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Master's Thesis
Academic Year 2025

Movook: A Toolkit Fusing Paper and Magnetism to Enhance Children's Creativity and Storytelling

Keio University
Graduate School of Media Design

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A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

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Abstract of Master's Thesis of Academic Year 2025

Movook: A Toolkit Fusing Paper and Magnetism to Enhance Children's Creativity and Storytelling

Category: Design

Summary

While traditional papercraft excels in tactile engagement, it remains static. In contrast, digital media is dynamic but often limits hands-on creativity. This research bridges this gap by proposing **Movook**, a tangible toolkit that fuses papercraft with programmable magnetic motion. We introduce and validate a novel **motion → story → character** creative pipeline, where observable, abstract motion acts as the initial spark for imagination.

The toolkit allows children to animate their own handmade paper characters. Through three workshops with children (n=57, ages 2-8), we demonstrate that motion serves as a powerful catalyst for creative engagement. We observed the spontaneous emergence of complex storytelling, validating the **motion-first** approach. The findings show that motion-driven, tangible interaction can effectively support children's creativity, offering new principles for designing future hybrid learning tools.

Keywords:

Tangible Interaction, Storytelling, Papercraft, Educational Technology, Child-Computer Interaction, Magnetism

Keio University Graduate School of Media Design

YUANXIAO ZHANG

Contents

Acknowledgements **viii**

1 Introduction **1**

1.1. Background 1

1.2. The Challenge: Bridging Physical Creation with Dynamic Storytelling 3

1.3. Our Proposal: The **Movook** Toolkit 4

1.4. Research Questions 4

2 Related Works **6**

2.1. Theoretical Foundations: Play, Agency, and Tangible Interaction . 6

2.2. Tangible Storytelling and Interactive Papercraft 7

2.3. Motion as a Catalyst for Narrative Creation 10

2.4. Enabling Design: Magnetism and Modularity 12

2.5. Research Gap and Our Contribution 15

3 Design Process **18**

3.1. Foundational Philosophy: Motion-Driven Creativity and Learning 18

3.2. Toolkit Design and Core Technology 20

3.2.1 Design Rationale: Leveraging Magnetism for Dynamic Papercraft 20

3.2.2 GFACE (Electromagnetic Actuator Board)– Enabling Programmable Motion 20

3.2.3 MoveKit (Magnetic Motion Module)– Translating Fields to Action 22

3.2.4 Papercraft Integration – Supporting Handmade Creativity 24

3.3. Interaction Framework: From Motion to Storytelling 25

3.3.1 Movement as a Catalyst for Imagination and Narrative . . 25
3.3.2 Simplified Programming for Creative Expression 29
3.3.3 The Creative Workflow: Bringing Stories to Life 29
3.4. Usability and Application in Educational Settings 30
3.5. Iterative Prototyping and Design Refinement 32
3.5.1 Initial Experiments: Exploring Magnetic Actuation 32
3.5.2 Iterative Demos: Balancing Motion, Interaction, and Early Creative Potential 33
3.5.3 Conclusion 40

4 Evaluation: Assessing Impact and Usability 41
4.1. Introduction to Evaluation Approach 41
4.2. Workshop Methodology 41
4.2.1 General Approach 41
4.3. Study 1:“Monkey Forest” Zoo Workshop 44
4.3.1 Workshop Design, Process, and Objectives 44
4.3.2 Key Findings and Analysis 47
4.3.3 Discussion of “Monkey Forest” Workshop Findings 52
4.4. Study 2: Kindergarten Workshop 54
4.4.1 Workshop Design, Objectives, and Process 54
4.4.2 Key Findings and Analysis 57
4.4.3 Discussion of Kindergarten Workshop Findings 62
4.5. Comparative Discussion 63
4.6. Study 3: Family Session 64
4.6.1 Workshop Design, Objectives, and Process 64
4.6.2 Key Findings and Analysis 65
4.6.3 Discussion of Family Session Findings 67
4.7. Overall Discussion of Workshop Findings 67

5 Discussion and Future Works 69
5.1. Answering the Research Questions 69
5.2. Broader Implications for Design 70
5.3. Limitations 71
5.4. Future Work 71

5.5. Conclusion 72

References **73**

List of Figures

2.1	Moveables created with MoveableMaker.	7
2.2	The Crafting Stories picture book	8
2.3	Prototyping process with color materials	9
2.4	“The Life of a Frog” diorama created by PaperTouch.	9
2.5	User testing session with the telling board prototype.	10
2.6	The system pipelines of StoryDrawer.	11
2.7	Example animated crafts created on AnimaStage	12
2.8	Example of Interactive Automata, a jazz band with five members	13
2.9	Magnetact Animals	13
2.10	The application example that use the shape changing interface as button.	14
2.11	A tangible version of the video game “Pac-Man”	14
2.12	Left: Shape Display Example; Right: Tactile Display Example	15
2.13	Four types of magnetic forces and their related actions	16
2.14	The six rectangular design elements.	16
3.1	The front side of the GFACE’s PCBA structure	21
3.2	The working principle of a slide Movekit.	22
3.3	a thin Shrink Plastic used to create Movekit	23
3.4	Movekits consist of shrink plastic and neodymium magnets (diameter exceeding 39 mm)	23
3.5	The principle of the slide Movekit and a demo that shows a chick coming out of an egg using slide motion.	24
3.6	A demo shows a heart bump using a Jump Movekit.	25
3.7	Example: A function to move back and forth along the x-axis	29
3.8	A prototype test of the Rising Sun demo.	33
3.9	The mouth part of the frog papercraft.	34

3.10 The mouth opens only slightly due to the weak repulsive force. . 34
3.11 A child narrated a new story while playing with the paper character. 36
3.12 The PCR storybook demo. 37
3.13 The design process of a Jump Movekit. 37
3.14 Touch sensor integration 38
3.15 Children are engaging in the interaction. 39

4.1 Photos capturing the zoo workshop process and the forest board with monkeys crafted by children. 45
4.2 The setup of the workshop. 46
4.3 Zoo Workshop Drop-in Flow (Under 10 mins per child) 47
4.4 Observed types of character customization 50
4.5 A child is creating his monkey. 51
4.6 Children are figuring out where to place it to make the monkey move. 52
4.7 “I’m walking across the rope hand in hand with a friend monkey.” 53
4.8 SEA demos shown in the Kindergarten workshop 56
4.9 The workshop flow in 30 minutes. 56
4.10 The creations made by children during the kindergarten workshop. 59
4.11 A child drew “motion lines” around his characters 60
4.12 “Jellyfish is going shopping with a bag!” 61
4.13 The kid is playing Movook toolkit. 65

List of Tables

3.1 Basic Motion Library Examples 27

4.1 Observed types of character customization and example content . 49

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Chapter 1
Introduction

1.1. Background

1. Picturebook and Storytelling

Picturebooks have long served as essential media for nurturing children's imagination, language development, and empathy in both home and educational settings. A fundamental dichotomy exists between physical and digital formats. **Printed picturebooks** offer unparalleled tactile engagement and open-ended expressiveness, which are known to promote creativity. In contrast, **digital picturebooks**, while enhancing dynamic presentation through animation and sound, often lack opportunities for hands-on creation and physical manipulation.

Beyond the medium itself, storytelling is also a vital developmental process that enhances not only linguistic and structural competence but also emotional and social understanding through narrative expression. The act of **visual storytelling** —which combines verbal narration with visual creation—is a powerful form of creative expression that has been shown to enhance cognitive skills and support literacy development. [1]

2. Papercraft and Creativity

Paper, as a physical medium with inherent advantages such as tactility and manipulability [2], is a cornerstone of early creative education. Handcraft-based paper art (**papercraft**) is closely linked to the development of children's creativity and fine motor skills.

This aligns with foundational learning theories like **Constructionism**, which emphasizes that children construct knowledge and foster creativity through the active manipulation of physical objects and interaction with their environment. [3]

Furthermore, the theory of **Embodied Cognition** posits that our physical interactions are grounded in perception and bodily action, suggesting that this physical engagement with materials can directly stimulate creativity-related cognitive processes like idea generation [1].

3. Challenges in Modern Educational Settings

However, while these traditional creative activities are fundamental, they face challenges in contemporary educational environments. To better understand this context, we conducted preliminary observations of children's creative sessions. Several key insights emerged that motivate our research:

- **Sustaining Engagement with Static Crafts:** In a free-form papercraft session at a kindergarten, we observed a clear pattern: while children were initially focused, a noticeable decline in deep engagement occurred after approximately 15 minutes. Some would disengage from the primary task, suggesting that the static nature of traditional crafts struggles to sustain the attention of children accustomed to dynamic media.

- **Preference for Active Play over Passive Reading:** Further observations from a children's daycare revealed a clear preference for active engagement. Given the choice, children consistently gravitated towards hands-on crafting and subsequent imaginative play with their creations, rather than passively reading a picture book. This highlights their intrinsic desire for physical interaction and agency in their learning and play activities.

- **The Gap from Making to Meaning:** In both settings, children demonstrated remarkable imagination in their creations (e.g., a "Pokémon computer" or a "dragon train"). However, the activity often concluded once the physical object was made. There was a missed opportunity to extend this creative act into a richer narrative exploration. The static nature of the final artifact limited its potential as a prompt for storytelling or further imaginative play.

These observations highlight a practical need in educational settings for tools that can preserve the invaluable tactile and creative benefits of papercraft while infusing it with a level of dynamic interactivity. Such a tool should aim to sustain attention and, more importantly, bridge the gap from simply *making* an object to actively playing and telling a story with that object.

4. Tangible Interface

The framework of Tangible Interaction (TI) offers a promising pathway to address this need. TI enables interaction with digital content through manipulable physical objects, directly merging the physical act of making with dynamic digital feedback. Research in this field has shown that tangible interfaces positively impact children's creativity by providing crucial opportunities for exploration and risk-taking, which in turn fosters ideation and divergent thinking [4]. This body of work establishes the fundamental value of creating tactile and visually dynamic learning experiences that honor child agency. However, While powerful, many existing TI systems rely on custom hardware or complex software setups, which can create a significant implementation barrier for educators and parents who are not technical experts.

1.2. The Challenge: Bridging Physical Creation with Dynamic Storytelling

Despite the rich potential of both physical and digital media, a significant gap exists between them.

- **Printed picturebooks and papercraft** offer unparalleled tactile engagement and open-ended creativity but are inherently static.
- **Digital picturebooks and apps** excel at dynamic presentation through animation and sound but often lack opportunities for hands-on creation, sometimes confining children to predefined narratives.

From this context, two primary challenges emerge:

1. A **high technical barrier** prevents many non-expert users, including children and educators, from creating their own dynamic, interactive content. Tools that successfully bridge the gap between hands-on creativity and programmable motion remain scarce and are often complex.

2. A deeper challenge lies in supporting novel creative workflows. Most existing tools presume a traditional `story → character → action` pipeline. There is a scarcity of tools designed to explore an alternative process where abstract motion itself serves as the initial catalyst for a story, which is then embodied by a handmade character. We refer to this as the **motion → story → character** creative pipeline.

Therefore, the core design challenge is to develop a new form of interactive picture book that functions as an accessible, tangible learning tool to bridge the physical-digital divide. Such a picture book must not only support open-ended, hands-on creativity but also serve as a storytelling tool to improve storytelling, as a picture book always does.

1.3. Our Proposal: The Movook Toolkit

To address these challenges, this research proposes and investigates **Movook**, a modular, tangible toolkit designed to bring dynamic, programmable motion to traditional papercraft. The system consists of three main elements: the **GFACE** electromagnetic actuator board, magnet-embedded **MoveKits**, and a simplified programming interface.

By creating a seamless fusion of physical making and digital control, **Movook** is specifically designed to support the **motion → story → character** creative pipeline. It aims to use motion as a spark for imagination, which children can then develop into stories and embody through their own handmade, animated characters.

1.4. Research Questions

This study is guided by the following research questions:

1. **Toolkit Design:** How can a tangible toolkit be designed to effectively support hands-on creative expression and dynamic storytelling for young children, while also being accessible and meaningful for non-expert educators?

2. **Impact on Creativity:** In what ways does the integration of physical making and dynamic motion influence children's creative processes and output?

By investigating these questions through the design and evaluation of the **Movook** toolkit, this research aims to contribute valuable insights into creating novel tangible learning tools that powerfully support and enhance children's **creativity**.

Chapter 2
Related Works

This chapter reviews literature from several key areas to situate the contribution of the **Movook** toolkit. We begin by establishing the theoretical foundations that underscore the value of play, agency, and tangible interaction in early childhood education. We then examine prior work in interactive papercraft and storytelling to highlight the state of the art. Next, we critically analyze the concept of using motion as a catalyst for narrative, which is central to our work, and discuss the enabling technology of magnetism and design principles. By synthesizing these areas, we identify a clear research gap that **Movook** aims to address.

