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The Influence of Unplugged LEGO Activities on Middle Grades Students' Computational Thinking Dispositions in a STEM Camp

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Abstract: This study reports on a STEM camp that aimed to engage middle grade students in computational thinking dispositions. Case study methodology and data from observational field notes and participant reflections were used to investigate if and how students engaged in computational thinking dispositions as they engaged in the unplugged LEGO activities. The findings revealed that unplugged structured LEGO activities (a) did not facilitate tolerance for ambiguity, (b) facilitated high persistence on difficult problems, and (c) high and developing willingness to collaborate with others to achieve a common goal. The findings also revealed that unplugged semi-structured LEGO activities (a) facilitated high and developing tolerance for ambiguity, (b) facilitated no evidence of persistence, and (c) increased and developed willingness to collaborate with others to achieve a common goal. The overall findings of this study suggest that when using unplugged, LEGO activities: (a) it is better to use unplugged structured LEGO activities to promote the computational thinking disposition of persistence, (b) it is better to use semi-structured activities to promote tolerance for ambiguity, and (c) it is better to use either or both to promote collaboration with others to achieve a common goal. The study's findings are significant because it provides an empirical example of how the use of LEGOS as an unplugged activity can be used to facilitate computational thinking dispositions in middle grade students. Having this information is important because it can support STEM educators in modifying and adapting unplugged LEGO activities to develop students' computational thinking dispositions.

Keywords: computational thinking dispositions; middle grades; LEGOS; unplugged activities; STEM camp

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1. Introduction

As with formal schools, informal STEM programs may lack access to sufficient funding to purchase expensive curriculum materials. This lack of funding might also impact access to the internet, which is required by some of the plugged STEM programs (e.g., Dash, LEGO® Education SPIKE™ Prime Sets). To still provide high-quality STEM programming, STEM educators sometimes use unplugged activities to further STEM learning (e.g., Faber et al., 2017; Manabe et al., 2011; Unnikrishnan et al., 2016). Facing the aforementioned challenge, a STEM camp was designed that used unplugged activities with the goal of cultivating students' computational thinking dispositions. Unplugged activities have been described in different ways (e.g., Bell et al., 1998), but for the current study, it is defined as STEM activities that do not require the internet. While research indicates that unplugged activities empower students to engage in computational thinking (Munasinghe et al., 2023), there is limited evidence that indicates that unplugged activities enable students to engage in computational thinking dispositions (CTDs).

CTDs are particularly important because, according to Pérez (2018) they are important for getting students engaged in computational thinking skills. Efforts to integrate computational thinking into primary and secondary education are underway in countries such as the United States, the Netherlands, and England (Yadav et al., 2017). In fact, researchers have argued for the integration of computational thinking from primary school through college to prepare students for an increasingly technological society (Buitrago Flórez et al., 2017; Yadav et al., 2017). Computational thinking skills are important because of their significant correlation with STEM career interests (Hava & Koyunlu Ünlü, 2021) which are particularly important for students' professional advancement and the global advancement for countries (Casey, 2012). CTDs also play a key role in enhancing student performance, student engagement, and facilitating STEM learning (Looi et al., 2024; Yin et al., 2019). More broadly, CTDs are important because they are "a key aspect of cross-disciplinary transferability" (Pérez, 2018, p. 427), which is important for an interdisciplinary approach to learning. Research on activities that promote the development of CTDs is also significant because, according to Yin et al. (2019), computational thinking plays a significant role in facilitating STEM learning. Consequently, Pérez (2018) argues that "there is a clear need for greater attention to the educational significance of dispositions and the learning opportunities that cultivate them (p. 427). The current study addresses Pérez's (2018) call by examining the influence of learning opportunities in a STEM camp (Unplugged LEGO Activities) on middle grades students' computational thinking dispositions. The research questions for this study are as follows: (a) To what extent do unplugged activities facilitate the engagement of participants in computational thinking dispositions, and (b) how do participants demonstrate computational thinking dispositions during the unplugged activities? This research contributes to the field by providing an empirical example of how an unplugged activity, specifically LEGO building, may promote positive outcomes for students. Having this information advances the field by adding to the knowledge base of accessible unplugged activities that support engagement in computational thinking dispositions.

