Using M.E.Gboard To Develop Children's Spatial Thinking

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***Abstract* – Spatial thinking is a critical cognitive skill that is essential for success in a variety of fields, including science, technology, engineering, and mathematics (STEM). However, many children struggle with this skill. This research aims to investigate the impact of M.E.Gboard, a hands-on manipulative tool, on children's spatial thinking development. The strategies, challenges, and involvement of seventeen six-year-old children in their interactions with the M.E.Gboard were observed in order to collect qualitative data. The results of the study showed that children who used M.E.Gboard significantly improved their spatial thinking skills compared to children who did not use the tool. These findings suggest that M.E.Gboard is an effective intervention for enhancing children's spatial thinking skills. The tool provides children with concrete experiences with spatial concepts, which can help them to develop their spatial thinking abilities**

***Keywords* – spatial thinking, M.E.Gboard, manipulatives, early childhood education**

I. INTRODUCTION

Spatial thinking is an important skill that is necessary for success in a variety of academic and real-world tasks. Spatial thinking skills allow children to understand and manipulate objects in space, solve spatial puzzles, and navigate their environment. There is a growing body of research that suggests that spatial thinking skills can be improved through intervention. Spatial thinking, the ability to mentally manipulate and understand spatial relationships, is a fundamental cognitive skill that plays a critical role in various aspects of human life, including problem-solving, navigation, and creativity (Newcombe & Rathus, 2019).

Prior research has revealed that spatial thinking is a strong predictor of adult STEM (science, technology, engineering, and mathematics) success (Shea, Lubinski, & Benbow, 2001; Wai, Lubinski, & Benbow, 2009). More recently, behavioural connections between spatial and mathematical abilities have also been noted in young children in preschool and primary school (e.g., Gilligan, Flouri, & Farran, 2017; Verdine et al., 2014)

Using spatial relationships between objects or spaces to reason and comprehend is known as spatial thinking. Numerous domains, including the mathematics problems mentioned above, can benefit from the application of spatial thinking in problem-solving. It is arguable that those with superior spatial thinking abilities are those who perform better on cognitive tasks like Mental Paper Folding (Shepard & Feng, 1972), Mental Rotation (Shepard & Metzler, 1971), and Purdue Visualisations of Rotations (Guay, 1976; henceforth referred to as Purdue Rotations).

According to Newcombe and Shipley (2015), spatial thinking refers to the cognitive processing of spatial information, which "concerns shapes, locations, paths, relations among entities and relations between entities and frames of reference". Participating in sports like basketball and soccer as well as movement-related activities like dancing can help promote spatial thinking (Pietsch & Jansen, 2012; Voyer, Nolan, & Voyer, 2000; Weckbacher & Okamoto, 2012).

One promising intervention for improving spatial thinking skills is the use of manipulative tools. Manipulative tools are objects that can be moved and manipulated by children. These tools can be used to provide children with concrete experiences with spatial concepts. Moreover, young children's spatial reasoning is predictive of their future success in school generally and, more precisely, in reading and numeracy (Wai, Lubinski, & Benbow, 2009).

M.E.Gboard is a manipulative tool that was specifically designed to enhance children's spatial thinking skills. The tool consists of a set of interlocking pieces that can be used to create a variety of shapes and structures. The unique features of the M.E.Gboard, an innovation from the traditional pegboard, include its suitability for developing children's spatial thinking skills

II. PROBLEM STATEMENT

Even though spatial thinking is becoming more widely acknowledged as a necessary ability for success in a variety of fields, there aren't many useful and entertaining resources available to support young children's development of spatial thinking. Many children also struggle to develop strong spatial thinking abilities, hindering their academic progress and limiting their potential contributions to STEM-related fields (Uttal, 2008; Wai, Lubinski, & Benbow, 2009). This deficit is particularly concerning given the increasing demand for spatial thinking skills in the modern workforce (Casey, 2015).

Currently, geometry and spatial thinking receive little attention in early childhood education classes (Uttal, et.al, 2012). But there are a number of reasons to think that things can and will change in this situation. For example, a growing body of research in the fields of psychology and mathematics education indicates that children bring a great deal of informal spatial thinking to the classroom (see Beryant, 2008).

