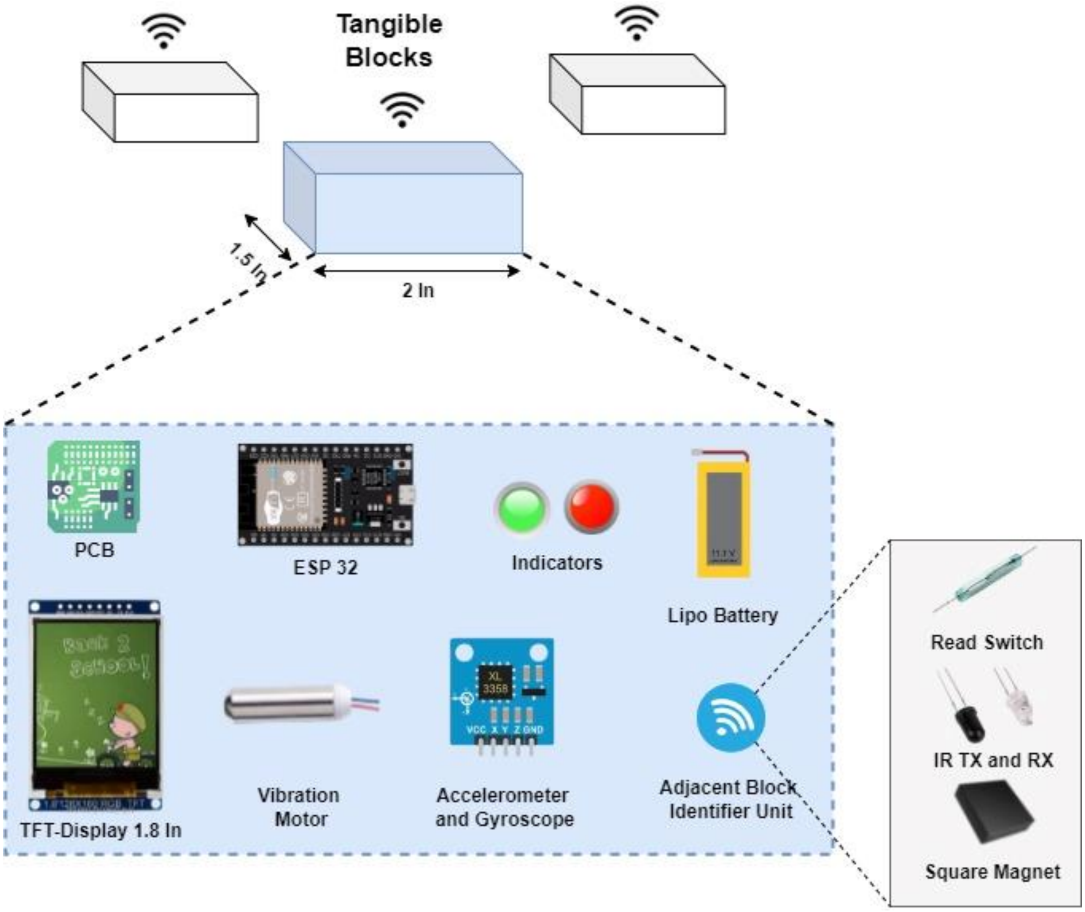

Figure 2.1:Development of Tangible Cubes

where the child directly interacts to perform the activities. These cubes are the most vital part of this proposed solution because this is the part where the child directly interacts to perform the activities. This kit consists of 12 tangible cubes. These cubes can be called dynamic cubes because they will have the capability to change the digital properties of the cube according to the activity. This dynamic cube gives visual outputs and haptic feedback to the child. To achieve this there a communication method must be configured. When an activity is chosen from the central console, the cubes' values will be dynamically assigned without limiting the child to a limited number of activities. With the digital display, it can offer various activities. For example, it can offer children to play with Letters, Numbers, Sentences, Colors, Words. Tangible cubes will be designed from a design perspective. After creating the design of cube, the cube will be designed, including PCBs to the cube to make the cube in a size that can be easily useable by children.

