# Spatial abilities in early childhood

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***Abstract*—Spatial abilities are the capacity to comprehend shapes of objects, their positions and the spatial relations among objects. This paper, which establishes that spatial abilities belong to engineering abilities, presents a set of learning activities that promote the development of spatial abilities in early childhood, thereby proving that engineering abilities can be acquired in early childhood. Spatial abilities promote success in engineering and other STEM fields. For example, an astronomer must be able to visualize the elements of the universe, and an engineering should be able to visualize the components of machinery (s)he is working with. Certain engineering abilities can be developed in very young students, in early childhood. Spatial abilities belong to this category. Children use spatial abilities intuitively in their day-to-day life. By promoting spatial abilities in very young children, they are set up for achievements in engineering and other STEM fields through their life. The purpose of this project is to demonstrate that abilities pertaining to engineering are not confined to higher education, and in fact engineering abilities can be acquired by very young students as well. In the following paper, a set of spatial abilities that qualify as engineering abilities appropriate to early childhood are discussed. Further, a set of tools and a set of corresponding learning activities are identified which promote these abilities. These activities are based on the usage of childhood STEM toys such as LEGO building blocks. The target audience are students in their early childhood, between the ages of 2 and 5 years old. The focus is on their acquisition of these abilities through these learning activities. Through this demonstration, the acquisition of spatial abilities as engineering abilities in early childhood is established.**

***Index Terms*—STEM, Spatial abilities, Engineering education, early childhood education**

## I. Introduction

Engineering is defined as the branch of science and technology concerned with the design, building, and use of engines, machines, and structures. Engineering consists of many branches, such as chemical engineering, mechanical engineering, and civil engineering. In order to be a successful engineer, one must cultivate several abilities, including problem solving abilities, quantitative abilities, mechanical aptitude, and spatial abilities. The foundation for a good engineer lies in the development of these abilities.

Spatial ability is the capacity to understand, reason and remember the spatial relations among objects or space. It has been identified that spatial abilities are crucial for success in STEM fields. Therefore, it may be inferred that spatial abilities are crucial to succeed in engineering as well [1].

The development of engineering abilities are typically associated with higher education. However, the making of an engineer starts much earlier in life. Several seemingly elementary toys used in early childhood are crucial to the honing of early engineering abilities. For example, a toy which requires children to place rings on a tower in order of size requires spatial abilities of comprehending size and position. Shape sorters, seemingly elementary toys teach shapes, and matching a shape to its appropriate slot. They help develop fine motor abilities and hand-eye coordination as well. Shape sorters can double up as stacker toys, blocks, even grab-ables for young children [2].

Blocks of all kinds are considered to be excellent sources of STEM learning. It has been demonstrated that playing with blocks of all kinds is crucial in the development of spatial abilities [3].Success with early block play determines mathematical success in later years Blocks can be of several different kinds such as wooden blocks, Lincoln Logs, Lego, Megablox, and several more varieties. While each kind of block differs in structure, the purpose of all these toys remains the same: to construct a structure. Some blocks, such as Lego or Megablox, have a bump on top called a ”stud” which helps to join two blocks together. These blocks are also called ”bricks”.

In the following sections, a set of spatial abilities attained in early childhood, instructional tasks using blocks and other children’s toys used to attain these abilities, and the level of difficulty of each activity have been analyzed.

## II. Literature survey

In the 1990s, NSF first started referring to Science, Technology, Engineering and Mathematics Education as ”SMET”. Over the course of the next twenty years, this term has morphed into STEM. STEM is a curriculum based on the idea of educating students in four specific disciplines science, technology, engineering and mathematics in an interdisciplinary and applied approach. Rather than teach the four disciplines as separate and discrete subjects, STEM integrates them into a cohesive learning paradigm based on real-world applications [5].

The relationship between Engineering and STEM is better defined in recent years. Engineering is being integrated into education from the stage of early childhood, with young children studying the life cycle of plants and high school students working on robotics. Project-based learning also incorporates engineering into a STEM-based curriculum.

Spatial ability is a construct aptly defined by Lohman as the ability to generate, retain, retrieve, and transform well-structured visual images [4]. Spatial ability was characterized as an individual differences attribute with particular relevance for learning the advanced scientific and technical material needed for developing outstanding STEM (science, technology, engineering, and mathematics) contributors, those individuals capable of moving engineering and physical science disciplines forward [14].