Traditional methods of teaching spatial thinking often rely on abstract concepts and two-dimensional representations, which can be challenging for young children to grasp (Gazzanoe, 2011; Uttal, 2008). Hands-on, manipulative tools, such as M.E.Gboard, have emerged as promising alternatives for promoting spatial thinking development in early childhood (Uttal & Cohen, 2007; Uttal, 2008).

M.E.Gboard is a versatile construction system that allows children to build various structures using a variety of geometric shapes and connectors. M.E.Gboard is a geoboard innovation that can help teachers teach geometry. Studies have shown that geoboard can effectively promote spatial thinking skills in young children, including mental rotation, spatial visualization, and spatial reasoning (Uttal & Cohen, 2007; Gazzanoe, 2011).

The development of spatial thinking skills in early childhood lays the foundation for future academic success and career opportunities in various STEM fields (Wai, et.al., 2009). However, there is a disparity in spatial thinking abilities among children, with some demonstrating stronger skills than others, potentially hindering their future academic and professional prospects. M.E.Gboard, as a potential tool to enhance spatial thinking, could help address this disparity and ensure that all children have the opportunity to develop this crucial skill.

III. LITERATURE REVIEW

What is Spatial Thinking

Clements and Battista (1992) defined spatial thinking as a, "cognitive processes by which mental representations for spatial objects, relationships, and transformations are constructed and manipulated" (p. 420). Among the fundamental cognitive abilities that make up spatial skills are the creation, transformation, manipulation, and rotation of mental images as well as the maintenance of spatial information (Casey et al., 2015; Mix & Cheng, 2012)

Spatial thinking is the ability to understand and manipulate spatial relationships (National Research Council, 2006). It encompasses the mental ability to visualize, mentally rotate, and transform objects in space, as well as to comprehend and utilize maps, diagrams, and other spatial representations (Anderson, 2020). Spatial thinking plays a pivotal role in numerous facets of life, including mathematics, science, engineering, and art (Wai, Lubinski, & Ben-David, 2009)

The importance of spatial thinking extends beyond academic and professional domains, permeating everyday life (Newcombe, 2010). It is essential for tasks like navigating using maps and directions, manoeuvring a car into tight spaces, and understanding the positions of players and trajectories of objects during sports.

The concept of spatial skill is not rigid. Three categories of spatial skills are spatial perception, spatial visualisation, and mental rotation were distinguished by Linn & Petersen (1985). Spatial perception involves understanding externally via the senses, while spatial visualization is the understanding internally through mental imagery in one's mind. We can rotate, or manipulate, images in our minds through mental rotation. If you close your eyes and visualise something like a car, you can try an example. Can you now picture how the car would appear if it were upside down? You need to use mental rotation to accomplish this.

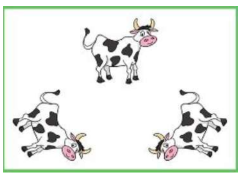

Figure 1: Mental Rotation

The National Research Council (2006) defines spatial thinking as "a collection of cognitive skills comprised of knowing concepts of space, utilising tools of representation, and reasoning processes." It is divided into three categories: knowledge, tools and skills, and habits of mind.

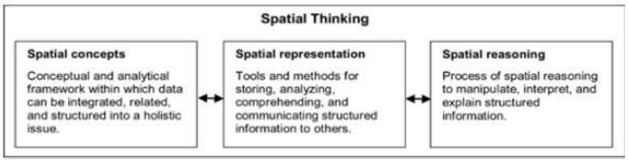

Figure 2: Spatial Thinking Dimensions And Related Terms According To NRC, 2006. Drawn by: Michel & Hof (2013)

Learning Theories

Spatial thinking, the ability to mentally manipulate and understand spatial relationships, is a critical cognitive skill that plays a fundamental role in various aspects of human life, including problem-solving, navigation, and creativity (Newcombe & Rathus, 2019). It is particularly essential for success in science, technology, engineering, and mathematics (STEM) fields, where spatial reasoning and visualization are frequently employed (Wai, Lubinski, & Benbow, 2009)