2.1. Theoretical Foundations: Play, Agency, and Tangible Interaction

Our research is grounded in the principle of **Learning through Play** [5], a philosophy that emphasizes holistic development through engaging, child-led activities. A critical component of playful learning is **child agency**, which refers to a child's power to make choices, express their ideas, and take initiative in their own learning process. Research has shown that when children can direct their own learning, they are more motivated, more engaged, and better able to construct deep, personal understanding from their experiences.This agency is not total freedom but rather a balanced partnership where adults provide structure and support while children lead the exploration.

This perspective aligns closely with theories of **Constructionism**, which argue that children build knowledge most effectively when actively making and physically interacting with meaningful artifacts. [6]

The framework of **Tangible Interaction (TI)** provides a direct pathway to realizing these theories. Research in TI has specifically shown that tangible interfaces positively impact children's creativity by providing crucial opportunities for exploration and risk-taking, which in turn fosters ideation and divergent thinking [4]. This body of work establishes the fundamental value of creating tactile and visually dynamic learning experiences that honor child agency and are intuitive and developmentally appropriate.

2.2. Tangible Storytelling and Interactive Papercraft

(Source:MoveableMaker, by Annett et al. [7])

Figure 2.1 Moveables created with MoveableMaker.

Within the broader field of TI, our work focuses on the augmentation of paper —a familiar, low-cost, and highly malleable medium that serves as the foundation for both picturebooks and papercraft. Picturebooks are one of the most common and powerful tools for children's learning, providing a tangible context for storytelling that is deeply integrated into both home and kindergarten life.
Research confirms that making paper crafts enhances children's creativity, spatial reasoning skills, and cognitive development [8]. Projects like MoveableMaker [7](Figure 2.1) and papertoys [8] further demonstrate how the process of papercraft itself can be a rich site for learning and creative expression. That again emphasize the importance of using paper picture book that combine papercrafts in improving children's creativity.

Building on this, prior research has explored bridging paper's tactile nature with digital capabilities to create interactive picturebooks and storytelling experiences.

- **Focus on Tactile and Multisensory Experience:** One stream of research emphasizes the tactile and multisensory experience of the picture book itself. Projects like "Crafting Stories" [9](Figure 2.2) and "Hello World" [10] focus on how the physical act of crafting and rich sensory feedback can enhance interactivity to create a more engaging reading experience.

(Source: Crafting Stories, by Posch et al. [9])

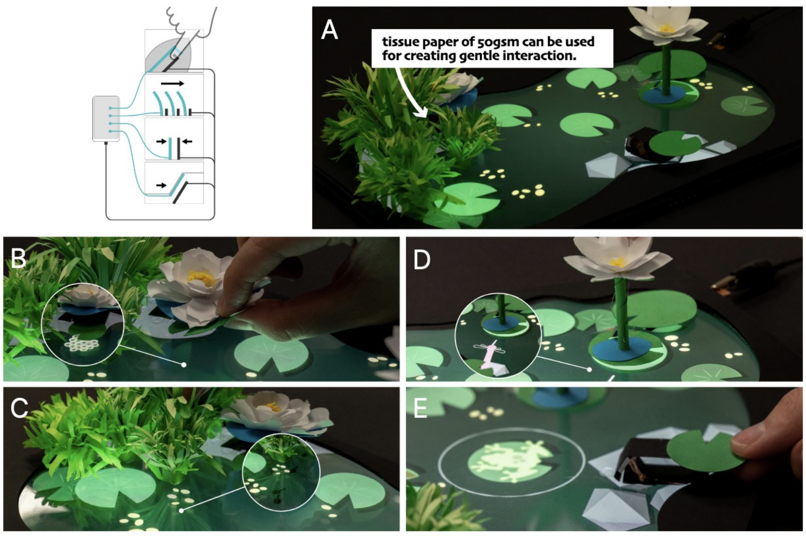
Figure 2.2 The Crafting Stories picture book

- **Focus on Interaction Mechanics:** Another primary focus is on interaction mechanics. Systems such as the "Interactive Drawing Book" [11](Figure 2.3), "Papertouch" [12](Figure 2.4), and "Elegami" [13] concentrate on adding electronic components to paper. Their primary contribution lies in making static paper surfaces responsive to user input like touch, thereby creating novel forms of interaction.

While these diverse approaches are valuable, their contribution is primarily in the visual and interaction mechanics. **There is comparatively less research exploring the creative potential of a rich and varied vocabulary of physical**

(Source:The Interactive Drawing Book, by Min et al. [11])

Figure 2.3 Prototyping process with color materials



(Source: PaperTouch, by Yong et al. [12])

Figure 2.4 “The Life of a Frog” diorama created by PaperTouch.

movements that can be generated directly on the papercraft itself to make the physical picturebook more appealing without a screen.

2.3. Motion as a Catalyst for Narrative Creation

The previous section highlights that motion is often a secondary element in tangible storytelling. This section argues for our core premise: **positioning motion as a storytelling trigger, not just a final effect.** To understand the novelty of this **'motion-first'** approach, we first review how conventional digital storytelling tools support creativity.

These tools typically assist the narrative process by providing content, structure, or AI-driven inspiration, following a **'story-first'** or **'content-first'** model.

(Source:The telling board, by Powell et al. [14])

Figure 2.5 User testing session with the telling board prototype.

The first approach is **providing multimedia components for assembly**. "TellTable" [15] and "KidPad" [16] allow children to build stories from drawings, photos, and text. Tools like "The Telling Board" [14](Figure 2.5) provide physical cards representing plot points (e.g., character, conflict) to help children structure their ideas.

A second major approach is **assisting in content generation**. "StoryDrawer"

[1](Figure 2.6), for instance, using AI to translates a child's oral storytelling into real-time drawing, others use social robots to facilitate collaborative storytelling [17].

(Source:StoryDrawer, by Yao et al. [1])

Figure 2.6 The system pipelines of StoryDrawer.

While these approaches are valuable, they typically require a child to begin with a character, scene, or story idea. However, a separate body of research has long demonstrated the powerful link between **animation, motion, and children's creativity.**

- **Animation as a Creative Mediator:**Sharon's research showed how animation can positively mediate the creative narrative process [18]. Also a recent work [19], which allowed children to animate their own drawings and act as "puppeteers", was found to effectively spark creative desire, encourage expression, and foster collaboration.

- **Motion Inspiring Personalized expression:** studies like "Paper Mechatronics" [20] confirm that children are highly engaged by making objects that can move and that they naturally develop detailed, personalized stories based on the specific movements of their creations. Similarly, tools like "Animastage" [21](Figure 2.7) highlight that dynamic crafts significantly expand children's expressive capabilities.

This reveals a crucial gap. Despite clear evidence that seeing motion inspires storytelling, it is usually treated as the final result of a creative process. Very few tangible storytelling tools use simple, abstract motion as the primary catalyst or

(Source:AnimaStage, by Nakagaki et al. [21])

Figure 2.7 Example animated crafts created on AnimaStage

initial inspiration. A gap remains for a toolkit specifically designed to provide programmable motions (e.g., slide, jump, rotate) as open-ended prompts or a "blank space" that invites children to engage in meaning-making and construct narratives from the ground up.

Our research directly addresses this gap. We argue for an alternative **'motion-first' pipeline**, investigating how this "motion-as-seed" approach can catalyze the creative process in new and powerful ways.

2.4. Enabling Design: Magnetism and Modularity

To realize this **'motion-first' pipeline**, our design relies on specific technological and structural choices.

primary challenge in creating dynamic picture books is embedding motion mechanisms without sacrificing the thin, portable form factor of a book. While systems like "Paper Mechatronics" [20] ,"FoldMecha" [23] and "Automatastage" [22](Figure 2.8) are effective, their mechanical linkages are often too bulky. This is precisely where **magnetic actuation** emerges as a compelling solution, offering several key advantages for creating tangible paper interfaces.

- **Flat Structure for Seamless Integration:**
  The foremost advantage of magnetism is its ability to enable free, non-contact motion through an inherently flat structure. The active components, such as the electromagnetic coil arrays in the GFACE system [24], are implemented as thin, multi-layered PCB coils. Similarly, the passive components in the characters are flat, ranging from the flexible magnetic

(Source: AutomataStage, by Jeong et al. [22])

Figure 2.8 Example of Interactive Automata, a jazz band with five members

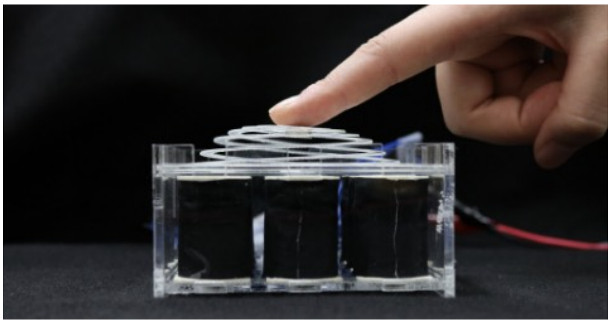
sheets used in “Magnetact animals” [25] (Figure 2.9)to the tiny neodymium magnet (powders) or patches in systems like “MagneSwift” [26] and “Flux-paper” [27]. This flatness allows the entire actuation system to be perfectly embedded within the pages of a book or under a paper-based play scene, enabling free, non-contact motion without physical tethers.

(Source: Magnetact Animals, by Yasu et al. [25])

Figure 2.9 Magnetact Animals

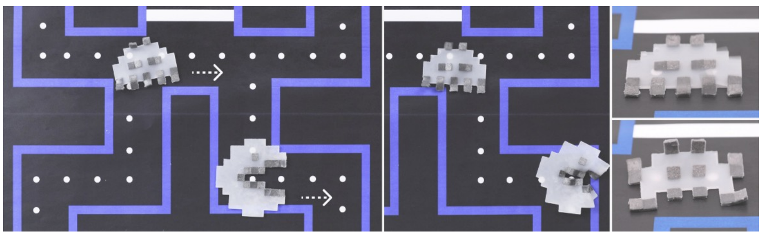
- **Rich Vocabulary of Movement:**

Magnetism supports a diverse vocabulary of movement through the controlled use of both attraction and repulsion. For instance, “FluxPaper” [27] utilizes magnetic attraction to slide thin neodymium patches across a surface. In contrast, “Magneshape” [28] and “Morpho Sculptures” [29] (Figure 2.10)uses the repulsive force create lifting or flapping motions. More complex systems like “Magpixel” [30] utilize NdFeB powder to create bipolar magnetic pixels, enabling vivid, lifelike creature movements through both attraction and repulsion(Figure 2.11).



(Source:Morpho Sculptures, by Takazawa et al. [29])

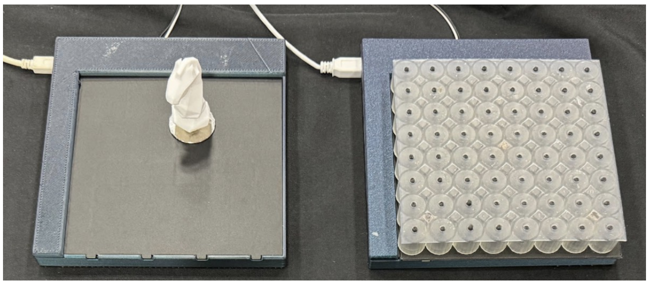
Figure 2.10 The application example that use the shape changing interface as button.



(Source:MagPixel, by Fan et al. [30])

Figure 2.11 A tangible version of the video game “Pac-Man”

- **Low Barrier for Non-Expert Users:** Finally, this technology becomes highly accessible when an electromagnetic actuator like GFACE [24] is connected to a microcontroller like an Arduino. The complex physics are abstracted into simple programming commands, providing children and educators with a low-barrier way to create sophisticated, programmable dynamics, such as a "snake walk" motion.(Figure 2.12)



(Source: GFACE, by Wang. [24])

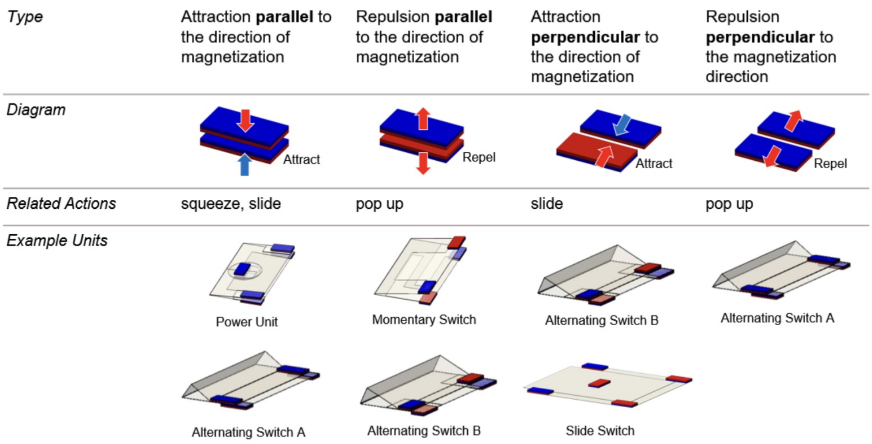
Figure 2.12 Left: Shape Display Example; Right: Tactile Display Example

In addition to the choice of technology, the principle of modular design is crucial for making our approach accessible. Inspired by prior work that demonstrates the value of modularity, including systems like "Paper mechatronics" [20] and research into accessible soft robotics [31](Figure 2.13) [32](Figure 2.14), our toolkit provides modular components—the physical MoveKits and the corresponding digital motion commands—that can be easily combined to create various movement patterns. This empowers users to experiment and allows for the animation of pre-existing papercrafts.