2.2.2 Console development with required hardware

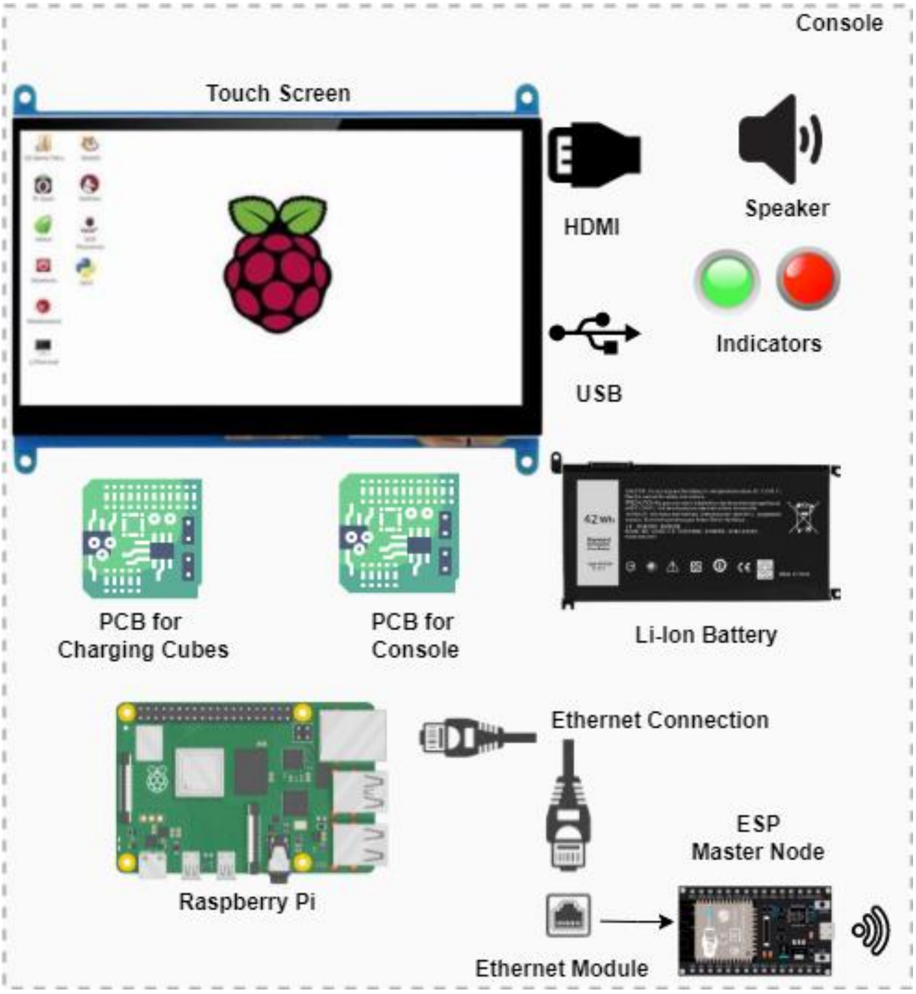

Figure 2.2:Console Overview

This is the other vital part of this proposal which will contain the other required hardware. This will contain the main controlling unit, and a communication unit. This will contain the required hardware to host the application software with learning activities. All the tangible blocks will bound to this main console. This is also will be a prominent part of the research. This console must be developed considering the aspects of children between 4-7 years. So, this will also include a drawing process. After designing the console, it must be developed considering the aspects of children. This will include PCBs to make the product more compact and lighter in weight. Console will be responsible deliver the activities to the child.

2.2.3 Power Management of blocks and console

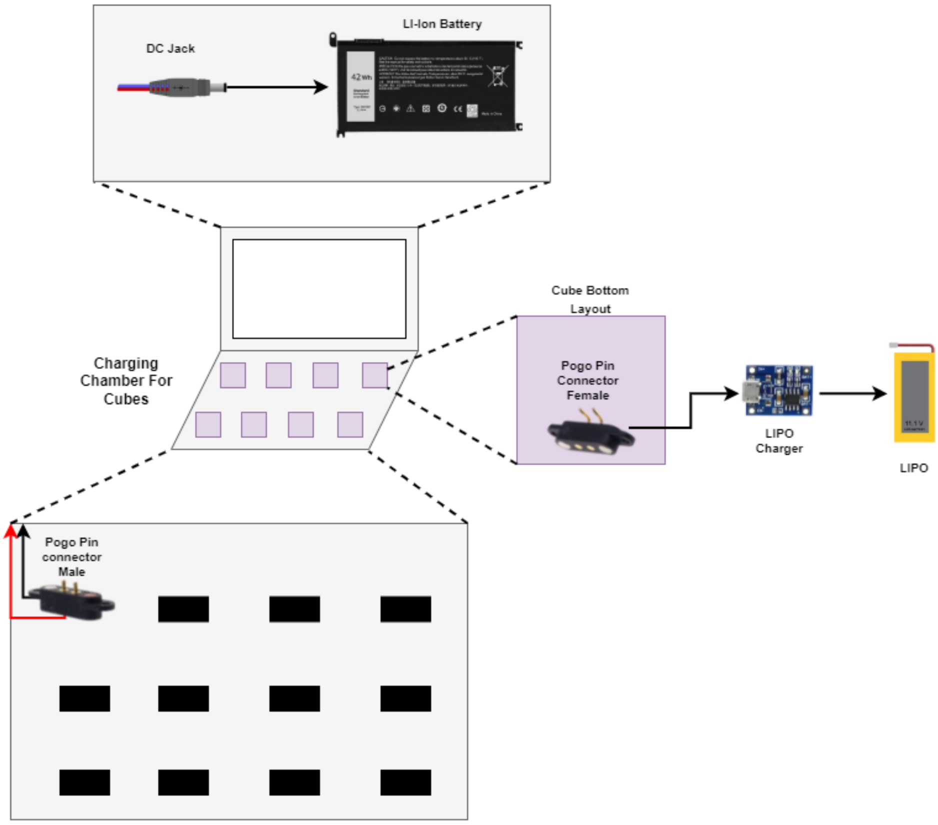

Figure 2.3:Power Management

This proposed solution will contain tangible cubes, and the cubes are dynamic. So, power must be managed in both cube and the central console. Furthermore, the cubes are digital and directly give the output to the child, because of that the cubes must be powered up with safety for the children

3 METHODOLOGY

TangiGuru, the proposed tangible learning solution, would be developed in the following ways to deliver an efficient learning experience to kids in their early life.