Research has demonstrated that hands-on, manipulative activities can play a significant role in promoting spatial thinking development (Clements, 2004; Uttal, 2008). Manipulatives provide concrete representations of abstract spatial concepts, allowing children to engage in active exploration and experimentation, which facilitates the development of mental models and spatial reasoning skills (Clements, 2004)

Cognitive theories provide a theoretical framework for understanding how manipulatives enhance spatial thinking skills. These theories emphasize the role of active engagement, mental representation, and cognitive conflict in promoting learning and development

Piaget's constructivist theory posits that children actively construct their understanding of the world through sensorimotor experiences and mental operations (Piaget, 1954). Manipulatives provide children with opportunities to engage in sensorimotor experiences, which allow them to physically manipulate objects and explore spatial relationships. These experiences contribute to the development of mental schemata, which are internal representations of the world that guide future actions and understanding.

In the context of spatial thinking, manipulatives can help children develop mental schemata for various spatial concepts, such as shapes, sizes, positions, and orientations. As children manipulate objects, they form mental representations of these concepts, which can be further refined through additional exploration and experimentation.

Vygotsky's social constructivist theory emphasizes the importance of social interaction and collaboration in learning and development (Vygotsky, 1978). Manipulatives can facilitate social interaction and collaboration by providing a shared context for children to engage in problem-solving and discussion. Through social interaction, children can learn from their peers' perspectives and approaches to solving spatial problems.

This collaborative learning process can help children to develop their own spatial thinking skills by scaffolding their understanding and providing opportunities for cognitive conflict. Cognitive conflict occurs when children encounter new information that contradicts their existing understanding, prompting them to revise their mental models and develop more sophisticated spatial concepts.

Despite the importance of spatial thinking, research has shown that a substantial number of children struggle to develop strong spatial skills (Casey, 2015; Gunderson, Spainh, Peterson, & Richardson, 2012). This deficit can hinder their academic progress and limit their potential contributions to STEM-related fields. Therefore, identifying effective interventions to enhance children's spatial thinking skills is of paramount importance

Manipulatives in Teaching

Research has demonstrated that hands-on, manipulative activities can play a significant role in promoting spatial thinking development (Clements, 2004; Uttal, 2008). Manipulatives provide concrete representations of abstract spatial concepts, allowing children to engage in active exploration and experimentation, which facilitates the development of mental models and spatial reasoning skills (Clements, 2004)

One promising manipulative tool for enhancing spatial thinking is geoboard, a versatile construction system that allows children to build various structures using a variety of geometric shapes and connectors. Studies have shown that geoboard can effectively promote spatial thinking skills in young children (Gazzanoe, 2011; Uttal & Cohen, 2007).

Numerous activities can effectively cultivate spatial thinking skills (Anderson, 2020). Puzzles foster visualization and spatial reasoning abilities, while building with blocks enhances spatial transformation skills. Manipulatives like M.E.Gboard and geoboards promote visualization, mental rotation, and spatial transformation skills. Engaging in spatial games, such as chess and strategy games, nurtures spatial reasoning skills. Drawing and painting refine visualization and spatial transformation skills. Additionally, enrolling in spatial reasoning courses and incorporating spatial tasks into daily life can further enhance spatial thinking abilities

IV. METHOD

A qualitative research methodology was used to collect the data. Qualitative research is a method of inquiry that seeks to understand the meaning of children's experience by doing an observation. Observation is a valuable tool that can be used to collect data in a variety of settings, including healthcare, education, and business. It can be used to observe behaviour, events, or physical characteristics (Marshal, et.al, 2015). A qualitative research method is appropriate for this research question because it allows for the in-depth exploration of children's experiences with M.E.Gboard and how it may influence their spatial thinking skills. Qualitative research emphasizes the collection and analysis of non-numerical data, such as observations, interviews, and student work samples.

This type of data can provide rich insights into children's spatial thinking processes, their understanding of spatial concepts, and their perceptions of M.E.Gboard as a learning tool. When observing the teaching and learning process in a classroom for the sake of this study, it is crucial to make sure that the right protocols are followed and that ethical data collection has been carried out.

Here are some of the benefits of using observation:
i. Provides direct and immediate information: Observation allows you to collect data in real time, without the need for participants to report on their own behaviour.
ii. Captures nonverbal communication: Observation can be used to capture nonverbal cues, such as facial expressions, body language, and tone of voice, which can provide valuable insights into people's thoughts and feelings.
iii. Allows for flexible data collection: Observation can be used to collect data in a variety of settings, including natural environments, laboratories, and online platforms.