2.5. Research Gap and Our Contribution

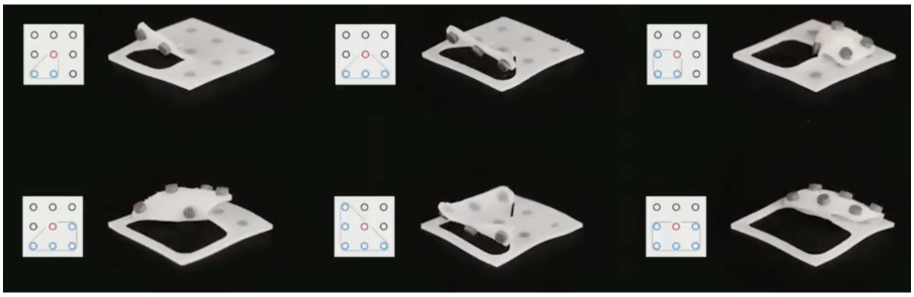
Our review of the literature identifies a clear and specific research gap at the intersection of tangible interaction, papercraft, and creative storytelling. While many innovative tools exist, we have identified three key limitations in prior work:

1. **Limited Focus on Motion:** Existing research on interactive papercraft, while valuable, primarily focuses on touch-based interaction mechanics or the tactile/multisensory experience of crafting. There is comparatively less research that explores a rich and varied vocabulary of physical motion as the core interactive element.



(Source: Enhancing Accessibility in SoftRobotics, by Yang et al. [31])

Figure 2.13 Four types of magnetic forces and their related actions



(Source:MagneDot, by Sun et al. [32])

Figure 2.14 The six rectangular design elements.

2. **Dominance of the "Story-First" Paradigm:** The vast majority of digital and tangible storytelling tools are designed for a story-first or content-first workflow, where children assemble pre-existing media or structure existing ideas. There is a distinct lack of systems built to investigate a **motion-first creative pipeline**, where abstract motion serves as the initial catalyst for narrative creation.

3. **The Form Factor Challenge:** Tools that do offer dynamic motion are often too bulky, technically complex, or not physically flat, making them difficult to integrate with the simple, accessible, and book-like medium of paper.

Crucially, very few systems are designed to explicitly support the **motion → story → character** creative pipeline in an accessible, paper-based format.
This research contributes by proposing and evaluating the **Movook** toolkit, a system designed to fill this gap. Our key innovations are:

- **A "motion-as-seed" storytelling mechanism**, which uses abstract motion as the primary catalyst for narrative creation.
- **The augmentation of traditional papercraft**, leveraging its proven creative and developmental benefits while seamlessly integrating into familiar educational and home settings.
- **A flat-structured, magnet-driven actuation system** that seamlessly integrates programmable dynamics with **traditional papercraft**.
- **A tangible narrative path** that guides children from observing motion, through meaning-making and story ideation, to the final embodiment of their ideas via handmade characters.

Chapter 3
Design Process

This chapter details the design process of our modular, magnet-driven toolkit, **Movook**. It outlines the foundational philosophy guiding its creation, the technical design of its core components, and the interaction framework that enables the **motion → story → character** creative pipeline.

3.1. Foundational Philosophy: Motion-Driven Creativity and Learning

The primary motivation for this research was twofold: to transform the traditional paper picture book into a more dynamic and engaging experience that fosters children's imagination, and to lower the technical barriers associated with creating such interactive content.

Our design is rooted in a core creative and pedagogical process centered on the sequence:

Motion → Story → Character (handmade papercraft)

We posit that observable motion can serve as a powerful spark for imaginative storytelling. This process encourages children to engage in meaning-making by attributing narrative significance to physical actions, thereby cultivating their storytelling abilities. The hands-on creation of paper characters then allows them to concretize these ideas.

This pedagogical approach is supported by several key interaction elements:

A. Motion as a Spark for Imagination

The toolkit provides "motion possibilities" as open-ended prompts, designed to pique curiosity and create a "blank space" for children to project their own narrative ideas rather than follow a predefined script.

B. Dynamic Storytelling & Meaning-Making Children are encouraged to integrate observed or programmed movements into their conceived stories, imbuing actions with specific meanings (e.g., a sliding motion representing a character shopping, or a searching movement).

C. Handmade Realization & Character Creation
Through papercraft, children bring their characters and scenes to life, physically manifesting the stories that emerge from the interaction with motion.

D. Key Skill Development
The entire process is designed to comprehensively enhance creativity, refine fine motor skills through crafting, and develop narrative fluency.

To realize this vision, we established three core design principles:

1. **Zero-Barrier Creation:** To eliminate the need for extensive coding or circuit knowledge, making the tool accessible for children and non-expert educators particularly in environments like kindergartens.

2. **Physical-Digital Fusion:** To seamlessly integrate traditional papercraft with programmable magnetic fields, leveraging motions created by magnetism as a key creativity catalyst.

3. **Plug-and-Play Prototyping:** To provide modular components that support rapid iteration and experimentation, allowing for both the creation of new works from scratch and the revitalization of existing ones.

The system designed to embody this philosophy consists of three main elements: GFACE & Arduino (the control system), MoveKits (the motion modules), and Papercraft (the user's creative medium).

3.2. Toolkit Design and Core Technology

The development of the toolkit focused on creating robust, accessible hardware that could reliably deliver dynamic motion while integrating seamlessly with papercraft.

3.2.1 Design Rationale: Leveraging Magnetism for Dynamic Papercraft

Magnetism was selected as the core technology because it allows for multiple, complex movements within a flat structure, making it ideal for integration with paper and picture books. This characteristic also supports the re-utilization of existing handmade crafts and allows for simple storage and setup , a key advantage in educational settings. The final design was achieved through iterative prototyping to effectively harness these benefits.

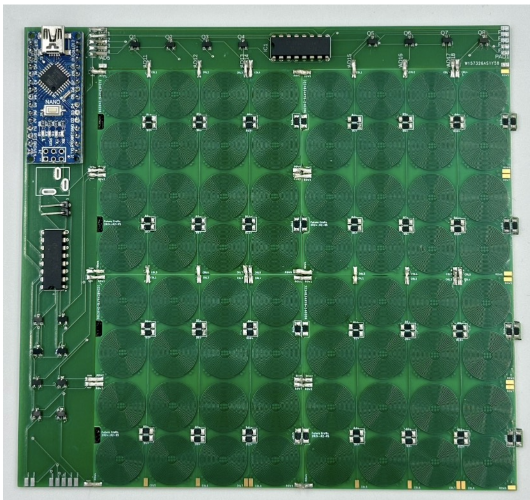
3.2.2 GFACE (Electromagnetic Actuator Board)– Enabling Programmable Motion

We introduce GFACE, an Arduino-controlled electromagnetic actuator board patterned with a grid of PCB coils. Developed by Wang (2024) as a design tool for creating innovative displays, GFACE was selected for this project because it directly addresses the limitations of traditional bulky actuators, offering a thin, quiet, and inexpensive platform for generating programmable magnetic fields [24]

1. **Design Rationale and Architecture**
   The core design goal of GFACE is to provide a versatile and accessible tool for designers. To overcome the form-factor challenge of mechanical motion systems, GFACE leverages an array of electromagnetic coils fabricated directly onto a Printed Circuit Board (PCB). This results in an inherently flat and scalable structure, making it ideal for seamless integration into paper-based interfaces like our dynamic picture book.

2. **PCB Coils and Magnetism Generation**
   GFACE uses a matrix-addressable PCB coil array. To efficiently control

the entire grid without requiring a dedicated pin for each coil, the system employs a multiplexing technique with a diode array. This allows an entire 8x8 grid of coils to be controlled with far fewer connections. The board's design underwent multiple iterations, evolving from a simple 2-layer PCB to a more powerful 12-layer version to increase the number of coil turns, thereby enhancing the magnetic field strength while maintaining a slim profile.



(Source: GFACE, by Wang. [24])

Figure 3.1 The front side of the GFACE's PCBA structure

3. **Programmed Timing & Control**
   An Arduino microcontroller, via MOSFET driver circuitry and shift registers, controls the switching of each individual coil. This is dictated by high-level Arduino scripts, enabling precise temporal and spatial control of the magnetic fields. The complexity of the underlying electronics is intentionally abstracted away from the end-user, allowing creators to focus on designing motion patterns rather than on low-level circuit management.

4. **Interaction Principle: How GFACE Moves a MoveKit** Motion is achieved through the controlled magnetic interaction between the GFACE board and the permanent magnets embedded in the MoveKits. When a

magnet is placed within proximity of the magnetic field generated by current in the GFACE coils, it interacts with the field based on the fundamental principle that like polarities repel while opposite polarities attract. GFACE uses this principle to maneuver objects in two dimensions. By strategically selecting which GFACE coils are active, and in what sequence and polarity, one can precisely pull (attract), push (repel), or apply torque to the MoveKit, resulting in various animations. For example, a simple sliding motion is created by sequentially activating adjacent coils, causing the MoveKit to be pulled from one magnetic field to the next across the surface.

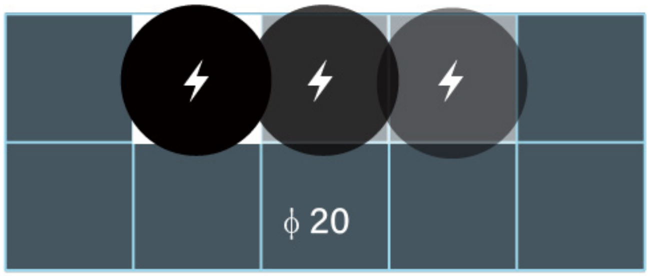


Figure 3.2 The working principle of a slide Movekit.

3.2.3 MoveKit (Magnetic Motion Module)– Translating Fields to Action

MoveKits are the physical carriers that transform GFACE's magnetic field into mechanical motion. They are thin plastic modules embedding neodymium magnets, designed for easy attachment to paper characters.

1. **Module Construction**
   Each MoveKit consists of a thin Shrink Plastic (polystyrene, 0.4mm) carrier, into which one or more neodymium magnets are embedded. The magnetization direction, orientation, and placement of these magnets are critical design parameters, chosen to produce distinct force and torque responses.

Each MoveKit is designed with a diameter exceeding 39 mm to comply with safety standards and prevent ingestion by young children.

Figure 3.3 a thin Shrink Plastic used to create Movekit

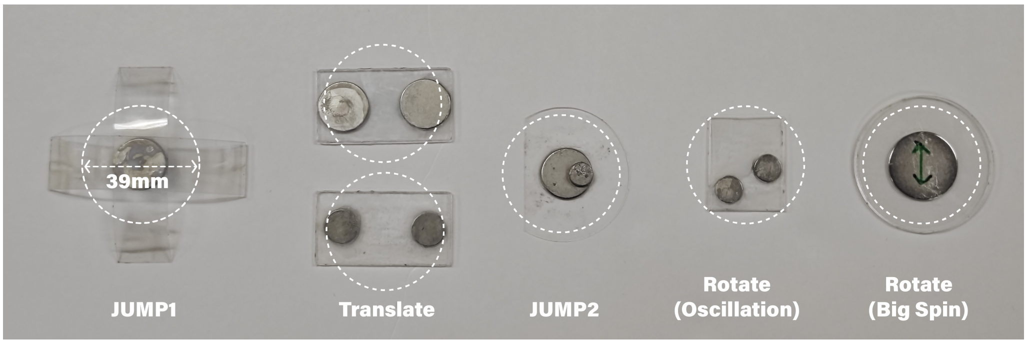


Figure 3.4 Movekits consist of shrink plastic and neodymium magnets (diameter exceeding 39 mm)

2. **Working Principle**

   The MoveKits are designed to respond to the dynamic magnetic fields generated by the GFACE board, as described in the section above. The unique arrangement of magnets within each type of MoveKit determines how it will react to the magnetic forces, allowing for a variety of distinct movements such as sliding, rotating, or jumping. For example, a dual-magnet MoveKit with alternating coil activation in a localized region can create a swaying motion.(figure 3.5) (Detailed descriptions of each specific motion pattern are provided in the **Basic Motion Library** in Section 3.3.1).