3.1 Requirement Analysis

Most of the analysis for this study came from current research articles and persons working in early childhood development. They took part in one-on-one interviews over the phone and used online chat platforms to share domain expertise and needs for an early childhood development solution in their domain. The gathered data was utilized to identify and examine unmet needs, unsolved problems, and potential improvements in early childhood development to establish tasks, objectives, and goals that this proposed early childhood development kit must meet.

3.2 Feasibility Study

The final product in this proposal document, TangiGuru, will combine electronics, cloud computing, mobile, and software. So, to develop the product according to the mentioned specifications, the members should have the technical feasibility to use the technologies and finish the development of the product to the given aspects.

3.3 Implementation

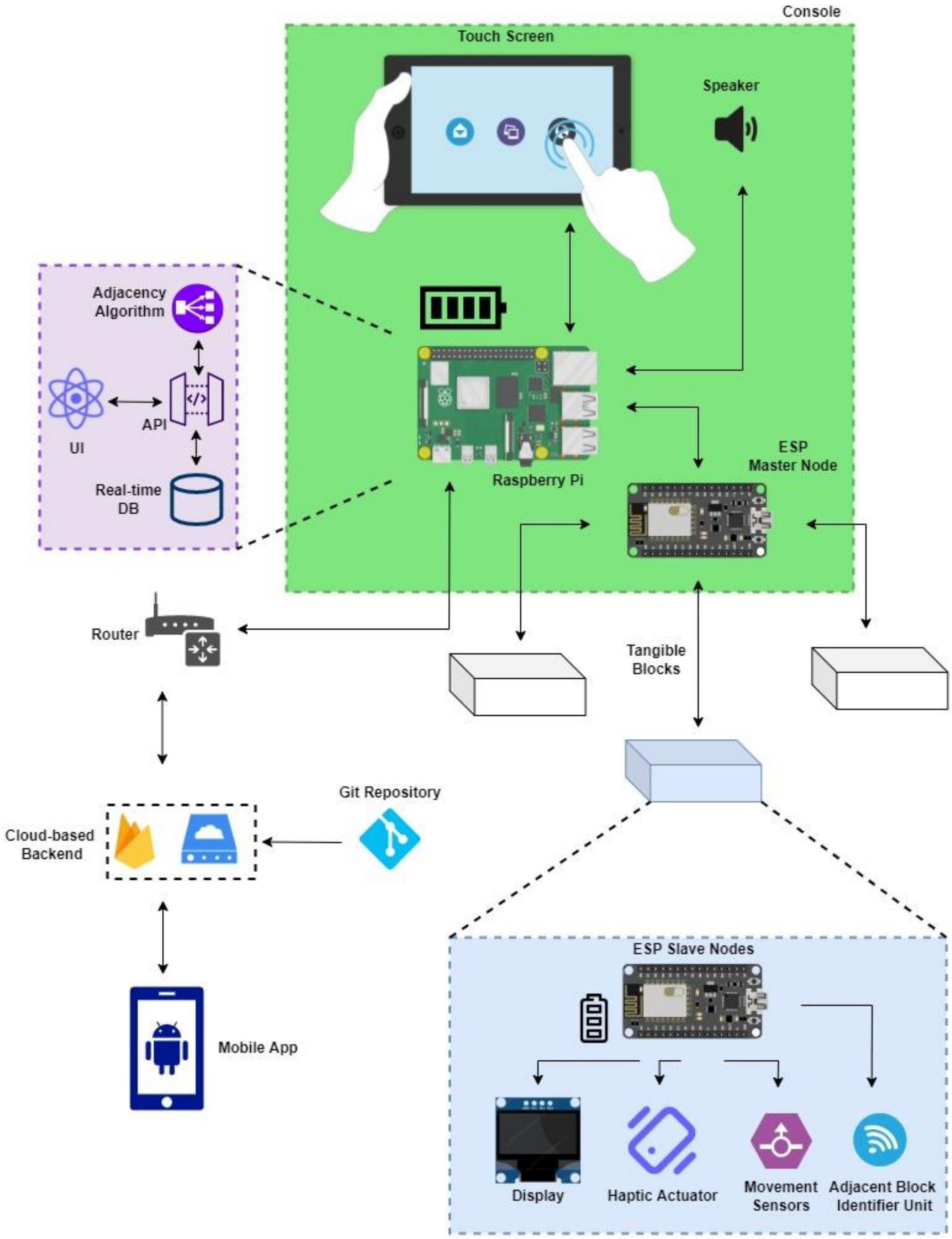

Figure 3.1: System overview diagram

TangiGuru's design is built on cutting-edge hardware, software, and cloud technologies. TangiGuru will primarily consist of a console, a set of 12 identical physical blocks, and a growing number of learning activities concentrating on early childhood development that will be produced. These 12 blocks may be dynamically allocated a value for each learning activity, and the blocks will be aware of their surroundings. A built-in touch screen is also included in the proposing console, offering learning activities to the pupils. The UI/UX of the material presented on the touch screen will be highly optimized for early childhood pupils. They cannot follow written instructions and are unfamiliar with the fundamental symbolic icons we often use in day-to-day intelligent gadgets. In addition, instead of on-screen written instructions, the console will have a speaker that will deliver audio instructions. The console will be designed as a portable mobile gadget that a youngster in that age group may carry. As a result, its form factor, weight, and rechargeable battery pack will all be created accordingly.