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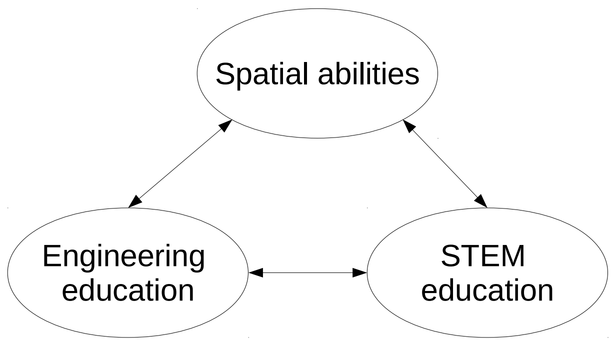


Fig. 1. Relationship between STEM, engineering, and spatial abilities

Spatial thinking is essential for scientific thought; it is used to represent and manipulate information in learning and problem solving [12]. It is also required in many intellectual endeavors such as solving problems in engineering, design, physics and mathematics [13] [11]. Traditionally, any engineering curriculum at a university level includes engineering design graphics subjects in which, during at least one academic year, students received basic training in systems of representation, sketching, technical drawing, and CAD. In this context, the development of spatial abilities has been considered an indirect learning outcome [15].

Efforts to enhance spatial learning in preschool and elementary school age children may have large benefits in terms of building abilities that have been shown to be important to STEM success. Moreover, it is believed that building strong spatial abilities early can help prevent spatial anxiety, an impediment to success in the STEM disciplines [7]. Prior work suggests that the abilities are best formed early in life [6].

It has been identified that the attention being paid to development of engineering abilities in early childhood and pre-teens is insufficient.

Block play has been linked with math abilities, too. In one study, the complexity of a child's LEGO play at the age of 4 had long-term predictive power: More complex play during the preschool years was correlated with higher mathematics achievement in high school, even after controlling for a child's IQ [8].

It may be concluded that spatial abilities, STEM fields, and engineering education are all related as described in Figure 1. As it has been established that early childhood education pays insufficient attention to the development of these abilities, in this work, the focus is on the development of spatial abilities in early childhood.

## III. Spatial abilities

Spatial information concerns the representation of relations between locations, configurations, shapes, objects, and paths; that is, representations in which the key elements and relations are spatial in nature. Spatial learning includes various cognitive processes operating over representations of spatial information. Spatial learning is classified into four categories as follows [9].

### A. Categories of spatial abilities

1) Intrinsic-Static abilities involve the processing of objects or shapes, or parts of objects or shapes, without further transformation. Tasks that measure this ability often require this processing to occur amidst distracting background information. For example, while using Lego blocks, identifying a block based on the number of studs would classify as an intrinsic static ability.
2) Intrinsic-Dynamic abilities, in contrast, involve the processing and manipulation or transformation of objects or shapes. Mental folding and mental rotation fit into this category. For example, aligning and joining two Lego blocks require these abilities.
3) Extrinsic-Static abilities require the processing and encoding of the spatial relations between objects, without further transformation of these relations. For example, a child who has to find the right position of a block on a base would require these abilities.
4) Extrinsic-Dynamic abilities involve the transformation of the relationship between objects, or the relationship between objects and frames of reference.

### B. Abilities

An ability is defined as proficiency, facility, or dexterity to perform a specific task that is acquired or developed through training or experience. The terms ability and skillintrinsic0dynamic are used interchangeably. In this section, a series of spatial abilities and competencies is elaborated upon.

The following are the spatial abilities focussed on during this project. It is to be noted that these abilities have been selected based on the focus of the instructional activities chosen

- S1: Selection: This ability involves selecting the right blocks to join, based on their size, purpose, and number of studs.
- S2: Alignment: Alignment is a crucial ability required to perform any activity with blocks. Lego blocks will not join together unless they are properly aligned with respect to the studs on adjacent blocks.
- S3: Balance: The abilities of alignment and balance go hand in hand. Balance of blocks involve ensuring that a vertical stack of blocks are able to stand without falling down. For example, a child must be able to understand that while they can place a block with 2 studs over one with 4, the tower may topple if the configuration is reversed.
- S4: Reconstruction: The ability of reconstruction is a culmination of several other abilities. It involves analyzing an image or an object, identifying its configuration, identify the appropriate blocks required to reconstruct the object, and finally, build the object.
- S5: Visualization: Spatial visualization involves mentally transforming object-based spatial information and is assessed through intrinsic - dynamic spatial abilities such as mental rotation.
- S6: Use spatial language: This ability involves verbally describing the object in question. Spatial language