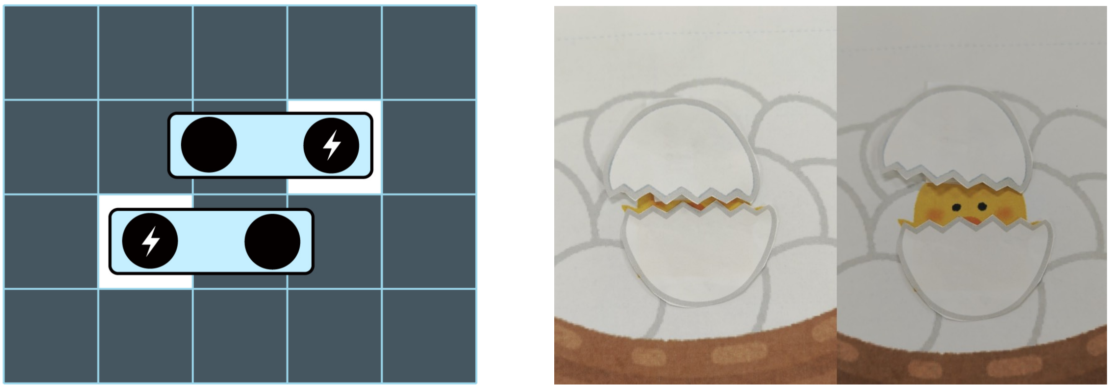


Figure 3.5 The principle of the slide Movekit and a demo that shows a chick coming out of an egg using slide motion.

3.2.4 Papercraft Integration – Supporting Handmade Creativity

Users can create their own original artwork or use online resources, then physically assemble these paper elements onto the MoveKits and position them on the GFACE board. This seamless integration with handmade processes is a core Creativity Catalyst. It allows for:

- **Personalization for Creativity:** Children can design unique characters with distinct emotions and motivations through personalized features like facial expressions, clothing, and items.
- **Cultivation of Fine Motor Skills:** The act of cutting, folding, and assembling paper elements inherently exercises and develops these essential skills.

The design allows for intuitive mapping of motions to story contexts. For instance, a heart-shaped kirigami piece attached to a MoveKit and programmed with a JUMP() sequence creates a “beating heart” animation.

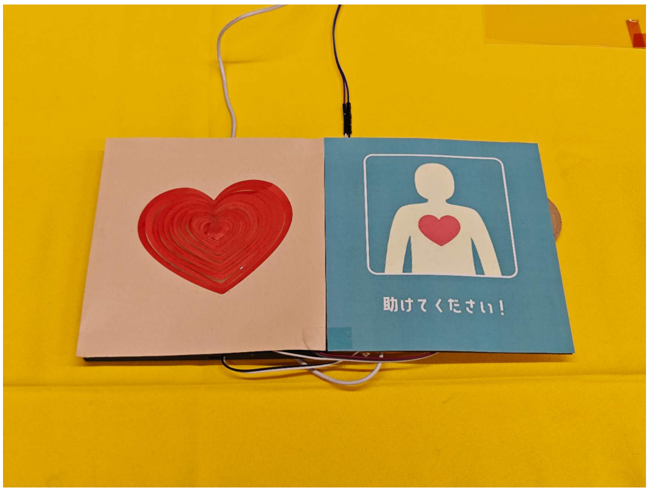


Figure 3.6 A demo shows a heart bump using a Jump Movekit.

3.3. Interaction Framework: From Motion to Storytelling

The interaction framework is designed to bridge the gap between the technical capabilities of the hardware and the creative storytelling goals of the user, emphasizing ease of use and imaginative exploration.

3.3.1 Movement as a Catalyst for Imagination and Narrative

A central design decision was to leverage Movement as a Creativity Catalyst. The toolkit supports two primary modes of engagement:

- **Mode 1: Sparking Creation from Scratch – Movement as an Initiator:** This mode emphasizes “motion as an open-ended prompt” . The toolkit provides basic “motion possibilities” (e.g., a simple slide, a sudden jump) that serve as initial stimuli, leaving a large “blank space” for children’s imagination. This catalyzes a creative flow:

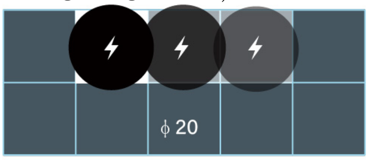
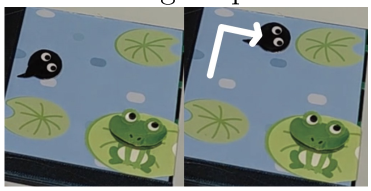
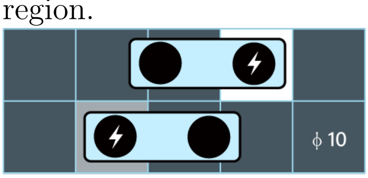
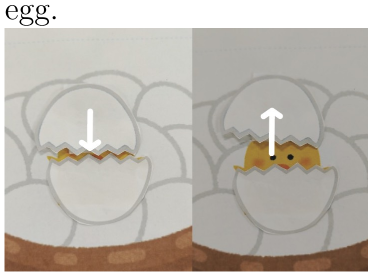
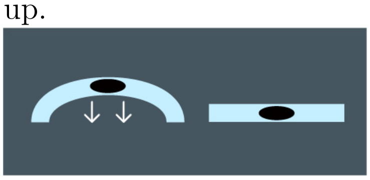
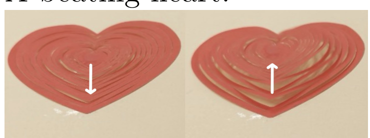
Motion Possibility
→ *Imaginative Exploration*
→ *Story & Meaning Construction*
→ *Handmade Character/Scene Creation*
→ *Enjoyment & Fun*

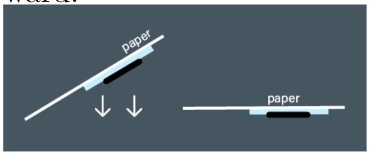
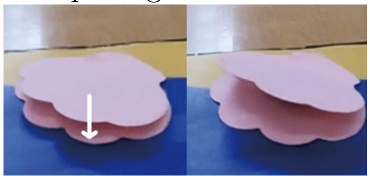
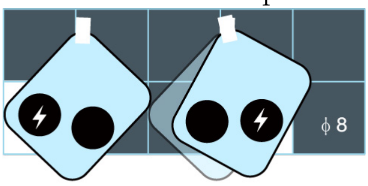
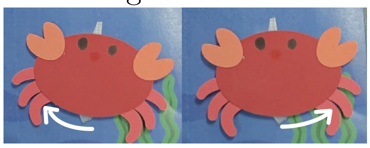
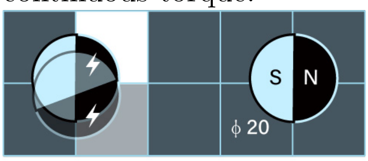
This approach aims to enhance curiosity and engagement.As observed in our workshops, when children see the demo, they often immediately begin to interpret the actions (“The octopus is swimming!”) or are inspired with a completely new idea for the motion, leading them to create their own unique characters and stories.

- **Mode 2: Revitalizing Existing Resources – Movement as an Enhancer:** The toolkit is also designed to add dynamic life to pre-existing papercrafts created in classes or elements from online picture book resources . This promotes resource re-utilization, allowing children to see their previous creations in new, interactive ways.

The following “Basic Motion Library Examples” chart3.1 illustrate the palette of movements available:

Table 3.1: Basic Motion Library Examples

Motion Type	**Coil Control Sequence (Simplified)**	**Example Effect**
Translate (Slide)	Sequentially activate adjacent coils (e.g., energize coil *i+1* while de-energizing coil i). 	A swimming tadpole. 
Translate (Sway)	For a dual-magnet MoveKit, alternate coil activation within a localized region. 	A chick breaking out of an egg. 
Jump(X-shaped kit)	Activate a coil to attract, then rapidly de-energize. This causes the magnet at the center of the X-shaped “Jump 1” MoveKit to pop up. 	A beating heart. 

Motion Type	**Coil Control Sequence (Simplified)**	**Example Effect**
Jump2(flat kit)	Activate a coil to create attract, then rapidly de-energize. This requires the paper to be pre-folded upward. 	An opening shell. 
Rotate (Oscillation)	Use a dual-magnet MoveKit with one point as a pivot and alternate the activation of adjacent coils.This creates a back-and-forth torque. 	A walking crab. 
Rotate (Big Spin)	Use a diametrically-magnetized magnet and activate coils sequentially around it to generate continuous torque. 	A dinosaur is opening his mouth. 

3.3.2 Simplified Programming for Creative Expression

To ensure broad accessibility and keep the focus on storytelling, the complexity of coil control is abstracted through a set of simple, high-level Arduino functions. An example is shown as Figure 3.7.

```
void lineWalkX(int x1, int x2, int y, int
    dTime) {
  turn(x1, y, ON);
  write();
  delay(dTime);
  turn(x2, y, ON);
  write();
  delay(dTime);
}
// Function call example
lineWalkX(3, 2, 2, 300);
```

Figure 3.7 Example: A function to move back and forth along the x-axis

While the current implementation uses Arduino, a key future work direction is to create an intuitive GUI to make the toolkit even more accessible for non-technical users.

3.3.3 The Creative Workflow: Bringing Stories to Life

The process for creating animated paper picture books with this toolkit is designed to be intuitive and iterative, directly supporting the “Make-and-Move” paradigm.

The typical user workflow is as follows:

1. **Decide Story Theme:**

   Users create or download illustrations and characters for their picture book, setting the narrative foundation.

2. **Attach & Place:**

Users determine the types of motion required for different characters or story elements. Each paper character is affixed to a MoveKit and placed on the target coil cell(s) of the GFACE board.

3. **Script the Motion:**

   In the Arduino IDE (or a simplified scripting interface), use high-level commands like **lineWalkX(x1,x2,y,dTime);, JUMP(x,y,dTime);** to define the desired animation sequence for each character.

4. **Execute & Iterate:**

   Upload the script to the Arduino. The microcontroller then toggles the GFACE coils according to the programmed sequences. Users can watch their paper elements spring to life, then refine the character placement, MoveKit orientation (if applicable), or script timing to achieve richer and more expressive storytelling.

This tangible workflow transforms passive reading into an active storytelling experience. It outlines the complete creative process for an author or educator to design a full dynamic picture book, allowing them to link their assembly and scripting choices directly to on-page motion. This process showcases the full potential of the toolkit. In the following chapter, we will describe how we distilled and simplified key elements of this comprehensive workflow into shorter, focused activities designed to evaluate the core creative experience with young children.

3.4. Usability and Application in Educational Settings

A key driver throughout the design process was ensuring the toolkit's usability, particularly within educational environments such as kindergartens. The toolkit is intentionally designed for ease of use and seamless integration into early childhood education practices:

- **Leveraging Familiar Materials and Practices:**
  The toolkit utilizes materials already common in early childhood education,

such as papercraft and picture books. This familiarity significantly lowers the barrier to adoption. Furthermore, the emphasis on handmade creation aligns perfectly with existing kindergarten curricula that include crafting and drawing, naturally promoting fine motor skills and creativity.

- **Ensuring Practicality for Educators:**
  It is designed for easy deployment with no significant technical threshold. Validation from workshops indicated that the system can be set up quickly (e.g., a 1-hour workshop requiring only 5 minutes for setup), making it highly practical for busy educators.

- **Promoting Sustainability and Extended Value:**
  The ability to re-utilize existing handmade papercrafts or adapt current storybook materials not only adds educational value but also promotes sustainability within the classroom.

These design considerations collectively aim to make the toolkit not just a novel technology, but a truly accessible, engaging, and enriching tool that educators can confidently integrate into their daily activities.

Application Prospects

Building on these foundational aspects of usability and alignment with creative practices, the toolkit is envisioned for two primary application directions:

1. **As a Children's Creative Toy:** Empowering children to design and animate their own dynamic books and interactive stories. This offers a rich platform for imaginative play, storytelling, and learning through hands-on creation, directly leveraging the toolkit's emphasis on papercraft and tangible interaction.

2. **As an Educational Toolkit (Future Work):** Based on its demonstrated ease of use in educational contexts, a significant future direction is to further develop the toolkit for educators and learning designers. This would position it as a versatile authoring tool for creating customized interactive teaching aids and engaging learning experiences across various subjects, extending its application beyond free play into more structured educational scenarios.

3.5. Iterative Prototyping and Design Refinement

The development of the MoveKit toolkit, which was designed to integrate with the existing GFACE system, was an iterative process, marked by early experiments and a series of internal demos. These prototypes were crucial for identifying challenges, validating core concepts, and progressively refining the toolkit's design, mechanics, and interaction paradigm.