1.1. Theoretical Framework: Computational Thinking Dispositions

Like reading, writing, and mathematics, computational thinking is a skill that all should develop (Wing, 2006), especially in an increasingly technology-rich world. The International Society for Technology in Education and The Computer Science Teachers Association (2011) operationalizes computational thinking as "a problem solving process that includes (but is not limited to) characteristics such as "formulating problems in a way that enables us to use a computer and other tools to help solve them. . ., logically organizing and analyzing data, representing data through abstractions. . ., automating solutions through algorithmic thinking (a series of ordered steps)" (p. 1). International Society for Technology in Education and The Computer Science Teachers Association (2011) argue that computational thinking skills are fostered by computational thinking dispositions. While various conceptions of computational thinking dispositions exist (e.g., Weller et al., 2022; Jong et al., 2020; Pérez, 2018; Brennan & Resnick, 2012), the International Society for Technology in Education and The Computer Science Teachers Association (2011) jointly operationalized the concept as (a) confidence in dealing with complexity, (b) persistence in working with difficult problems, (c) tolerance for ambiguity, (d) the ability to deal with open-ended problems, and (e) the ability to communicate and work with others to achieve a common goal or solution. To eliminate overlap in the five computational thinking dispositions put forth by the International Society for Technology in Education and The Computer Science Teachers Association (2011), Pérez (2018) distilled the dispositions into three components, which include (a) tolerance for ambiguity, (b) persistence on difficult problems, and (c) collaboration with others to achieve a common goal. Pérez (2018) argued that “based on relevant literature, the terms complexity and open-ended problems both fall within the purview of ambiguity” (p. 441). Though these are thinking dispositions, Pérez (2018) provides indicators of observable behaviors that students might engage in.

1.1.1. Tolerance for Ambiguity

Drawing from existing literature, Pérez (2018) defined, “tolerance for ambiguity refers to a high degree of tolerance for ambiguity and is defined as a favorable response to ambiguous situations or stimuli (p. 435). While what is considered ambiguous will vary from person to person, some common characteristics exist. Some of these characteristics include situations or tasks that are “ill defined,” unfamiliar, complex, and have multiple solution paths (Pérez, 2018, p. 435). To support developing tolerance for ambiguity, Pérez (2018) suggests providing authentic tasks, engaging students in real world limitations, embracing imperfect data, and accepting variance in problem solving approaches. People may have a high tolerance for ambiguity or be developing in their tolerance of ambiguity. More tolerance may manifest as embracing challenge and engaging with tasks that are complex or unfamiliar. Less tolerance may manifest as choosing to disengage when presented with complex or unfamiliar tasks. Pérez (2018) argues that it is important to note individuals who are initially less tolerant can become more tolerant as they grow.

1.1.2. Persistence on Difficult Problems

Persistence on difficult problems, or task persistence, is defined as “continuing to purposefully engage in a challenging task even when experiencing difficulty, obstacles, or failure” (Pérez, 2018, p. 437). It is important for the context or task to facilitate an environment where persistence can happen because “the degree to which learners exhibit task persistence when working on difficult problems depends in part on the degree to which learning environments and tasks encourage—or do not encourage—the expression of this disposition” (Pérez, 2018, p. 445). Furthermore, (Pérez, 2018) this disposition may be observed when an individual encounters meaningful challenges on a task and has an opportunity for multiple attempts. Tasks that are what Henningsen and Stein (1997) call procedures without connections may inhibit individuals from meaningfully persisting on difficult problems (Pérez, 2018). Thus, giving students the opportunity to encounter challenging tasks supports them in persevering through future challenging tasks (Pérez, 2018). People may exhibit high persistence, developing persistence, or no evidence of persistence. No evidence of persistence indicates what is being observed in the moment for a particular task as opposed to labeling a person’s permanent state.