TABLE I
SPATIAL ABILITIES AND THEIR COGNITIVE AND PSYCHOMOTOR DOMAIN POSITIONS

| ability | Cognitive ability | Psychomotor ability |
|---|---|---|
| S1: Selection | Understand | Guided response |
| S2: Alignment | Apply | Mechanism |
| S3: Balance | Apply | Mechanism |
| S4: Reconstruction | Analyze | Adaptation |
| S5: Visualization | Create | Origination |
| S6: Use spatial language | Apply | Perception |

includes words like large vs. small, above vs. below, next to, etc.

*1) Bloom's Taxonomy and Spatial Abilities:* Before proceeding, a description of Bloom's taxonomy for cognitive, affective and psychomotor domains is provided. The cognitive domain refers to the knowledge based abilities attained by the child, the affective domain refers to the emotive based abilities and the psychomotor domain refers to the action based abilities. For this work, the focus is on the cognitive and psychomotor domains. The cognitive domain consists of the broad abilities of Remember, Understand, Apply, Analyze, Evaluate and Create. The psychomotor domain consists of the broad abilities of Perception, Set, Guided Response, Mechanism, Complex Overt Response, Adaptation and Origination. Table I is an analysis of each ability with respect to the cognitive and psychomotor domains. The abilities obtained in Bloom's taxonomy are hierarchical. This implies that all the abilities in lower cognitive or psychomotor domains are subsumed by those in higher levels. Based on this, levels of cognitive and psychomotor difficulty are assigned in increasing order as follows. Further, Table II computes the cognitive and psychomotor difficulty levels based on this.
Cognitive difficulty levels:

1) Remember
2) Understand
3) Apply
4) Analyze
5) Evaluate
6) Create

Psychomotor difficulty levels:

1) Perception
2) Set
3) Guided Response
4) Mechanism
5) Complex Overt Response
6) Adaptation
7) Origination

Table II maps the spatial abilities to their cognitive and psychomotor difficulty levels.

The sequence of the spatial abilities as per their cognitive hierarchy in increasing order of difficulty would be S1, S6, S2, S3, S4, S5. The sequence of the spatial abilities as per their psychomotor hierarchy in increasing order of difficulty would be S6, S1, S2, S3, S4, S5. The following list maps the cognitive difficulty levels to the spatial abilities.

1) CL1: S1

TABLE II
COGNITIVE AND PSYCHOMOTOR DIFFICULTY LEVELS

| ability | Cognitive difficulty level | Psychomotor difficulty level |
|---|---|---|
| ability | Cognitive ability | Psychomotor ability |
| S1: Selection | 2 | 3 |
| S2: Alignment | 3 | 4 |
| S3: Balance | 3 | 4 |
| S4: Reconstruction | 4 | 6 |
| S5: Visualization | 6 | 7 |
| S6: Use spatial language | 3 | 1 |

2) CL2: S6
3) CL3: S2, S3
4) CL4: S4
5) CL5: S5

The following list maps the psychomotor difficulty levels to the spatial abilities.

1) PL1: S6
2) PL2: S1
3) PL3: S2, S3
4) PL4: S4
5) PL5: S5

In the following subsections, a series of instructional activities designed to build a child's spatial abilities is identified. For each activity, a series of components which the child must accomplish to complete the entire activity is also identified. Each component has a set of spatial abilities associated with it. Based on the table above, the cognitive and psychomotor levels of each activity is computed. The difficulty of each activity as computed as a result of the number of components, cognitive and psychomotor levels.

### C. Spatial Competencies

A competency is defined as a cluster of related knowledge and abilities that enable a person to effectively carry out a task. As expected, a child's first set of Lego Duplo can open up a world of learning opportunities. Studies have been carried out establishing the importance of Lego in STEM Education. [10] However, the analysis provided is the specific set of abilities attained by blocks. The obvious first competency to be achieved by the child appeared to be to put two blocks together. Further analysis proved that this wasn't the first competency achieved by a child. While the child is fascinated by the first sight of the Lego blocks, and even though it seems elementary, (s)he couldnt start off with putting two blocks together. Therefore, the task commenced with what seems like the second competency: Taking two blocks apart. The following are sub-competencies for the two competencies of putting together and taking apart Lego blocks:

C1 Taking blocks apart given a set of blocks that are joined together
- C1.1: Identify where the two blocks meet
- C1.2: Grip the blocks in the right way that they come apart

TABLE III
ACTIVITY A1: SPATIAL ABILITIES

| Activity component | Spatial abilities | Cognitive difficulty | Psychomotor difficulty |
|---|---|---|---|
| A1.1 | Selection | CL1 | PL2 |
| A1.2 | Selection, Alignment | CL3 | PL3 |
| A1.3 | Alignment, Balance | CL3 | PL3 |
| A1.4 | Balance | CL3 | PL3 |

C1.3: Pull in the right direction until they come apart

C2 Putting blocks together

C2.1: Identify two blocks that will fit together

C2.2: Identify the right location to join them

C2.3: Grip them appropriately to push them together

C2.4: Join the two blocks together

### D. Instructional activities

The following are a set of Instructional Activities associated with spatial abilities. Each Instructional Activity is divided into a list of sub-activities to be completed, and each sub-activity is mapped to a set of spatial abilities it is associated with. Further, the difficulty of each instructional activity based on the complexity of abilities involved has been analyzed, and the most difficult activities have been computed.

A1: Build a tower of blocks. This activity requires a child to build a tower of blocks of the same size. The child may choose of base of their choice with any number of studs. Thereafter, the child must select several blocks of the same size as the base, align each block to the top block on the stack, and join the blocks. Therefore, the components of building the tower are:

A1.1: Select a base.

A1.2: Select a block with the same number of studs as the base.

A1.3: Align the block to the top block on the tower.

A1.4: Join the new block with the top block on the tower.

The spatial abilities which are developed during this activity are Selection, Alignment, Balance, and Visualization. Table III elaborates on the spatial abilities, cognitive difficulty and psychomotor difficulty of each activity component.

This competency requires the ability of alignment. The child must give the tower a base, ensure that each block placed on on top of the other has the same number of studs, and align consecutive blocks such that they fit. The blocks must also be chosen such that they have the same number of studs.

A2 Build an object, such as a car or house. This competency requires a child to identify an object, select the appropriate base, and choose blocks accordingly to the structure.

For example, the child can be asked to build a car, or a house. The components of this activity are:

A2.1: Know what the object in question is. The child should know what is the object in question, whether a car/house and be able to map the word to a mental image of the object.

A2.2: Choose the appropriate base for the object.

A2.3: Compute the appropriate dimensions of the object.

A2.4: Choose the appropriate number of blocks to construct the object.

A2.5: Construct the object.

The spatial abilities developed during this activity are Selection, Alignment, Balance, Reconstruction, and Visualization. Table IV elaborates on the spatial abilities, cognitive difficulty and psychomotor difficulty of each activity component.

TABLE IV
ACTIVITY A2: SPATIAL ABILITIES

| Activity component | Spatial abilities | Cognitive difficulty | Psychomotor difficulty |
|---|---|---|---|
| A2.1 | Requires domain knowledge | CL1 | Does not require psychomotor abilities |
| A2.2 | Selection | CL1 | PL2 |
| A2.3 | Visualization | CL5 | PL5 |
| A2.4 | Visualization, Alignment, balance | CL5 | PL5 |
| A2.5 | Alignment, Balance, Repair | CL5 | PL5 |

A3 Reconstruct an object based on visual instructions. This activity involves the child in building an object based on an image provided. The components of this activity are:

A3.1: Choose the appropriate base for the object.

A3.2: Compute the appropriate dimensions of the object.

A3.3: Choose the appropriate number of blocks to construct the object.

A3.4: Construct the object.

The spatial abilities developed during this activity are Selection, Alignment, Balance, Reconstruction, and Visualization. Table V elaborates on the spatial abilities, cognitive difficulty and psychomotor difficulty of each activity component.

A4 Problem solving. This activity involves the child in solving a problem using the blocks. The problem can be one of their own choice or a question posed to them by a parent/teacher. Here, the focus is on problems that involve constructing a structure to store specific objects. For example, one such activity would be to build a structure to house toy animals.