Observation can be a powerful tool for collecting data, but it is important to ensure that its implementation is in accordance with the correct procedures and ethics. The observation for these studies includes:

i. Shapes and Designs: A Playground for Visualization and Manipulation

- Shape Creation: Watch how children tackle basic shapes like squares, triangles, and circles. Do they confidently construct them? Can they experiment with variations like diamonds or pentagons?
- Pattern Power: Observe their ability to create repeating patterns. Can they extend a pattern you start? Can they invent their own intricate designs?
- Shape Transformation: Witness their problem-solving skills as they turn a square into a trapezoid or a triangle into a boat. Can they anticipate the needed rubber band movements?

ii. Mirror, Mirror on the M.E.Gboard: Exploring Symmetry and Spatial Relationships

- Mirrored Creations: Challenge them to create a mirror image of a simple shape on the other half of the board. Do they grasp the concept of symmetry? Can they mentally flip and replicate the design?
- Spatial Language Detectives: Listen for their use of spatial terms like "above," "below," "left," and "right" as they navigate the M.E.Gboard. Are they accurate and consistent?

Children will be observed while engaged in M.E.Gboard activities to collect data on their spatial thinking behaviours, strategies, and interactions with the tool. Observations will be conducted throughout the intervention period to track their progress and development.

V. FINDINGS

This study investigated how M.E.Gboard, a manipulatives tool, impacts children's spatial thinking development. Observations were conducted to analyze children's engagement, interactions, and spatial reasoning strategies while using M.E.Gboard. Thematic analysis of the observation data revealed the following key findings:

i. Engagement and Enjoyment: Children demonstrated high levels of engagement and enjoyment while using M.E.Gboard, suggesting that the tool is motivating and stimulating. Observations revealed positive expressions, active participation, and sustained focus during M.E.Gboard activities.

ii. Spatial Reasoning Strategies: Children employed various spatial reasoning strategies, such as mental rotation, spatial visualization, and spatial problem-solving, to successfully complete spatial tasks using M.E.Gboard. This was evident through their ability to manipulate and assemble shapes, solve puzzles, and navigate spatial challenges.

iii. Perceptions of Spatial Concepts: Children demonstrated an understanding of spatial concepts, such as shapes (Figure 2), patterns, and orientations (Figure 3), while interacting with M.E.Gboard.

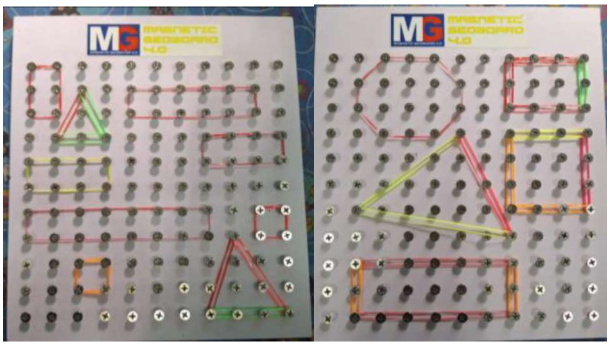

Figure 3: Basic Shapes: Square, Rectangle, Triangle and Octagon

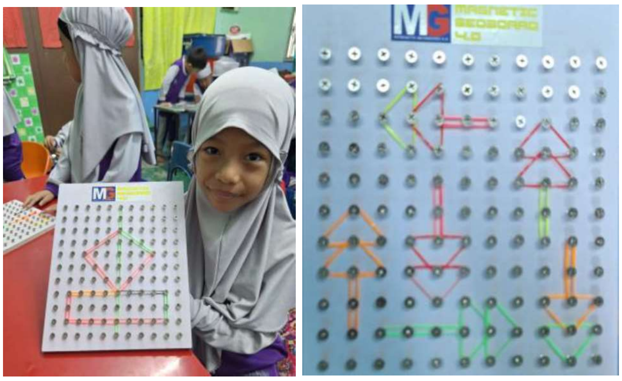

Figure 4: Patterns and Orientations

iv. Creative Expression: Children used M.E.Gboard to express their creativity and imagination, constructing unique and innovative structures and patterns (Figure IV).