Tangible Blocks will be designed to fit into the console for improved mobility. As a result, the blocks will be roughly 2" x 2" x 0.75" in size. Each block will have a reduced bezel display and a haptic feedback motor for visual and physical output. In contrast, physical inputs will be handled by an accelerometer sensor and a gyroscope sensor. In addition, for adjacency tracking among tangible blocks, an infrared-based optical communication system will be deployed. An ESP series chipset will be used to control all these components. Rechargeable batteries are included within the tangible blocks, and they will be recharged while within the console.

3.4 Dynamic Tangible Learning Cubes and Central Console

A new aspect of a tangible cube will be developed as mentioned previously in specific objectives. This cube will be created considering the children's phycology and the electronic technologies. The dynamic tangible cube will allow child to perform the learning activities that has been sent from the console dynamically. Compared to a static tangible this dynamic tangible cubes will offer range of activities for the children. So, child will not be framed to perform a set of activities. These tangible cubes are the main component of this research because, the cube will be developed from the designing step. This cube will be child friendly, and it will evaluate the child after performing an activity. So, to achieve all these tangible cubes need to be developed.

The central console also will be developed considering the child phycological aspects and digital electronics. The console will be responsible to get the information from the child and send the instructions to the tangible cubes and give visual and audio output to the child. When it comes to the development of the console, without just assembling the hardware the useability for a child will be considered ,and the console will be developed considering the phycological aspect of a child.

3.5 Work Breakdown Structure

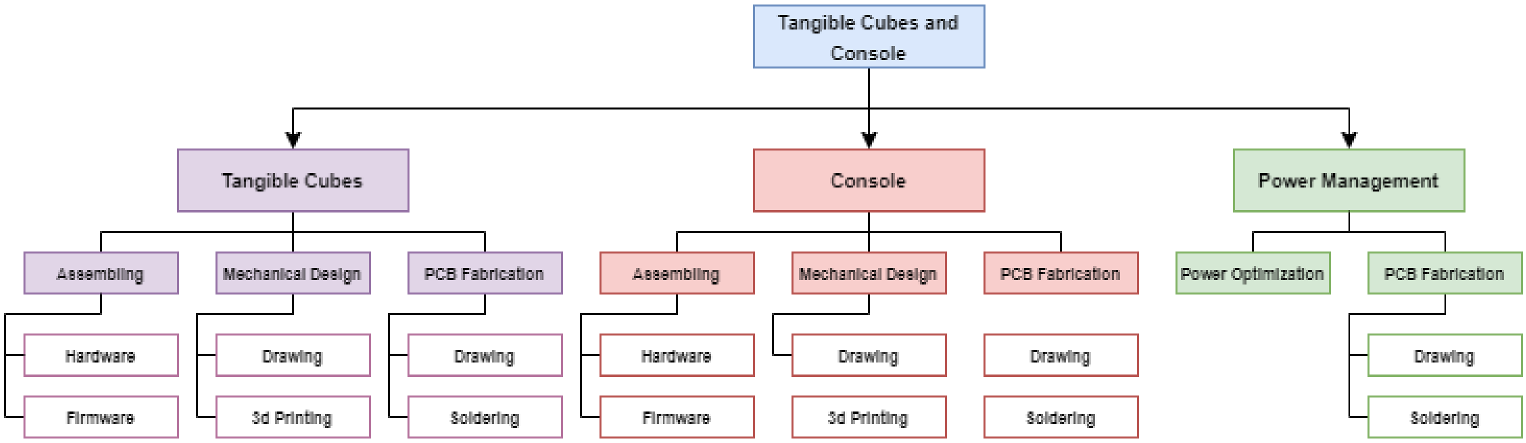

Figure 3.2:Work Breakdown Structure

3.6 Testing

3.6.1 Alpha Testing

In this testing, all the functionalities of the hardware components will be tested. In addition, unit testing will be done at the end of each component development completed. However, system testing will be carried out once the whole system is completely developed, planned for early September.

3.6.2 Beta Testing

The final solution will be tested with its target audience during the Beta testing stage. Beta testing will take place from mid-September to early November, during which time the proposed TangiGuru kit will be developed. In this step, the output of the proposed solution will be compared against non-tangible alternatives for the same goal in terms of quantitative efficiency. TangiGuru will be tested on 4 to 8 youngsters ranging in age from 4 to 7 years old as the intended audience.

To identify the outcomes in TangiGuru and its alternatives, the test sample will be split into two groups of equal size, group A and B, within each age range. A mobile application will be supplied as an alternative with a similar effect. The children in Group A of a certain age will then be given a chance to play with TangiGuru for a specified learning result. At the same time, students in Group B of the same age will be given the option to play with a different mobile application for the same learning objective. Each task will be timed, and the student will be personally reviewed after completing it to see how effective TangiGuru and its alternative are.

3.7 Gannt Chart

This proposing research is planned to carry out as follows to meet the required deadlines without any conflicts. Project implementation will be started in late February and expected to complete by mid-September while testing will be carried out from mid-August to end of October. The proposing research project will be completed by December 2022.