3.5.1 Initial Experiments: Exploring Magnetic Actuation

Our initial explorations focused on leveraging magnetic repulsion for simple vertical motion. An early experiment involved attempting to create a "sun-rising" movement. A paper "sun" attached to a small magnet was positioned above another magnet oriented to create a repulsive force. While the sun did rise briefly, demonstrating the basic potential of repulsion-driven motion, this approach presented significant challenges:

- **Unstable Repulsion:** The suspended magnet was highly prone to flipping over or lateral displacement due to the inherent instability of balancing repulsive forces. Controlling the repulsion precisely was difficult; modules often drifted off-center or unexpectedly flipped and snapped downwards.
- **Limited Control Precision:** This single-magnet, single-cell setup lacked the necessary resolution to achieve fine control over movement, making it difficult to synchronize motion with any narrative pacing.

To address these critical stability and control issues, we made a pivotal design shift towards a primarily magnetic attraction-based system. This led to the integration of the GFACE framework [24], a thin, quiet, and inexpensive electromagnetic actuator board featuring a grid of addressable coils. The GFACE board's capability for generating localized, programmable attractive fields offered a more stable and controllable foundation for motion, paving the way for the development of the MoveKit motion module library.

Figure 3.8 A prototype test of the Rising Sun demo.

3.5.2 Iterative Demos: Balancing Motion, Interaction, and Early Creative Potential

With the GFACE platform as a base, we conducted further demos to refine MoveKit designs and explore interaction patterns.

Demo 1: "Frog Life" Picture Book (Shiodome Summer School 2024 NTV Engagement)

Concept: A single-page interactive picture book depicting a frog's lifecycle, intended to feature a swimming tadpole and a frog with a mouth-opening action.

Mechanics Explored:

- **Move:** A tadpole image attached to a simple MoveKit was programmed to slide across a designated "water" area on the GFACE board.
- **Jump (Mouth Open):** A frog head element was designed to simulate mouth opening and closing, initially using the repulsive force between a magnet attached to the upper mouth and the GFACE magnetic field.

Limitations Identified & Design Implications

1. **Weak Force Limits Motion:** Early MoveKit prototypes using weaker magnets resulted in limited "jumping" height (average 0.7cm for the mouth action). This meant the intended "frog jump" was reduced to a subtle mouth opening. **Implication:** Since GFACE parameters were fixed, this

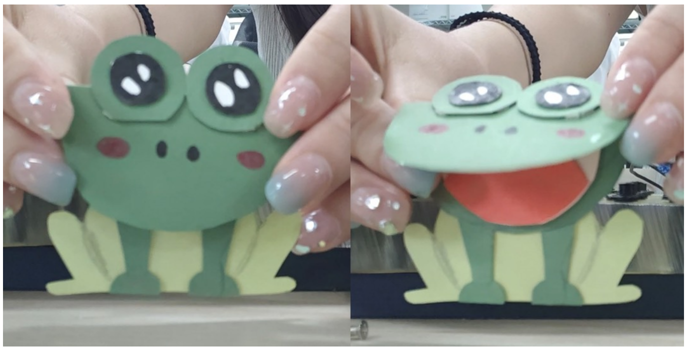


Figure 3.9 The mouth part of the frog papercraft.

Figure 3.10 The mouth opens only slightly due to the weak repulsive force.

highlighted the critical need to focus on developing MoveKits with significantly stronger neodymium magnets and optimized mechanical designs. The goal was to achieve more pronounced and varied motion, including effective repulsion for jump-like effects, by solely enhancing the MoveKit's capabilities.

2. **Limited Motion Patterns:** Simple, single-magnet MoveKits primarily allowed for basic slide or limited jump/lift movements. The lack of diverse motion patterns was perceived as potentially reducing long-term engagement.

   Implication: This spurred the idea for developing a library of MoveKits with different magnet configurations to support a wider range of movements like rotation and more complex paths.

3. **Passive Viewing Experience:** The initial demo was largely observational. While engaging, it lacked direct user interaction to trigger or modify the animations.

   Implication: This insight initially led to the consideration of integrating simple Arduino sensors (e.g., touch sensors) to allow children to trigger or influence the animations, making the experience more interactive.

4. **Lack of Hands-on Making for Users:** The demo was pre-assembled, missing an opportunity to involve users in the creative construction process.

   Implication: This reinforced the importance of integrating a "handmade" component for children into the core user experience to stimulate creativity directly.

Inspirations: Narrative Potential

Despite its limitations, an inspiring observation occurred when a child reinterpreted the frog's subtle mouth movement ("open and close its mouth") by narrating, *"Maybe it's eating tadpoles!"* This highlighted how even simple, abstract movements could serve as powerful catalysts for children's imagination and storytelling, reinforcing a core design goal.

Figure 3.11 A child narrated a new story while playing with the paper character.

Demo 2: KMD Forum Interactive PCR Storybook

Building on insights from Demo 1, this iteration aimed to enhance interactivity and explore more robust motion mechanics, specifically addressing the **passive viewing experience** noted in the previous demo.

Concept: A two-page picture book designed to illustrate the PCR (Polymerase Chain Reaction) process in an engaging way. When a reader firmly pressed the 'heart' of a character depicted as 'fallen' or in need, an integrated touch sensor would detect this input. This action triggered a kirigami heart, attached to a newly designed X-shaped "jump" MoveKit, to start pulsing. **Mechanics & Toolkit Iterations**

- **Jump (New MoveKit):** For this demo, a new type of MoveKit was developed, combining PET film hinges with neodymium magnets in an X-shape. Experimentation with materials like paper strips and wool attached to this X-shaped MoveKit allowed for varying jump heights and visual effects, creating a more effective "pulsing" or "beating" heart.

- **Touch Sensor Integration to Enhance Interaction:** To directly address

Figure 3.12 The PCR storybook demo.

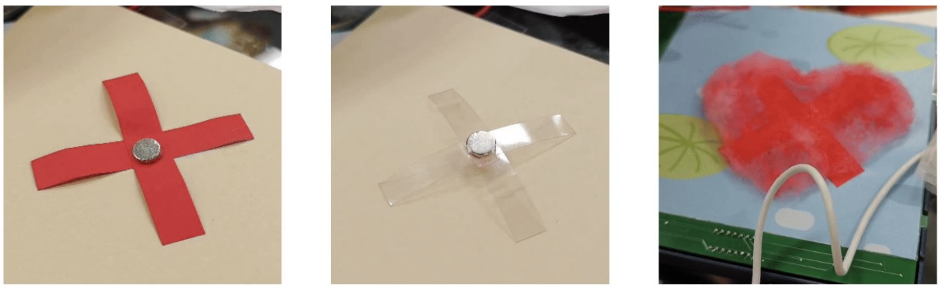


Figure 3.13 The design process of a Jump Movekit.

the previous limitations of a passive experience, an Arduino touch sensor was incorporated. This allowed the reader's touch to directly trigger the heartbeat animation, providing a direct, tangible way for children to advance the story with their own hands and fostering a sense of accomplishment through active participation.

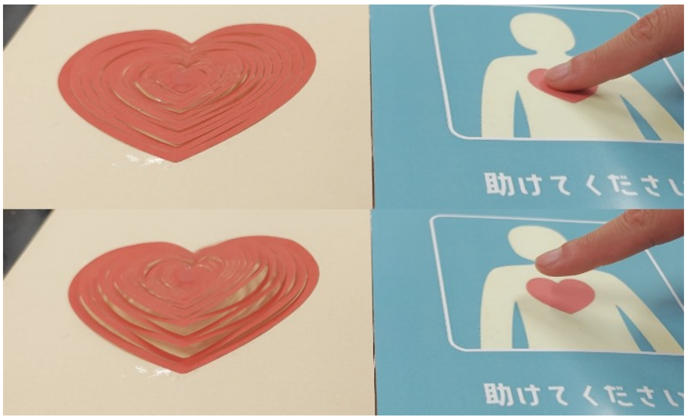


Figure 3.14 Touch sensor integration

Reconsideration of Implementing Sensors for Subsequent Prototypes However, for the subsequent picture book prototypes, this electronic interaction was temporarily deferred. The primary reasons included:

1. **Safety and Durability:** Concerns about the robustness and safety of exposed electronic components (like a touch sensor with potentially sharp connection points) in a product intended for young children, especially in environments like kindergartens.

2. **Focus on Core Mechanics:** A decision to first prioritize perfecting the core tangible interaction with the MoveKits and the "handmade" aspect of the picture book itself before adding electronic complexity.

3. **Future Option:** While not implemented yet, integrating simple sensors remains a viable option for future iterations or specific versions where a more controlled and protected integration of electronics can be ensured.

Feedback and Further Limitations Identified

Feedback on this demo was generally positive. The tactile interaction significantly

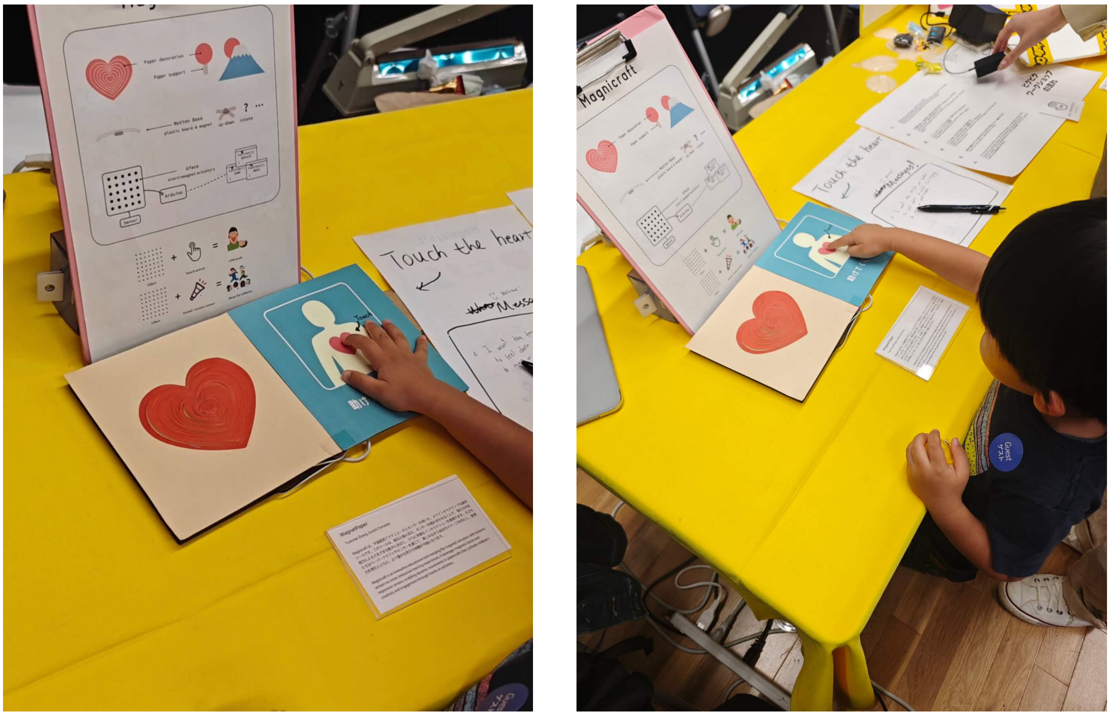


Figure 3.15 Children are engaging in the interaction.

increased engagement (average interaction time: 1.2 min vs. 0.4 min in Demo 1), indicating that users found it **fun and engaging**. However, constructive points emerged regarding the toolkit itself:

- **Limited Variety of Movements:** Observers noted that the range of distinct movements and opportunities for deep customization by users was still somewhat limited, making it difficult for some to fully envision its broader application as a versatile dynamic picture book platform.
- **Lack of User Customization:** A key piece of feedback was the absence of opportunities for children to customize elements of the experience them-

selves, which was seen as a missed opportunity for deeper creative engagement.

Next Steps for Toolkit Design (Derived from Demo 2) This feedback, combined with self-reflection, led to clear future directions for the toolkit's development:

1. **Need for More Diverse MoveKits:**

   To make the picture book concept more robust and adaptable to different narratives, a key next step was to design and develop a broader library of MoveKits (e.g., for different types of rotation, more complex paths, and varied jump characteristics).

2. **Enhancing Customization for Users:**

   Recognizing the limited opportunities for children to freely customize their experience, a future goal became to incorporate more elements that children could personalize. Therefore, I aim to incorporate more elements that children can personalize, potentially by integrating diverse paper craft techniques and allowing for more varied movements.

3.5.3 Conclusion

This iterative prototyping phase, moving from basic force exploration to more complex interactive demos, was instrumental in shaping the core GFACE and MoveKit system, refining the interaction paradigm, and clarifying the design requirements for a truly creative and accessible toolkit. The insights gained directly informed the more mature version of the toolkit, which was subsequently used in user-focused evaluation workshops.