TABLE V
ACTIVITY A3: SPATIAL ABILITIES

| Activity component | Spatial abilities | Cognitive difficulty | Psychomotor difficulty |
|---|---|---|---|
| A3.1 | Selection | CL1 | PL2 |
| A3.2 | Visualization | CL5 | PL5 |
| A3.3 | Alignment, Balance | CL3 | PL3 |
| A3.4 | Visualization, Alignment, Balance, Reconstruction | CL5 | PL5 |

TABLE VI
ACTIVITY A4: SPATIAL ABILITIES

| Activity component | Spatial abilities | Cognitive difficulty | Psychomotor difficulty |
|---|---|---|---|
| A4.1 | Requires domain knowledge | CL1 | Does not require psychomotor abilities |
| A4.2 | Visualization | CL5 | PL5 |
| A4.3 | Alignment, Balance | CL3 | PL3 |
| A4.4 | Visualization | CL5 | PL5 |
| A4.5 | Alignment, Balance, Visualization, Reconstruction | CL5 | PL5 |

The components of this activity are:

- A4.1: Analyzing the dimensions of the objects to be stored.
- A4.2: Compute the total dimensions of the structure required based on the dimensions of the objects and the total number of objects.
- A4.3: Choose the appropriate base for the object.
- A4.4: Choose the appropriate number of blocks to construct the object.
- A4.5: Construct the object.

Table VI elaborates on the spatial abilities, cognitive difficulty and psychomotor difficulty of each activity component.

The spatial abilities developed during this activity are Selection, Alignment, Balance, Reconstruction, using spatial language and Visualization.

A5 Puzzles This activity involves a child solving a simple puzzle. In this case, the focus is on puzzles which have knobs for easy grasping for toddlers. The components of this activity are:

- A5.1 Analyze the dimensions of the puzzle pieces and the slots.
- A5.2 Identify the appropriate piece for each slot.
- A5.3 Align the piece with the slot.
- A5.4 Place the piece appropriately into the slot.

The spatial abilities developed during this activity are Selection, Alignment, and Visualization. Table VII elaborates on the spatial abilities, cognitive difficulty and psychomotor difficulty of each activity component.

TABLE VII
ACTIVITY A5: SPATIAL ABILITIES

| Activity component | Spatial abilities | Cognitive difficulty | Psychomotor difficulty |
|---|---|---|---|
| A5.1 | Visualization | CL5 | PL5 |
| A5.2 | Selection | CL1 | PL2 |
| A5.3 | Alignment | CL3 | PL3 |
| A5.4 | Alignment | CL3 | PL3 |

TABLE VIII
ACTIVITY A6: SPATIAL ABILITIES

| Activity component | Spatial abilities | Cognitive difficulty | Psychomotor difficulty |
|---|---|---|---|
| A6.1 | Visualization, knowledge of shapes | CL5 | PL5 |
| A6.2 | Visualization, knowledge of shapes | CL5 | PL5 |
| A6.3 | Alignment | CL3 | PL3 |
| A6.4 | Alignment | CL3 | PL3 |

A6 Shape sorters These seemingly elementary toys teach shapes, and matching a shape to its appropriate slot. They help develop fine motor abilities and hand-eye coordination as well. The components of this activity are:

- A6.1 Identify the shapes on the shape sorter.
- A6.2 Identify the shape of each block.
- A6.3 Turn the shape sorter until the matching slot for the block is identified.
- A6.4 Push the block into the identified slot with the right angle so it goes in.

The spatial abilities required in this activity are Selection, Visualization and Alignment. Table VIII elaborates on the spatial abilities, cognitive difficulty and psychomotor difficulty of each activity component.

A7 Beading This activity involves threading large beans onto a pipe or fuzzy wire. This task is simpler than using an elastic rope for a toddler, as a fuzzy wire or pipe will remain sturdy compared to the elastic rope, thereby the child only needs to concentrate on one moving object i.e the bead. The components of this activity are:

- A7.1 Identify the hole in the bead through which the wire should be threaded.
- A7.2 Align the hole with the end of the wire.
- A7.3 Thread the bead through the wire.

The spatial abilities developed during this activity are Alignment, Visualization, and Repair. Table IX elaborates on the spatial abilities, cognitive difficulty and psychomotor difficulty of each activity component.