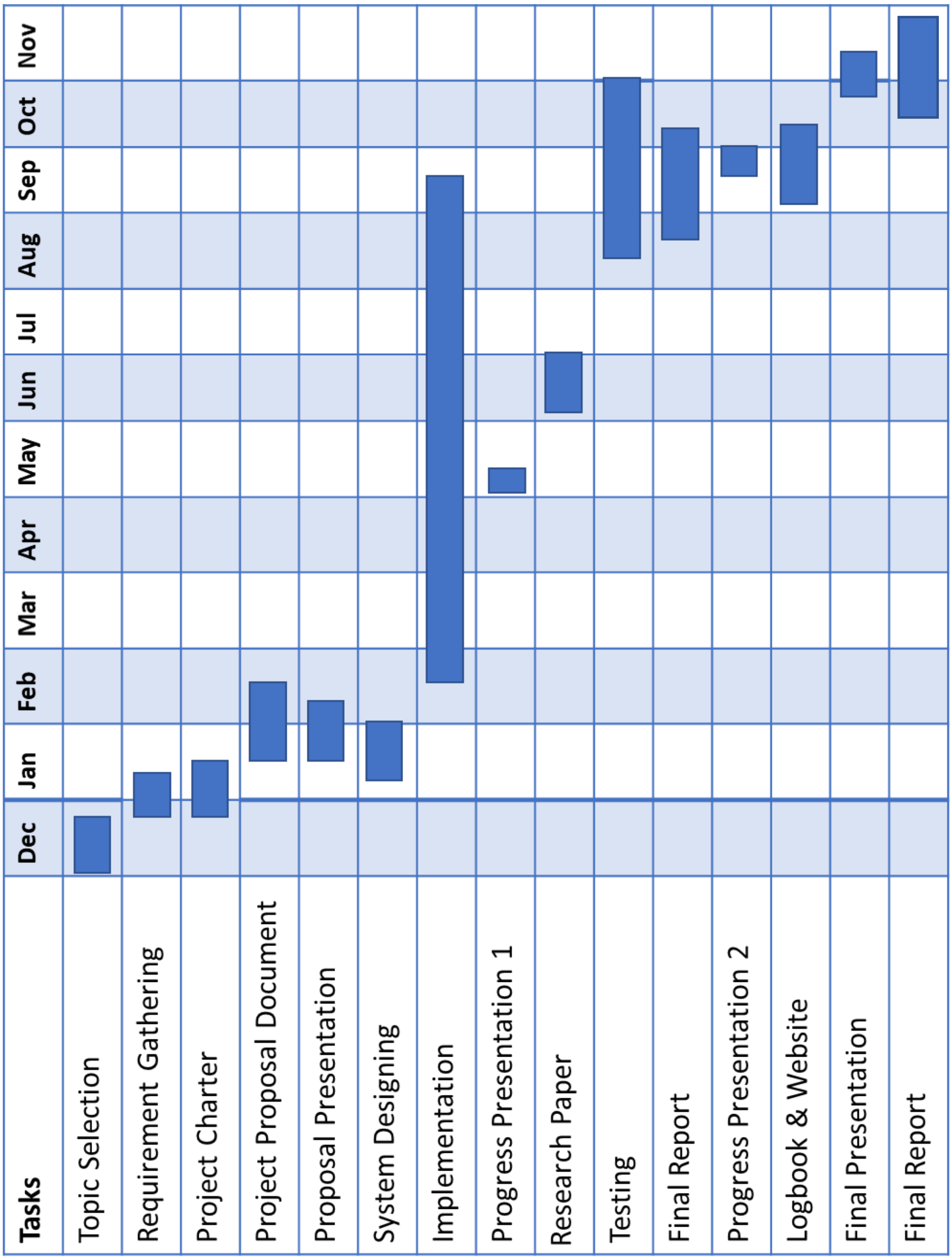

Figure 3.3:Gannt chart

4 DESCRIPTION OF PERSONNEL & FACILITIES

Ms Shashika Lokuliyana is in charge of this study. She teaches Information Security, Computer Systems and Networking, and Computer Systems Engineering as a Senior Lecturer. She is now employed with the Faculty of Computing, Sri Lanka Institute of Information Technology (SLIIT), Malabe, Sri Lanka, in the Information Systems Engineering Department.

As an Assistant Lecturer in the Department of Information Systems Engineering, Faculty of Computing, Sri Lanka Institute of Information Technology (SLIIT), Malabe, Sri Lanka, Ms Narmada Gamage is co-supervising this project.

Mr. Rajitha de Silva joins this research as the external supervisor. He is a PhD scholar of University of Lincoln, England, UK.

This research will be conducted by the following 3 members as shown below.

1. T.C.D.S. Hettiarachchi – He is responsible for the parallel research component of developing the dynamic tangible blocks to interact with the child with specified features. This includes,
    a. Developing the interacting parts of the cubes and communication between blocks and the center console.
    b. Developing the console casing with the required hardware.
    c. Developing power management of the blocks and the console.

2. L.S. Semasinghe – He is responsible for developing a technology to identify the adjacent blocks, and intermediary for communication between blocks and applications. This includes,
    a. Implement a mechanism to identify the adjacent blocks.
    b. Creating the incoming API between blocks and application software.
    c. Implement the system software for the console.

d. Implement the cloud servers to store the user data and software updates.

3. M.M.D. Ratnasuriya – She is responsible for the parallel research component of developing the interactive, child-friendly UI/UX which is easily understandable for children and related learning activities suitable for required learning outcomes in the early childhood development. These include,
   a. Develop the frontend software application.
   b. Develop the learning activities for the children aligned with early childhood development milestones and related literature.
   c. Develop the UI/UX design for the web application to be child friendly.
   d. Implement the mobile application to view the statistics of the child and control.