Chapter 4

Evaluation: Assessing Impact and Usability in Creative Workshops

4.1. Introduction to Evaluation Approach

This chapter presents the evaluation of the **Movook** toolkit. Our primary focus is to assess its usability and, more importantly, its effectiveness in supporting the core creative process we envision: guiding children from an initial motion stimulus, through story ideation and meaning-making, to the handmade realization of characters and narratives. We employed a qualitative, observational approach in workshop settings to gather rich insights into how the toolkit fosters creativity, storytelling, and fine motor skills, and how it leverages key creativity catalysts such as Motion and Handmade crafting.

4.2. Workshop Methodology

4.2.1 General Approach

This research is grounded in a qualitative, observational methodology, designed to capture and understand children's spontaneous behaviors, interactions, and creative processes within a naturalistic workshop setting. Our approach is deeply informed by the theory of Constructionism, which posits that children build knowledge most effectively when they are actively engaged in creating personally meaningful artifacts. The **motion** → **story** → **character** pipeline at the heart of our workshops directly embodies this, as children construct their own understanding and narratives by physically making and animating their papercraft creations.

Furthermore, this study employs a Research through Design (RtD) approach.

The **Movook** toolkit itself is an evolving prototype, and each workshop serves not only to evaluate the tool but also to generate new knowledge that informs its subsequent iterations and our understanding of tangible, dynamic storytelling.

Data Collection and Analysis Methods

To comprehensively capture the children's experiences, we employed a mixed-methods approach, combining several data collection techniques across the workshops.

Data Collection

- **Video Recording:** Video recording was employed in both studies to capture dynamic interactions. The Kindergarten Workshop was recorded in its entirety for comprehensive micro-analysis, while shorter video clips were captured during the Zoo Workshop to document key moments and supplement observational notes.
- **Field Notes (Observation Notes):** Researchers took extensive real-time notes during the sessions, documenting specific behaviors, key quotes, unexpected creative choices (such as reinterpreting motions), challenges encountered, and the overall flow of the creative process.
- **Photographs of Process and Created Artifacts:** Detailed photographs were taken throughout the workshops, documenting both the creative process and the final handmade characters and scenes created by the children. These artifacts serve as crucial physical evidence of their design ideas, narrative concepts, and creative expression.
- **Post-workshop Questionnaires with Educators:** Following the Kindergarten Workshop, questionnaires were used to gather teachers' professional perspectives on the toolkit's usability, its educational potential, and its impact on children's engagement and creativity compared to typical classroom activities.

Data Analysis

- **Thematic Analysis:** The primary method for analyzing qualitative data (from video transcripts, field notes, and open-ended questionnaire responses) was thematic analysis. We iteratively coded the data to identify recurring patterns, behaviors, and concepts. This process led to the development of the key themes presented in our findings, such as *"Motion as a Creative Catalyst"* and *"Creative Reinterpretation of Motion."*

- **Artifact Analysis:** The children's created papercrafts were analyzed as tangible expressions of their stories and personalization choices, providing physical evidence for themes like character embodiment.

- **Descriptive Statistics:** Observational data was also used to generate simple descriptive statistics (e.g., "97% of children correctly distinguished...") to summarize behavioral frequencies and trends within the participant group.

- **Peer Debriefing:** To ensure the reliability and validity of our analysis, the identified themes and interpretations were regularly discussed among the research team and with academic supervisors to challenge assumptions and reach a consensus.

Ethical Considerations

All research activities were conducted in strict accordance with the ethical guidelines for research involving children and received formal approval from the Keio Media Design Ethics Committee.

Informed Consent and Assent: Prior to the workshops, informed consent was obtained from the parents or legal guardians of all child participants, as well as from the participating institution, Green Port Sakuragicho Nursery School. The consent forms provided a detailed overview of the research purpose, the materials to be used (e.g., paper, magnets, conductive sponges), data collection methods, and storage policies. It was explicitly stated that participation was completely voluntary and that participants had the right to withdraw at any time without penalty, with the option to have their data removed upon request.

Privacy and Anonymization: All collected data—including video recordings, photographs, and interview notes—have been anonymized to prevent the identification of individuals. As outlined in the consent form, the data is stored securely on the Future Crafts team's cloud storage and will be managed until March 31, 2030. The use of this data is strictly limited to academic research publications, reporting by the collaborating nursery school, and promotional activities by supporting organizations, as agreed upon by all stakeholders.

Participant Welfare: The wellbeing of the children was our top priority. The workshop environment was designed to be safe, supportive, and enjoyable. Researchers and facilitators were experienced in working with children and were prepared to provide assistance and ensure a positive experience for everyone involved.

4.3. Study 1:“Monkey Forest” Zoo Workshop – Observing the Motion → Story → Character Process

4.3.1 Workshop Design, Process, and Objectives

Date and Location

- **Date:** March 23, 2025, from 11:00 AM to 2:00 PM
- **Location:** Yumemigasaki Zoological Park , Kawasaki, Japan
- **Setting:** The activity was conducted as part of the zoo's 50th-anniversary event, which attracted a large number of families with children. A long desk was used to showcase the demo and for children to engage in the hands-on crafting activity.

Participants

Figure 4.1 Photos capturing the zoo workshop process and the forest board with monkeys crafted by children.

- **Children:** 36 children, aged 2–8 years (with the majority between 4–6 years old). Each child was accompanied by at least one parent or guardian who was available to assist with the hands-on process.
- **Facilitators:** The workshop was run by **3 facilitators**, including the primary researchers and supporting members.
- **Recruitment Method:** Participants were recruited via a drop-in, public engagement format rather than a formal, pre-registered workshop. Families visiting the zoo for the anniversary event were invited to stop by the activity booth to participate.

Materials and Tools

- On **Movook** a **“Forest” backdrop** with pre-set dynamic demonstrations (a monkey climbing a tree, another crossing a vine) was presented, providing the initial **“motion possibilities.”**
- Customization contents were provided for the handmade phase, including 6 body part types (body / tail / head / face / hair / ear) and colored pens for **facial expressions / cloth decorations / story items** (like banana, flower, etc.)

Figure 4.2 The setup of the workshop.

Procedure

Given the drop-in, public engagement format of this event, we adapted the comprehensive creator workflow described in Chapter 3 into a concise, three-phase creative journey, typically lasting less than 10 minutes for each child. This simplified procedure was designed to test the core experience of the

1. **Observation and Ideation:** First, children observed the dynamic monkey demonstrations to spark their imagination and initial story ideas.

2. **Handmade Creation:** Next, using the provided toolkit of paper parts and art supplies, they designed, assembled, and personalized their own monkey characters.

3. **Dynamic Storytelling:** Finally, children placed their handmade characters onto the backdrop, integrated them with the available motions, and were encouraged to narrate the stories they had created.

The primary objectives of the *"Monkey Forest"* Zoo Workshop were:

1. To observe and analyze the `motion → story → character` creative pipeline in action. This focused specifically on how children **first used pre-defined**

Figure 4.3 Zoo Workshop Drop-in Flow (Under 10 mins per child)

motion prompts to spark imaginative stories and engage in meaning-making, and **subsequently used personalized, handmade characters to embody and develop those emergent narratives.**

2. To evaluate the toolkit’s initial **usability and engagement** with young children in an informal learning environment, identifying age-related interaction patterns and key areas for design refinement.

4.3.2 Key Findings and Analysis

(A note on participant numbers: The analysis of narrative creation includes the 34 children who produced a story, while the analysis of character customization includes all 36 children who created an artifact.)

1. Motion-to-Creativity Conversion: Understanding Motion and Developing Stories

(The participant group for these findings is n=34 children, aged 2-7 years old, unless otherwise specified.)

Observation Points:
Q1: Motion Comprehension: After observing the demonstrations, did children grasp the directional nature of movements like “climbing” (vertical) and “crossing sideways” (horizontal)? Were they able to reflect this understanding in the placement and orientation of their handmade characters?
Q2: Creative Extension from Motion: Building on their understanding of the provided “motion possibilities,” did children attempt to imagine new movements or devise unique arrangements of their characters to express emergent story

ideas?

Findings:

A1: Grasp of Motion Mechanics: A significant number of children demonstrated a clear understanding of the different motions. 97% of children correctly distinguished between the vertical "climbing" motion and the horizontal "vine-crossing" motion, applying this understanding to how they positioned their characters. Furthermore, 88% of children actively adjusted their character's body angle to align with the slope of the terrain, indicating a nuanced comprehension of motion-environment interaction.

A2: Creative Application and Narrative Extension from Motion: The combination of motion demonstrations and the "Forest" background effectively stimulated imaginative play. Many children (70.5%) used their understanding of the toolkit to endow the motions with new definitions or expanded narratives, such as "My monkey is looking for bananas." A 5-year-old participant demonstrated an emerging cognition of action sequences by stating, "Let the monkey climb the tree first, then jump onto the vine!"

Conclusion:
Simple motion demonstrations, when paired with a suggestive environmental context (the backdrop), serve as powerful catalysts. They not only enable children to grasp basic principles of physical movement (direction, sequence, environmental interaction) but also empower them to creatively extend these observations into rich narrative expressions and imaginative scenarios.

2. Character Customization as a Narrative Catalyst: Fusing Handmade Creation with Motion and Story

(The participant group for these findings is n=36 children, aged 2-7 years old, unless otherwise specified.)

Observation Points:

- Through the process of selecting paper parts, drawing facial expressions or clothing, and arranging their characters, did children attempt to imbue their creations with unique personalities, motivations, or roles within a developing story?
- Were there instances of children expanding their character’s world and narrative, for example, by naming their monkeys or drawing additional companion animals or environmental details?

Findings:
Many children effectively utilized the “creative leeway” (余白) provided by the motion prompts to develop their own unique stories through the “Handmade/Crafting (手作り)” aspect. This process demonstrated a clear “chain of creation”: children developed stories from motion cues, deepened their characters through personalized creative activities, and finally linked these embodied characters back to the dynamic scene.

The following types of customizations were prominently observed as forms of narrative and character building（Table 4.1）
(Note: “Story Props” also includes items that children verbally narrated for their character due to time limitations on drawing.)

Table 4.1 Observed types of character customization and example content

Customization Type	**Incidence**	**Typical Examples**
Facial Painting	94.4%	**Defines emotional state:** a yawning monkey, happy smiles,etc.
Clothing Design	22.2%	**Defines social role or personality:** a bow tie, a heart pattern, etc.
Story Props(item)	11.1%	**Defines goals or actions:** a monkey is seeking a banana, etc.
Adding Other Animals	13.8%	**Defines relationships or world context:** a person walking a dog, an octopus, etc.

Figure 4.4 Observed types of character customization

Conclusion:

The process of character customization significantly amplifies the inspirational effect of motion demonstrations. It was confirmed that when children flexibly interpret motion cues, use them as a starting point for their own stories, and then embody these narratives through personalized drawing and crafting, their creativity is enriched, and their capacity for autonomous world-building is notably promoted.

3. Tool Usability & Design Evaluation

Observation Points:

- Were children able to independently (or with parents'/teachers' support) assemble the papercraft characters and attach them to the MoveKits?
- Which aspects of the assembly or interaction process did they find challenging, and what forms of assistance proved most effective?

Findings:

Paper Craft Assembly & Fine Motor Skills: Older preschoolers (4–5 years old) generally operated the crafting components with relative ease and confidence. They often verbalized an awareness of structure (e.g., “If the neck is here, then the tail goes here”), and many completed the assembly of their monkeys independently, demonstrating engagement with their **fine motor skills**.

Younger preschoolers (3 years old), however, more frequently showed confusion in placing parts correctly (e.g., “I didn’t know where to put the neck and legs, so it looked like an octopus,” or “I didn’t realize it needed ears”) and often required parental or facilitator assistance.

Despite these initial challenges for younger children, observation suggested that repeated engagement could lead to improved fine motor dexterity and structural understanding over time.

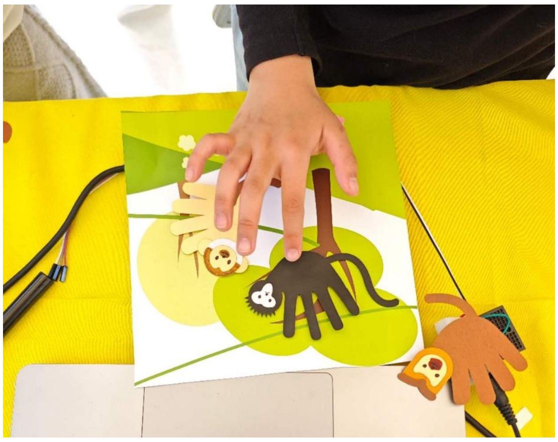
Figure 4.5 A child is creating his monkey.

MoveKit Placement for Interaction:

A recurring challenge was the placement of MoveKits on the GFACE board to achieve the intended motion. Due to a lack of explicit visual guides on the background, children sometimes struggled to identify the optimal spots for their characters to interact correctly with the underlying magnetic fields. This occasionally led to frustration if a character did not move as expected. → *Design Implication:* Consider including subtle reference lines or visual cues on future backdrops or the GFACE board itself to indicate active zones for different motions.