A8 Foam blocks This activity involves stacking large foam blocks to form a structure. These blocks are much larger than the conventional wooden blocks, forming structures large enough for a child to sit inside or climb on top of. Unlike Lego blocks / Megablox, these blocks do not have ”studs” to align

TABLE IX
ACTIVITY A7: SPATIAL ABILITIES

| Activity component | Spatial abilities | | |
|---|---|---|---|
| A7.1 | Visualization, knowledge of shapes | CL5 | PL5 |
| A7.2 | Visualization, knowledge of shapes | CL5 | PL5 |
| A7.3 | Alignment | CL3 | PL3 |

TABLE X
ACTIVITY A8: SPATIAL ABILITIES

| Activity component | Spatial abilities | Cognitive difficulty | Psychomotor difficulty |
|---|---|---|---|
| A8.1 | Visualization, Mental Rotation | CL5 | PL5 |
| A8.2 | Visualization, Mental Rotation | CL5 | PL5 |
| A8.3 | Alignment | CL3 | PL3 |

and join, therefore this task does not require the same level of alignment. The blocks may be of several different sizes and shapes. There are also ”connector” tubes which connect two different blocks by threading the tube through a hole in the block. Therefore, the child must be able to identify two blocks with whose shapes are compatible or a tube compatible with a block, and then place one on top of another in a way that they balance or join the blocks. The spatial abilities developed during this activity are Alignment, Visualization, and Mental Rotation.
The components of this activity are

- A8.1 Identify two blocks which are compatible.
- A8.2 Identify the rotation in which the blocks can be placed.
- A8.3 Place one block on top of the other.

Table X elaborates on the spatial abilities, cognitive difficulty and psychomotor difficulty of each activity component.

A9 Wooden blocks This activity involves stacking wooden blocks to form a structure. Unlike Lego blocks, these blocks do not have ”studs” to align and join, therefore this task does not require the same level of alignment. The blocks may be of several different sizes and shapes. Therefore, the child must be able to identify two blocks with whose shapes are compatible, and then place one on top of another in a way that they balance. The spatial abilities developed during this activity are Alignment, Visualization, and Mental Rotation.
The components of this activity are:

- A9.1 Identify two blocks with a compatible base.
- A9.2 Identify the rotation in which the blocks can be balanced one on top of the other.
- A9.3 Place one block on top of the other.

TABLE XI
ACTIVITY A9: SPATIAL ABILITIES

| Activity component | Spatial abilities | Cognitive difficulty | Psychomotor difficulty |
|---|---|---|---|
| A9.1 | Visualization, Mental Rotation | CL5 | PL5 |
| A9.2 | Visualization, Mental Rotation CL5 | PL5 | |
| A9.3 | Alignment | CL3 | PL3 |

TABLE XII
DIFFICULTY OF EACH ACTIVITY

| Activity | Number of components | Cognitive difficulty | Psychomotor difficulty |
|---|---|---|---|
| A1 | 4 | CL3 | PL3 |
| A2 | 5 | CL5 | PL5 |
| A3 | 4 | CL5 | PL5 |
| A4 | 5 | CL5 | PL5 |
| A5 | 4 | CL3 | PL3 |
| A6 | 4 | CL5 | PL5 |
| A7 | 3 | CL5 | PL5 |
| A8 | 3 | CL5 | PL5 |
| A9 | 3 | CL5 | PL5 |

Table XI elaborates on the spatial abilities, cognitive difficulty and psychomotor difficulty of each activity component.

### *E. Computation of difficulty*

It is best to sequence the instructional activities offered to children. By sequencing activities, the motivation of the child to complete the activity is best balanced with the challenge posed by the activity. In this section, the instructional activities are sequenced based on the computation of difficulty above. Table XI summarizes the number of components of each activity, and the highest cognitive and psychomotor difficulties of each activity as well. The easiest activity has the lowest number of components and the lowest levels of cognitive and psychomotor difficulty, while the most difficult activities have the highest number of components and the highest levels of cognitive and psychomotor difficulty. Table XII maps each activity to its difficulty.
Based on Table XII, the activities are organized into levels of difficulty as follows:

Difficulty level 1: Activities A1, A5
Difficulty level 2: Activities A7. A8, A9
Difficulty level 3: Activities A3. A6
Difficulty level 4: Activities A2, A4

## IV. CONCLUSION

In this paper, it has been established established that spatial abilities are crucial for success in engineering and STEM fields. The paper also stated that insufficient attention is being paid to these fields in early childhood education, and chosen early childhood as the focus audience for this study.

A set of spatial abilities to focus on for this study has been identified, and identified their difficulty based on their cognitive and psychomotor levels as per Bloom's taxonomy. A set of instructional activities using children's toys have been identified and classified based on their difficulty.

Future work involves administering a field study for children aged 2-5 years old using the instructional activities described in the paper. The field study will establish the efficacy of these activities in acquiring the spatial abilities identified.

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