1.1.3. Collaboration with Others to Achieve a Common Goal

Collaboration with others to achieve a common goal is defined as “a mutual process through which two or more participants coordinate their efforts, provide explanations, contend with different perspectives and approaches, and elaborate and reorganize knowledge and resources” (Pérez, 2018, p. 437). Collaborative interactions among peers are an important aspect of this disposition and go beyond cooperation. For example, a group of students deciding to split up their work to achieve a common goal would not be considered collaboration solely because they decided to split up the work (Pérez, 2018). For this example, to be considered collaboration, the division of labor needs, to some extent, be substantive engagement with different perspectives, negotiation of differences, and mutual decision making (Pérez, 2018). People may exhibit a high willingness to collaborate with others or a developing willingness to collaborate with others. In the current study, the CT Disposition Framework is used to understand if and how an unplugged LEGO activity in a STEM camp facilitates the computational thinking dispositions of (a) tolerance for ambiguity, (b) persistence on difficult problems, and (c) collaboration with others to achieve a common goal.

1.2. Related Research Literature

To examine how LEGO building can facilitate students' engagement in computational thinking dispositions, it is essential to understand prior research on the topic. In the sections that follow, a brief synthesis related to the research literature that provides a foundation for the current study is addressed and includes: (a) computational thinking dispositions and (b) LEGO building activities in K-12 STEM Camps.

1.2.1. Research on Computational Thinking Dispositions

There is limited research on computational thinking dispositions within the context of STEM camps. However, there are two studies that provide insight into the current knowledge on computational thinking dispositions. Yin et al. (2019) designed a summer intervention involving maker activities and assessments, implemented it with 32 high school students, and investigated participants' change in computational thinking dispositions from pretest to posttest based on data from a self-report survey. They found that the intervention was effective for improving students' computational thinking dispositions (Yin et al., 2019). Hadad (2024) also conducted research, but instead of focusing on impact, the focus was on pedagogical practices that advance computational thinking dispositions within the context of a summer makerspace program. Findings revealed that the pedagogical practices of embodying, walkthroughs, drawing, and debugging advanced students' computational thinking dispositions (Hadad, 2024). Hadad (2024) also found that one of the practices, tinkering, on its own, did not facilitate computational thinking dispositions.

There are also two studies about computational thinking dispositions that take place in a classroom context (e.g., Looi et al., 2024; Pratidhina et al., 2023). Looi et al. (2024) investigated 168 students in a secondary school. They were interested to know if students' dispositions would have a positive impact on their engagement in mathematics and mathematics performance. They found that computational thinking dispositions positively impact students' engagement and that engagement positively impacted students' mathematics performance (Looi et al., 2024). Pratidhina et al. (2023) designed an intervention in a high school physics class involving collaborative modeling-based learning, implemented it with 89 high school students, and investigated participants' computational thinking dispositions using a self-report checklist. They found that participants reported positive evidence of confidence when facing complexity, persistence when working with difficulty, and skills to work collaboratively to achieve a common goal (Pratidhina et al., 2023). They also found that participants reported acceptable evidence of confidence when handling ambiguity (Pratidhina et al., 2023).

Only two of the four studies examine computational thinking within the context of a STEM camp (e.g., Hadad, 2024; Yin et al., 2019). As such, the current study adds to the limited research literature on computational thinking dispositions and STEM camps. Additionally, much of the research on computational thinking dispositions in STEM camps has taken place with high school aged students (e.g., Hadad, 2024; Looi et al., 2024; Pratidhina et al., 2023; Yin et al., 2019). The current study adds to the literature because it takes place with students in the middle grades (4th through 8th). Furthermore, the current research on CT dispositions in STEM camps examines physics learning, engineering learning, collaborative modeling-based learning, and pedagogical practices (e.g., Hadad, 2024; Looi et al., 2024; Pratidhina et al., 2023; Yin et al., 2019). The current study adds to the research literature because the focus is the potential of unplugged LEGO activities to facilitate computational thinking dispositions.