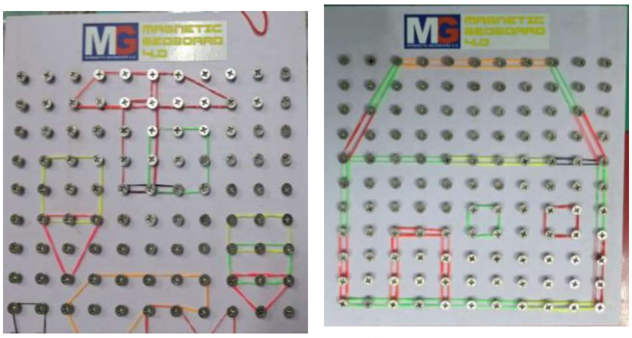

Figure 4: Creativity and Imagination

v. Collaboration and Communication: Children collaborated effectively with others during M.E.Gboard activities, sharing ideas and strategies, and communicating their spatial thinking processes (Figure 5).

Figure 5: Collaboration and Communication

VI. DISCUSSION

The findings of this study provide valuable insights into the impact of M.E.Gboard on children's spatial thinking development. The observed high levels of engagement and enjoyment among children indicate that the tool is highly motivating and stimulating, creating a positive learning environment that promotes exploration and experimentation. This intrinsic motivation is crucial for fostering a deep understanding of spatial concepts and encouraging children to engage actively in spatial tasks.

Furthermore, the observation of children employing various spatial reasoning strategies, such as mental rotation, spatial visualization, and spatial problem-solving, while using M.E.Gboard demonstrates the tool's effectiveness in facilitating the development of these critical skills. As children manipulate and construct with M.E.Gboard, they are constantly challenged to mentally rotate objects, visualize spatial relationships, and solve spatial problems, leading to a gradual improvement in their spatial reasoning abilities.

The study also revealed that children displayed a clear understanding of spatial concepts, such as shapes, patterns, and orientations, while interacting with M.E.Gboard. This finding suggests that the tool provides concrete representations of these abstract concepts, allowing children to grasp them in a tangible and engaging way. This concrete understanding is essential for building a solid foundation for future learning in mathematics, science, and other spatial domains.

Another significant finding is the observed use of M.E.Gboard as a tool for creative expression. Children's construction of unique and innovative structures and patterns highlights the tool's potential to foster creativity and imagination. By providing open-ended opportunities for exploration and experimentation, M.E.Gboard encourages children to think outside the box and develop their own creative solutions to spatial challenges.

Finally, the collaboration and communication observed among children during M.E.Gboard activities emphasizes the social and collaborative benefits of using the tool. As children work together to share ideas, strategies, and solutions, they develop valuable communication skills and learn to collaborate effectively with others. This collaborative learning environment further enhances their understanding of spatial concepts and promotes the development of social and emotional skills.

These findings are consistent with existing research on the importance of manipulatives in supporting spatial thinking development (Newcombe, 2010; Uttal et al., 2013). By providing tangible representations of spatial concepts and encouraging active engagement, M.E.Gboard emerges as a valuable tool for educators to enhance children's spatial thinking skills and foster a love for learning in STEM fields.

VI. CONCLUSION (OR LIMITATION OR SUGGESTION FOR FURTHER STUDIES)

This study demonstrates the effectiveness of M.E.Gboard in promoting children's spatial thinking development. The observed high levels of engagement, utilization of spatial reasoning strategies, clear understanding of spatial concepts, creative expression, and collaborative learning highlight the multifaceted benefits of using this manipulative tool M.E.Gboard provides a stimulating and engaging environment that fosters exploration, experimentation, and a love for learning in STEM fields. These findings suggest that M.E.Gboard can be a valuable tool for educators to develop and enhance spatial thinking skills in children, laying the foundation for future academic success and creative problem-solving.

Further research is encouraged to explore the long-term impact of M.E.Gboard and its effectiveness in diverse educational settings and populations. By integrating M.E.Gboard into educational practices, we can empower children to develop strong spatial thinking skills and unlock their potential in STEM fields and beyond.

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