Conclusion:

Providing age-appropriate support (such as clear guidelines, gentle hints for younger children, or templates with graduated difficulty) can significantly improve tool



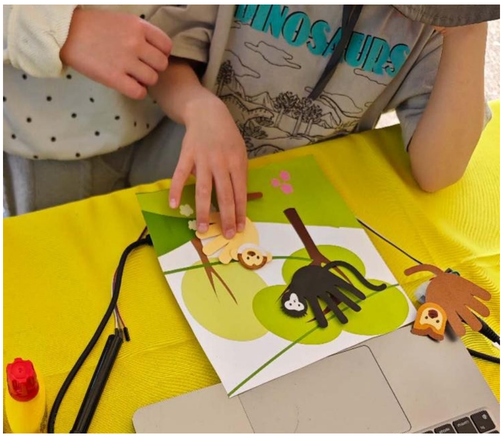


Figure 4.6 Children are figuring out where to place it to make the monkey move.

usability, thereby allowing more children to focus their energy on the creative aspects of the activity rather than procedural hurdles. For interactive elements like MoveKit placement, design considerations that promote intuitive use are paramount. Future iterations should aim to embed layered guidance and visual references to better accommodate the autonomous operation and creative experience of children at different developmental levels.

4. Inspiration: Social Interaction & Collaborative Creativity

Children frequently engaged in spontaneous social interactions. They talked with peers about their monkeys and discussed their stories. In over 22.2% of observations, children crafted direct verbal exchanges between their animated characters, effectively weaving collaborative storylines with statements like, "It's fun to play in the tree with everyone," or "I'm walking across the rope hand in hand with a friend monkey."

4.3.3 Discussion of "Monkey Forest" Workshop Findings

The "Monkey Forest" workshop effectively demonstrated the **Movook** toolkit's potential to engage children in a dynamic and deeply personal creative process. The findings highlight a powerful synergy between the key elements of our design

Figure 4.7 "I'm walking across the rope hand in hand with a friend monkey."

philosophy.

- **Motion as a Narrative Spark:** The initial demonstrations did not just capture attention; they provided a comprehensible set of "motion possibilities" that children could understand, interpret, and build upon, validating the initial `motion → story` phase of our model.
- **Handmade Customization Deepens Engagement:** The most profound creative work occurred when motion spark was combined with the handmade customization process. It was through the act of personalizing a character—giving it a yawning face, a bow tie, or a narrated banana—that children truly took ownership of the narrative. This suggests the `story → character (handmade)` link is not just a final step, but a crucial phase where abstract ideas are amplified and made meaningful.
- **Fostering Social Collaboration:** Furthermore, the workshop highlighted the importance of context. The social context of group work naturally led to collaborative storytelling, transforming individual creation into a shared world.

- **Usability Challenges:** Observations highlighted that while generally accessible, the toolkit's usability could be enhanced, particularly for younger children, through clearer visual guides for interactive elements (like MoveKit placement) and age-differentiated support for crafting. This is vital for maintaining a "Zero-Barrier Creation" experience.

In essence, the workshop validated our core design philosophy: the **motion → story → character** pipeline, catalyzed by observable motion and personalized crafting, effectively engages children in rich, imaginative play. These findings underscore the value of the toolkit's approach and provide clear directions for future iterations, primarily focusing on enriching the motion library, and optimizing user guidance for broader accessibility.

4.4. Study 2: Kindergarten Workshop – Observing Spontaneous Narrative Creation

This second study, conducted in a kindergarten setting, was designed to observe the spontaneous creative processes that emerge when children engage with the **Movook** toolkit in a familiar classroom environment. Building on insights from the Zoo Workshop, this study sought to understand if the **motion → story → character** pipeline would manifest naturally, without direct prompts for storytelling. A key focus was to analyze how children interpret "motion possibilities" and whether this would organically lead to narrative construction. We also aimed to evaluate the usability of design iterations, such as the inclusion of visual guides, in this context.

4.4.1 Workshop Design, Objectives, and Process

Date and Location

- **Date:** May 19, 2025, from 10:15 AM to 11:30 AM
- **Location:** Green Port Sakuragicho Nursery School in Yokohama, Japan.

- **Setting:** The activity was conducted as part of the kindergarten's regular art and creative play class . The workshop space utilized two large desks for showcasing the demo and for the children's hands-on crafting activities.

Participants

- **Children:** A total of **20 children**, aged 4–5 years old (senior class), participated. They were organized into 4 groups of 5 children each.
- **Facilitators & Support:** The workshop was run by 2 primary facilitators (the researchers and a supporting member),with each group also supported by their classroom teacher.
- **Recruitment Method:** Participants were selected in collaboration with the school's teaching staff, who recommended the senior class as most suitable for the activity following a preliminary demonstration.

Setting & Materials

- A **"Sea"** backdrop was presented with pre-set dynamic demonstrations: a sliding fish/octopus, an oscillating/side-walking crab, an expanding/pulsating jellyfish, and an opening/closing shell. These provided the initial **"motion possibilities."**
- Notably, the backdrop included **visual guidelines** to help children understand where to place MoveKits and characters for optimal interaction with the GFACE board.
- Customization contents were provided for the handmade phase, including pre-cut paper parts for various sea creatures and colored pens for personalization and further decoration.

Procedure

Figure 4.8 SEA demos shown in the Kindergarten workshop

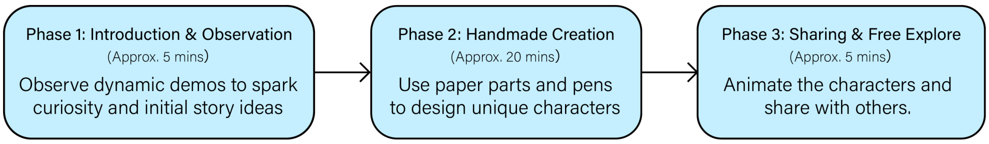


Figure 4.9 The workshop flow in 30 minutes.

The 75-minute event was structured as a station rotation... The 30-minute **Movook** workshop session itself adapted the full creator workflow into a structured yet open-ended creative journey suitable for a classroom setting. The process for each session unfolded as follows:

1. **Introduction & Demonstration:** The session began by demonstrating the dynamic motions to spark curiosity and establish the "motion possibilities."
2. **Handmade Creation:** Children were then invited to use the provided toolkit to create any sea creature they wished, inspired by what they saw. Critically, there was no direct instruction to invent a story.
3. **Sharing & Free Exploration:** In the final part of the session, children were encouraged to "show and tell" what they had made. Storytelling was not a required task but emerged organically from this sharing process.

Objectives:

The objectives of this workshop were twofold: to deeply analyze the children's creative process with the toolkit and to evaluate its practical usability in a classroom setting. Our primary aim was to observe the full pipeline, focusing on children's reactions to motion prompts, their process of meaning-making , and especially, their capacity for creative extension beyond the provided examples. Our secondary objective was to gather data on the toolkit's usability and engagement within a typical kindergarten environment, incorporating direct feedback from educators.

4.4.2 Key Findings and Analysis

The Kindergarten Workshop yielded rich observational data, illuminating how young children interacted with the **Movook** toolkit. The findings are organized below to follow the natural progression of the children's experience: from initial engagement, through the core creative process, to usability and social dynamics within the classroom context.

1. Motion as an Immediate Catalyst for Engagement and Creative Interpretaion

The dynamic nature of the toolkit served as a powerful hook. Children expressed immediate curiosity ("Why is it moving?") and quickly began to interpret the motions within the sea context ("The octopus and fish are swimming!"). This high level of engagement was noted by a supervising teacher:

> "I felt that even children who don't normally show much interest in crafting were enjoying themselves."

This initial fascination directly inspired their creative goals and interpretations. Children stated their intent to use specific motions ("I want the shell! I want it to flap its mouth!"), but they did not merely imitate. A key finding was their active reinterpretation of motion; they applied existing knowledge (deciding a shrimp should "walk sideways like crabs!") or assigned entirely new actions to creatures (making a jellyfish spin), demonstrating an understanding of motion as a designable element.

2. Spontaneous Emergence of Narrative through Handmade Embodiment

The most significant finding of this study was the spontaneous emergence of storytelling. Despite not being prompted to create a story, some children naturally developed and articulated narratives to explain their handmade creations. The process of personalizing a character served as the bridge from motion-inspired ideas to a full narrative.

Handmade Embodiment and Personalization: The handmade crafting phase was central to the children's creative process. As a teacher noted:

> "Instead of just using the pre-cut parts as intended for sea creatures, some children combined them in their own unique ways to create something completely different."

In one insightful example, a child drew "motion lines"—the radiating lines often seen in cartoons— around his characters, blending traditional drawing conventions with the toolkit's physical animation to enhance the sense of dynamism.

Figure 4.10 The creations made by children during the kindergarten workshop.

Figure 4.11 A child drew “motion lines” around his characters

Narratives Emerging from Creation: These personalized, handmade characters became the protagonists of emergent stories. For instance, one child created a story where a “Jellyfish is going shopping with a bag!” This narrative was not prompted; it was born from the act of crafting a bag for their character and imagining a purpose for its movement.

High-Level Cognitive Leaps in Storytelling Children also demonstrated advanced analogical thinking in their spontaneous narratives. One child, observing the shell’s open-close motion, transferred this concept to an entirely new context, exclaiming, “The frog goes ’paku-paku’ (mouth opening/closing)!” This unprompted creative leap is strong evidence of the toolkit’s potential to foster deeper conceptual thinking.

3. Usability and Educational Integration in the Kindergarten Context

The workshop provided critical insights into the toolkit’s practical application in a real-world educational setting.

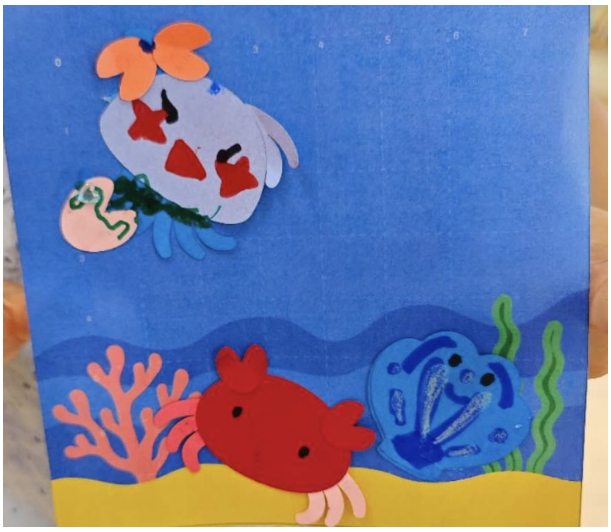


Figure 4.12 “Jellyfish is going shopping with a bag!”

Effectiveness of Visual Guidelines: The inclusion of visual guides on the backdrop for MoveKit placement—an improvement based on feedback from the previous workshop—proved effective in helping children successfully activate motions with less trial and error, and reduced frustration.

Flexibility and Reusability: The workshop demonstrated the toolkit’s flexibility. Some children drew their entire creature first before deciding how to animate it, showing that the toolkit can seamlessly bring pre-existing or independently created crafts to life. This highlights its potential for resource re-utilization in classroom settings.

Sustained Engagement: Compared to previous a observation of typical crafting activity (where children started to lose interest after 15 minutes), participants remained engaged throughout the entire 30-minute session. Many even asked, “Can I make more?”—indicating a strong desire to continue.

Ease of Setup and Storage: The toolkit’s flat structure offered a clear advantage for classroom logistics. The activity required only five minutes to set up and was equally easy to store, making it highly practical for busy educators.

Educator Needs and Future Potential eacher feedback also highlighted clear directions for future development. While 66.7% expressed a desire to incorporate the tool, they noted the need for a manual for troubleshooting ("I'm worried I wouldn't know what to do if it didn't work correctly."). Furthermore, the observation that children's first questions were often scientific ("Why does it move?")('What's inside it?') revealed an unforeseen potential for integrating STEM learning.

4. Social Interaction and Collaborative Play

Conducted in groups of five, the workshop naturally fostered a collaborative environment. Children were observed discussing their designs ("What movement are you giving your crab?") and spontaneously co-constructing narratives, such as one child initiating, "Your fish and my octopus are swimming together in the same sea area."

4.4.3 Discussion of Kindergarten Workshop Findings

The Kindergarten Workshop confirmed that the **Movook** toolkit successfully engages children in a deep creative process. The most significant finding from the Kindergarten Workshop was the spontaneous emergence of storytelling. This provides powerful evidence that the **motion → story → character** pipeline is not just a theoretical framework we impose, but an intuitive and natural creative process for young children when they are provided with the right catalyst. The toolkit did not need to ask for a story; the open-ended motion prompts and the engaging, hands-on creation process naturally elicited one.