5 BUDGET & BUDGET JUSTIFICATION

Table 5.1: Estimated Budget

Item	Amount(LKR)
ESP-32 chips (12)	9,600.00
Display (12)	7,200.00
MPU-6050 Accelerometer and Gyroscope (12)	5,880.00
3.7V 250mah 25C Lipo Battery (12)	5,160.00
Micro DC vibration motor	504.00
Design and fabrication Cost for cubes and console	10,000.00
Total Estimated	**38,344.00**

6 REFERENCES

[1] M. Przybylla and R. Romeike, “The nature of physical computing in schools findings from three years of practical experience,” *ACM Int. Conf. Proceeding Ser.*, pp. 98–107, 2017, doi: 10.1145/3141880.3141889.

[2] L. D. Rodić and A. Granić, “Tangible interfaces in early years’ education: a systematic review,” *Pers. Ubiquitous Comput.*, vol. 26, no. 1, pp. 39–77, 2022, doi: 10.1007/s00779-021-01556-x.

[3] I. Kazanidis, G. Palaigeorgiou, and C. Bazinas, “Dynamic interactive number lines for fraction learning in a mixed reality environment,” *South-East Eur. Des. Autom. Comput. Eng. Comput. Networks Soc. Media Conf. SEEDA_CECNSM 2018*, pp. 1–5, 2018, doi: 10.23919/SEEDA-CECNSM.2018.8544927.

[4] M. Weiser, “ The computer for the 21 st century ,” *ACM SIGMOBILE Mob. Comput. Commun. Rev.*, vol. 3, no. 3, pp. 3–11, 1999, doi: 10.1145/329124.329126.

[5] P. Wyeth and H. C. Purchase, “Tangible programming elements for young children,” *Conf. Hum. Factors Comput. Syst. - Proc.*, pp. 774–775, 2002, doi: 10.1145/506443.506591.

[6] A. Sabuncuoglu, “Tangible music programming blocks for visually impaired children,” *TEI 2020 - Proc. 14th Int. Conf. Tangible, Embed. Embodied Interact.*, pp. 423–429, 2020, doi: 10.1145/3374920.3374939.

[7] T. Wallbaum, S. Ananthanarayan, S. S. Borojeni, W. Heuten, and S. Boll, “Towards a tangible storytelling kit for exploring emotions with children,” *Themat. Work. 2017 - Proc. Themat. Work. ACM Multimed. 2017, co-located with MM 2017*, no. 1, pp. 10–16, 2017, doi: 10.1145/3126686.3126702.

[8] G. Revelle, A. Druin, and O. Zuckerman, “Tangible User Interfaces for Children,” pp. 2051–2052, 2005.

[9] H. Heiland, “Friedrich Fröbel: 1782–1852,” *Prospects*, vol. 23, no. 3–4, pp. 473–491, 1993, doi: 10.1007/BF02195130.

[10] “The Montessori Method.” https://digital.library.upenn.edu/women/montessori/method/method.html (accessed Jan. 24, 2022).

[11] M. Lou Maher, L. Lee, J. Gero, and R. Yu, “Design Computing and Cognition ’16,” *Des. Comput. Cogn. ’16*, no. January, 2017, doi: 10.1007/978-3-319-44989-0.

[12] C. O’Malley, S. Fraser, and Others, “Literature review in learning with tangible technologies,” *Halshsarchivesouvertesfr*, no. January 2004, pp. 1–52, 2004, [Online]. Available: http://hal.archives-ouvertes.fr/hal-00190328/%5Cnhttp://halshs.archives-ouvertes.fr/hal-00190328/.

[13] G. Revelle, O. Zuckerman, A. Druin, and M. Bolas, “Tangible user interfaces for children,” *Conf. Hum. Factors Comput. Syst. - Proc.*, no. September 2014, pp. 2051–2052, 2005, doi: 10.1145/1056808.1057095.

[14] O. Zuckerman, S. Arida, and M. Resnick, “Extending tangible interfaces for education,” no. June 2014, pp. 859–868, 2005, doi: 10.1145/1054972.1055093.

[15] J. A. Fails, A. Druin, M. L. Guha, G. Chipman, S. Simms, and W. Churaman, “Child’s play: A comparison of desktop and physical interactive environments,” *Proc. Interact. Des. Child. 2005, IDC 2005*, pp. 48–55, 2005, doi: 10.1145/1109540.1109547.

[16] G. E. Baykal, I. V. Alaca, A. E. Yantaç, and T. Göksun, “A review on complementary natures of tangible user interfaces (TUIs) and early spatial learning,” *Int. J. Child-Computer Interact.*, vol. 16, pp. 104–113, 2018, doi: 10.1016/j.ijcci.2018.01.003.

[17] M. Löchtefeld, F. Wiehr, and S. Gehring, “Analysing the effect of tangibile user interfaces on spatial memory,” *SUI 2017 - Proc. 2017 Symp. Spat. User Interact.*, pp. 78–81, 2017, doi: 10.1145/3131277.3132172.

[18] L. Scarlatos, “An application of tangible interfaces in collaborative learning environments,” *ACM SIGGRAPH 2002 Conf. Abstr. Appl. SIGGRAPH 2002*, pp. 125–126, 2002, doi: 10.1145/1242073.1242141.