This finding suggests that the act of handmade embodiment is the critical link that transforms an abstract interpretation of motion into a concrete narrative. When children personalize a character, giving it unique features or even drawn "motion lines," they are embedding it with personality and purpose. This personalized character then requires a story to explain its existence and actions. The narrative becomes a way for the child to make sense of and communicate their creative decisions.

From a practical standpoint, the workshop confirmed the toolkit's high viability for classroom use, although the feedback underscores the need for an educator's manual to ensure confident implementation. Furthermore, the children's unsolicited scientific curiosity reveals a valuable, emergent pathway for integrating STEM concepts.

In conclusion, this study provides strong validation for our "motion-first" approach. The findings suggest that by focusing on providing engaging motion and accessible creative tools, we can successfully catalyze a rich, self-directed process of narrative construction.

4.5. Comparative Discussion of Initial Workshops and Implications for Study 3

Synthesizing the findings from the initial two workshops—the Zoo Workshop (Study 1) and the Kindergarten Workshop (Study 2)—allows us to form a more nuanced understanding of the **motion → story → character** pipeline and derive key questions for further investigation.

A critical difference emerged between the two studies that highlights the crucial role of contextual scaffolding. The Zoo Workshop, with its strong narrative prompt (a monkey character in a forest setting), led to a high incidence of explicit storytelling. In contrast, the Kindergarten Workshop, which offered a more general theme (the sea) and intentionally withheld direct prompts for storytelling, resulted in children focusing more deeply on creative character design and motion interpretation, with spontaneous storytelling being less frequent, though still powerfully present.

This comparison suggests that while motion is a potent catalyst for imagination, the **motion → story** link does not happen in a vacuum. We argue that the **motion → story → character** creative pipeline is significantly amplified when children are provided with lightweight "scaffolding" This scaffolding can be a thematic context or simple, open-ended questions from a facilitator.

This insight directly informed the design of our third study. We aimed to address two key questions:

1. Can abstract motion itself catalyze creativity without any thematic backdrop? 2. Can a simple guide empower a non-expert facilitator (a parent) to

provide the necessary scaffolding?

4.6. Study 3: Family Session – Isolating Motion and Testing a Parent Guide

This third study was designed to test the core hypothesis of the `motion-first` pipeline in a more controlled manner and to evaluate the effectiveness of a facilitator guide in a home setting.

4.6.1 Workshop Design, Objectives, and Process

Workshop Settings

- Date: June 30, 2025, with no time limit.
- Participants & Setting: The study involved one 4-year-old child and his father, conducted in their home environment. The researcher provided the toolkit and the manual, then observed remotely via video recording.

Materials and Tools

- The toolkit included the **Movook** board, power cable, and MoveKits with pre-set "jump" and "sway" motions.
- A plain background paper with star marks (★) to indicate the active magnetic zones was provided.
- Customization contents consisted of various paper types for free-form cutting and design, with no pre-made character parts.
- A manual website which included sections on setup, procedure, facilitation hints, and troubleshooting.

Procedure The parent was instructed to use the online manual to facilitate the activity. The process was designed to be open-ended, inviting the child to create freely without any explicit requirement to create a story. The manual guided the parent-child dyad through a simple creative journey: first, observing an abstract motion demo; second, engaging in a free-form crafting session to create characters; and finally, sharing and playing with their animated creations. The detailed four-phase process from the manual is illustrated in the figure below.

4.6.2 Key Findings and Analysis

The session provided powerful evidence of the `motion-first` creative process unfolding naturally, and validated the effectiveness of the parent guide.

Figure 4.13 The kid is playing Movook toolkit.

1. From Abstract Motion to Concrete Narrative Idea

The most significant finding was how the child immediately translated the abstract motion into a concrete, familiar concept. After observing simple jumping and swaying motions, the child quickly decided to use jumping motion to create a "Doctor Yellow" Shinkansen (bullet train). The father, acting as a facilitator, helped affirm this connection, asking, "You decided to make a Doctor Yellow because it moves, right?" to which the child confirmed. This demonstrates a direct and spontaneous leap from motion to story idea. While creating a single character is not a full story in itself, it represents the crucial first step: the birth of a narrative concept grounded in the observed motion.

2. Handmade Embodiment and Narrative Expansion

The initial idea then expanded into a richer narrative through the process of making. Motivated by the availability of a second motion type swaying, the child decided to create another character: an "ice cream." This desire to create a more complex play scenario led to the culmination of the session, where a combined story emerged as the two characters interacted. The child placed the ice cream on the train, exclaiming, "Look, it's ice cream... I'll put the ice cream on here." The play concluded with the child narrating the final scene as the two objects moved together: "The ice cream got on the train!" expressing his delight as they created a new, combined "jiggling" motion. This sequence—from a single motion-inspired idea to a multi-character interactive scene—clearly validates the full motion to story to character pipeline, even in the absence of a thematic backdrop.

3. Parent as Scaffolder, Child as Creative Director

The video recording revealed a collaborative but child-led creative process, successfully scaffolded by the parent using the guide.

- **Child-Led Creativity:** The core creative decisions came from the child, who chose the characters (train, ice cream), the colors, the specific motions, and even the context ("I want a tree (besides the track)!").
- **Parent-Facilitated Making:** The parent acted as a supportive facilitator, asking questions to help the child articulate his ideas ("What color will you use?") and providing physical assistance when requested. For instance, the child directed the parent on what to draw for the background ("Draw tracks and trees"), with the parent acting as the "hands" for the child's vision. This interaction exemplifies the "balanced partnership" of child agency.
- **Effectiveness of the Manual:** The parent was able to successfully set up and run the entire activity using the provided manual. Although minor challenges like placing the MoveKit perfectly on the star mark required a few adjustments, the guide provided the necessary information for the parent to troubleshoot independently. This demonstrates that the manual

can effectively support the introduction of the toolkit into real-world home settings.

4.6.3 Discussion of Family Session Findings

This study provided the strongest evidence for our core hypothesis. It demonstrated that abstract motion alone is a sufficient catalyst to spark rich, concrete, and personal narratives. It also showed that a simple guide can successfully empower a non-expert parent to act as an effective facilitator, providing the lightweight scaffolding needed to support, but not direct, their child's creative process. These findings strongly suggest the toolkit's potential for use in a home environment as a tool for parent-child co-creation.

4.7. Overall Discussion of Workshop Findings

Synthesizing the findings from all three workshops allows us to form a comprehensive understanding of the motion to story to character pipeline and to validate the design of the **Movook** toolkit itself.

Our primary insight, derived from comparing the three studies, concerns the crucial role of contextual scaffolding. The Zoo Workshop, with its strong narrative prompt, led to a high incidence of explicit storytelling. In contrast, the Family Session, which removed the thematic backdrop entirely, provided the strongest evidence that abstract motion itself is a sufficient catalyst to spark a concrete narrative idea. This comparison suggests that while the motion to story link is robust, the creative process is significantly amplified when children are provided with lightweight "scaffolding," be it a thematic context or simple, open-ended questions from a facilitator.

Furthermore, the overall success of these workshops in eliciting rich creative behaviors directly validates the core design principles of the **Movook** toolkit, providing a clear answer to our first research question. The ability for children to so readily engage in this creative process stemmed from the toolkit's key features:

- **The low-barrier technical core,** using a flat magnetic actuation system with simple commands, allowed the focus to remain on creativity, not technology.

- **The intuitive and modular MoveKits** provided a simple, tangible bridge between a child's handmade creation and the dynamic system.
- **The familiarity of papercraft** lowered the barrier to entry, making the activity immediately accessible.
- **The iterative design improvements,** such as adding visual guides for placement, proved essential in creating a frustration-free experience, demonstrating the importance of embedded scaffolding.

In essence, these findings demonstrate that **Movook** , through its specific design choices, successfully functions as an accessible and effective platform for supporting the motion-first creative pipeline.

Chapter 5
Discussion and Future Works

This chapter synthesizes the findings from all three workshops to answer the research questions posed in Chapter 1. We begin by directly addressing each research question, discussing how our cumulative findings provide clear answers. Subsequently, we explore the broader implications of this work, acknowledge its limitations, and outline promising directions for future work.

5.1. Answering the Research Questions

Our findings across the three studies provide clear answers to the research questions outlined in Chapter 1.

RQ1: How can a tangible toolkit be designed to effectively support hands-on creative expression and dynamic storytelling, while also being accessible and meaningful for non-expert users?

Our answer is the **Movook** toolkit, whose iterative design was detailed in Chapter 3. As discussed in the overall workshop findings (Section 4.7), our evaluation confirmed that an effective design for such a tool should embody several key principles:

- A low-barrier technical core (flat-structured magnetic actuation with abstracted controls);
- Intuitive and modular physical components (the MoveKits);
- Familiarity (grounding in papercraft);
- Embedded and external scaffolding (visual guides and facilitator manuals)

RQ2: In what ways does the integration of physical making and dynamic motion influence children's creative processes and output?

Our research revealed that the integration of making and motion influences children's creative processes in a profound and specific way: it enables a novel **motion-first** creative pipeline. We observed that children consistently used the provided motion as a direct "seed" for their creativity. This process influenced their creative output in two key areas:

1. **Figural Creativity:** The motion prompts first inspired the physical forms of their creations. This was observed in the unique, personalized characters children built, combining parts in novel ways or even drawing "motion lines" to visually enhance the concept of dynamism. This act of making served as the crucial step of embodying their initial idea.

2. **Verbal Creativity:** The creation of this tangible, personalized artifact then served as a powerful catalyst for spontaneous storytelling. This was evidenced by the emergence of complex narratives and character dialogues, which occurred organically as a way for children to make sense of and communicate the story of the character they had just brought to life.

5.2. Broader Implications for Design

The successful design and evaluation of the Movook toolkit, which effectively answered our research questions, offers several broader implications for the design of tangible learning tools for children.

- **Prioritizing Motion as a Creative "Seed"**: Our work strongly suggests that designers should consider motion not just as a final output or reward, but as a powerful primary catalyst for imagination and storytelling. As demonstrated by Movook, providing abstract, open-ended motion can create a rich "blank space" for children's creativity, leading to more divergent and personal narratives than content-driven prompts.

- **Designing for Emergence and Scaffolding:** Our findings on spontaneous STEM inquiry and the crucial role of scaffolding suggest that designers should create affordances for unexpected learning pathways. A successful tool should not over-prescribe the experience. Instead, it should provide a stable platform with clear but minimal scaffolding (like visual guides or facilitation hints), allowing valuable emergent outcomes like social collaboration and scientific curiosity to flourish.

5.3. Limitations

This research has several limitations. The studies were conducted with a limited number of children (n=57 total across three workshops) in a specific cultural and geographical context (Japan), so the findings may not be universally generalizable. The workshop interactions were also relatively short (10–30 minutes per child); a longitudinal study would be needed to understand the long-term impact on creativity. Finally, the presence of experienced researchers as facilitators may have provided a higher level of support than a teacher could offer without specific training, reinforcing the importance of the proposed educator manual.

5.4. Future Work

Our findings provide a clear mandate for future research and development, which can be categorized into two main strategic directions: enhancing the toolkit's capabilities and expanding its application scenarios.

- **Enhancing the Toolkit's Capabilities and Accessibility:** To make the toolkit more versatile and user-friendly, future work should focus on two key areas. First is the development of an intuitive Graphical User Interface (GUI) to replace the Arduino IDE. A GUI would significantly lower the technical barrier for programming motion sequences, fully realizing the toolkit's potential as an accessible creative tool for both children and educators. Second is the exploration of new material possibilities, such as developing a more robust version of the toolkit capable of animating heavier materials like clay, as suggested by educators.
- **Expanding Application Scenarios and Learning Pathways:** Building on the emergent findings, we see exciting potential in formally exploring

broader applications. This includes developing comprehensive pedagogical support materials for educators, such as a manual with facilitation strategies and example lesson plans. It also involves designing specific activities that leverage the toolkit as a tangible STEM education tool to teach basic concepts of physics and robotics, addressing the scientific curiosity we observed. Finally, the toolkit could be adapted for deployment in informal learning environments like museums and libraries, or developed into a commercial creative toy for home use.

5.5. Conclusion

In conclusion, this research introduced and evaluated Movook, a tangible toolkit designed to investigate a novel **motion → story → character** creative pipeline. Through three workshops, we demonstrated that abstract, programmable motion can act as a powerful catalyst for a rich creative process encompassing spontaneous storytelling, handmade character embodiment, and deep imaginative engagement. Our findings contribute to the fields of Tangible Interaction and early childhood education by providing evidence for a new mode of creative play and offering concrete design principles for hybrid learning tools. Ultimately, this work shows a promising pathway for reinventing the traditional picture book, transforming it into a dynamic, user-creatable medium that nurtures the next generation of storytellers.

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