[19] N. Leggett, “Early Childhood Creativity: Challenging Educators in Their Role to Intentionally Develop Creative Thinking in Children,” *Early Child. Educ. J.*, vol. 45, no. 6, pp. 845–853, 2017, doi: 10.1007/s10643-016-0836-4.

[20] K. K. Urban, “On the Development of Creativity in Children,” *Creat. Res. J.*, vol. 4, no. 2, pp. 177–191, 1991, doi: 10.1080/10400419109534384.

[21] L. S. VYGOTSKY, “Imagination and Creativity in Childhood,” *J. Russ. East Eur. Psychol.*, vol. 42, no. 1, pp. 7–97, 2004, doi: 10.1080/10610405.2004.11059210.

[22] M. R. Sarsani, “Do high and low creative children differ in their cognition and motivation?,” *Creat. Res. J.*, vol. 20, no. 2, pp. 155–170, 2008, doi: 10.1080/10400410802059861.

[23] J. M. Keller, “Development and use of the ARCS model of motivational design,” *J. Instr. Dev.*, vol. 10, no. 1932, pp. 2–10, 1987.

[24] R. B. Cattell, *Intelligence: Its Structure, Growth and Action*. 1971.

[25] E. P. TORRANCE, “Can We Teach Children To Think Creatively?,” *J. Creat. Behav.*, vol. 6, no. 2, pp. 114–143, 1972, doi: 10.1002/j.2162-6057.1972.tb00923.x.

[26] W. Pang, “Promoting creativity in the classroom: A generative view,” *Psychol. Aesthetics, Creat. Arts*, vol. 9, no. 2, pp. 122–127, 2015, doi: 10.1037/aca0000009.

[27] S. Mednick, “The associative basis of the creative process,” *Psychol. Rev.*, vol. 69, no. 3, pp. 220–232, 1962, doi: 10.1037/h0048850.

[28] S. Matthews, S. Viller, and M. Boden, “‘...and We Are the Creators!’ Technologies As Creative Material,” *TEI 2020 - Proc. 14th Int. Conf. Tangible, Embed. Embodied Interact.*, pp. 511–518, 2020, doi: 10.1145/3374920.3374980.

[29] M. Batey and A. Furnham, “Creativity, intelligence, and personality: A critical review of the scattered literature,” *Genet. Soc. Gen. Psychol. Monogr.*, vol. 132, no. 4, pp. 355–429, 2006, doi: 10.3200/MONO.132.4.355-430.

[30] T. P. Rohlen, “8. Instruction,” *Japan’s High Sch.*, pp. 241–270, 2020, doi: 10.1525/9780520341302-010.

[31] V. Richard, J. C. Lebeau, F. Becker, E. R. Inglis, and G. Tenenbaum, “Do more creative people adapt better? An investigation into the association between creativity and adaptation,” *Psychol. Sport Exerc.*, vol. 38, pp. 80–89, 2018, doi: 10.1016/j.psychsport.2018.06.001.

[32] F. M. de Abreu and Á. Barbosa, “Creative Engagement: Multimodal Digital Games in Children’s Learning Environment in Macau S.A.R.,” *Proc. 8th Int. Conf. Digit. Arts*, no. 2008, pp. 47–54, 2017, [Online]. Available: http://doi.acm.org/10.1145/3106548.3106599.

[33] E. Y. L. Do, “Creating unique technology for everyone,” *Crossing HCI4D Asia Pacific Proc. ASEAN CHI Symp. ACHIS 2015 - co-located CHI 2015*, pp. 42–45, 2015, doi: 10.1145/2776888.2780363.

[34] G. India, G. Ramakrishna, J. Bisht, and M. Swaminathan, “Computational thinking as play: Experiences of children who are blind or low vision in India,” *ASSETS 2019 - 21st Int. ACM SIGACCESS Conf. Comput. Access.*, pp. 519–522, 2019, doi: 10.1145/3308561.3354608.

[35] G. Palaigeorgiou and C. Pouloulis, “Orchestrating tangible music interfaces for in-classroom music learning through a fairy tale: The case of ImproviSchool,” *Educ. Inf. Technol.*, vol. 23, no. 1, pp. 373–392, 2018, doi: 10.1007/s10639-017-9608-z.

[36] C. H. Lee, Y. P. Ma, and T. Jeng, “A spatially-aware tangible interface for Computer-Aided Design,” *Conf. Hum. Factors Comput. Syst. - Proc.*, pp. 960–961, 2003, doi: 10.1145/765891.766094.

[37] A. Loparev *et al.*, “BacPack: Exploring the role of tangibles in a museum exhibit for bio-design,” *TEI 2017 - Proc. 11th Int. Conf. Tangible, Embed. Embodied Interact.*, pp. 111–120, 2017, doi: 10.1145/3024969.3025000.

[38] M. Kazemitabaar, J. McPeak, A. Jiao, L. He, T. Outing, and J. E. Froehlich, “MakerWear: A tangible approach to interactive wearable creation for children,” *Conf. Hum. Factors Comput. Syst. - Proc.*, vol. 2017-May, pp. 133–145, 2017, doi: 10.1145/3025453.3025887.

[39] H. Oh, S. Hsi, M. Eisenberg, and M. D. Gross, “Paper mechatronics: Present and future,” *IDC 2018 - Proc. 2018 ACM Conf. Interact. Des. Child.*, pp. 389–395, 2018, doi: 10.1145/3202185.3202761.

[40] P. Te, “TADCAD: A tangible and gestural 3D modeling & printing platform for building creativity,” *Proc. IDC 2015 14th Int. Conf. Interact. Des. Child.*, pp. 406–409, 2015, doi: 10.1145/2771839.2771865.

[41] A. Sabuncuoğlu, M. Erkaya, O. T. Buruk, and T. Göksun, “Code notes,” pp. 644–649, 2018, doi: 10.1145/3202185.3210791.

[42] A. Panjwani, “Constructing meaning: Designing powerful story-making explorations for children to express with tangible computational media,” *IDC 2017 - Proc. 2017 ACM Conf. Interact. Des. Child.*, pp. 358–364, 2017, doi: 10.1145/3078072.3079723.

[43] M. N. Giannakos and L. Jaccheri, “From players to makers: An empirical examination of factors that affect creative game development,” *Int. J. Child-Computer Interact.*, vol. 18, pp. 27–36, 2018, doi: 10.1016/j.ijcci.2018.06.002.

[44] M. Resnick and B. Silverman, “Some reflections on designing construction kits for kids,” *Proc. Interact. Des. Child. 2005, IDC 2005*, pp. 117–122, 2005, doi: 10.1145/1109540.1109556.

[45] V. Zappi and A. P. McPherson, “Dimensionality and Appropriation in Digital Musical Instrument Design,” *NIME ’14 Proc. 2014 Conf. New Interfaces Music. Expr.*, pp. 455–460, 2014, [Online]. Available: http://www.nime.org/proceedings/2014/nime2014_409.pdf.

[46] C. Chen, Y. Tang, T. Xie, and S. Druga, “The humming box: AI-powered Tangible Music Toy for Children,” *CHI Play 2019 - Ext. Abstr. Annu. Symp. Comput. Interact. Play*, pp. 87–95, 2019, doi: 10.1145/3341215.3356990.

[47] B. R. Glowacki, “Bear abouts: Sharing stories across the physical and digital,” *IDC 2017 - Proc. 2017 ACM Conf. Interact. Des. Child.*, pp. 683–686, 2017, doi: 10.1145/3078072.3091980.

[48] C. Yang and S. J. Wang, “Sandtime: A tangible interaction featured gaming installation to encourage social interaction among children,” *Lect. Notes Inst. Comput. Sci. Soc. Telecommun. Eng. LNICST*, vol. 196, pp. 137–144, 2017, doi: 10.1007/978-3-319-55834-9_16.

[49] C. Latulipe, “The value of research in creativity and the arts,” pp. 1–10, 2013, doi: 10.1145/2466627.2485921.

[50] V. Yrjönsuuri, K. Kangas, K. Hakkarainen, and P. Seitamaa-Hakkarainen, “The Roles of Material Prototyping in Collaborative Design Process at an Elementary School.,” *Des. Technol. Educ. an Int. J.*, vol. 24, no. 2, pp. 141–162, 2019.

[51] K. Pitkänen, M. Iwata, and J. Laru, “Supporting Fab Lab facilitators to develop pedagogical practices to improve learning in digital fabrication

activities," *ACM Int. Conf. Proceeding Ser.*, 2019, doi: 10.1145/3335055.3335061.

[52] M. Lou Maher, L. Lee, J. S. Gero, R. Yu, and T. Clausner, "Design Computing and Cognition '16," *Des. Comput. Cogn. '16*, 2017, doi: 10.1007/978-3-319-44989-0.

[53] A. Soleimani, K. E. Green, D. Herro, and I. D. Walker, "A tangible, story-construction process employing spatial, computational-thinking," *Proc. IDC 2016 - 15th Int. Conf. Interact. Des. Child.*, pp. 157–166, 2016, doi: 10.1145/2930674.2930703.

[54] Q. Jin, D. Wang, and F. Sun, "Poster: Tancreator: A tangible tool for children to create augmented reality games," *UbiComp/ISWC 2018 - Adjun. Proc. 2018 ACM Int. Jt. Conf. Pervasive Ubiquitous Comput. Proc. 2018 ACM Int. Symp. Wearable Comput.*, pp. 82–85, 2018, doi: 10.1145/3267305.3267603.

[55] M. B. Parten, "Social play among preschool children," *J. Abnorm. Soc. Psychol.*, vol. 28, no. 2, pp. 136–147, 1933, doi: 10.1037/h0073939.

[56] H. H. van Huysduynen, L. de Valk, and T. Bekker, "Tangible Play Objects," pp. 262–270, 2016, doi: 10.1145/2839462.2839492.

[57] T. Sapounidis, S. Demetriadis, and I. Stamelos, "Evaluating children performance with graphical and tangible robot programming tools," *Pers. Ubiquitous Comput.*, vol. 19, no. 1, pp. 225–237, 2015, doi: 10.1007/s00779-014-0774-3.

[58] B. Zaman, V. Vanden Abeele, P. Markopoulos, and P. Marshall, "Tangibles for children, the challenges," *Conf. Hum. Factors Comput. Syst. - Proc.*, pp. 4729–4732, 2009, doi: 10.1145/1520340.1520727.

[59] M. Liang, Y. Li, T. Weber, and H. Hussmann, "Tangible interaction for children s creative learning: A review," *ACM Int. Conf. Proceeding Ser.*, 2021, doi: 10.1145/3450741.3465262.

7 APPENDICES

7.1 Plagiarism Report

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