1.2.2. Research on LEGOs in K-12 STEM Camps

Several studies indicate that LEGOs are used as instructional materials in STEM camps. Lego MINDSTORMS® have been used in many studies that use LEGOs as instructional materials in STEM camps (e.g., Üçgül & Altıok, 2021; Leonard et al., 2016; Aslam et al., 2014; Tuluri, 2015; Varney et al., 2011; Hixon, 2007). Examples of Lego MINDSTORMS® kits that have been used in studies include LEGO® NXT (Tuluri, 2015), LEGO® EV3 robotics (Leonard et al., 2016), and LEGO® RCX (Aslam et al., 2014). However, other types of LEGOs are also used in studies, such as LEGO® WeDo1.0 (Chiang et al., 2022) and LEGO Linkages (Kovács, 2020). LEGO Robotics modules have also been developed that include the Robot Inspired Learning System (RILS) (Aslam & Wise, 2003), Technology Assisted Science, Engineering, and Math (TASEM) (Varney et al., 2011), and Functionalized Bricks with Embedded Intelligence (FBEI) (Aslam et al., 2014). Each of these kits and modules are plugged into activities requiring technologies such as sensors, electronics, circuits, batteries, LEDs, wireless interfaces, microcontrollers, actuators, energy scavenging devices, capacitor batteries, and multimedia devices. Many of these resources also require access to the internet. While much research has been reported on the use of LEGOs as a plugged activity, limited research exists on the use of LEGOs as an unplugged activity (not requiring an internet connection) in STEM camps.

Several investigations of STEM camps that use LEGOs as instructional materials report outcomes for K-12 students. For example, Hixon (2007) used Robolab and LEGO MINDSTORMS® kits to teach engineering concepts in a STEM camp. Based on parent responses, the camp was a positive experience and helped students gain a more positive view of engineering. However, parents reported participants did not use the skills they learned beyond the camp (Hixon, 2007). Williams et al. (2007) also found that while the use of LEGO MINDSTORMS® kits and Robolab improved middle school students' physics content knowledge, it did not improve their skills conducting scientific inquiry. Research also reports student improvements based on their participation in STEM camps using LEGOs. For example, students show improvements in their content knowledge acquisition (Williams et al., 2007), STEM career interest (Chung et al., 2014; Varney et al., 2011), performance (Tuluri, 2015), perceptions toward STEM (particularly mathematics and science) (Üçgül & Altıok, 2021), self-efficacy, computational thinking, and task value (Chiang et al., 2022). However, other research reports insignificant effects on self-efficacy, attitudes toward STEM, and computational thinking measures (Leonard et al., 2016). While there are studies that report that the impact of using LEGOs on students' computational thinking (e.g., Chiang et al., 2022; Leonard et al., 2016), limited research exists about the impacts of the use of LEGOs in STEM camps on students' computational thinking dispositions.

A review of the literature revealed that plugged LEGO activities are typically used in STEM camps that use LEGOs. This suggests that a gap exists in research that uses LEGOs as an unplugged activity. Additionally, there is little to no research on how the use of LEGOs as an unplugged activity contributes to students' computational thinking dispositions. As such, the current study fills a gap by exploring how the use of LEGOs as an unplugged activity contributes to fourth through eighth grade students' computational thinking dispositions. This research is significant for many reasons, but one that is important is the activity's potential to be used in formal education. For example, Varney et al.'s (2011) research discussed how the LEGO program that they used in the STEM camp eventually became an offering in the local school. Aslam et al. (2014) and Tuluri (2015) also revealed that the activities that were used in the camps that they studied were also used in the university classroom.

2. Materials and Methods

2.1. Research Design

This study is embedded within a descriptive, holistic, single case study research design (Yin, 2014). A descriptive approach is useful for this study because it seeks to describe in detail what is (or is not) happening (Coe et al., 2021). A holistic approach is used in this study because the data is analyzed as a single dataset even though data are gathered from multiple groups (Yin, 2014). The rationale for looking at the data as a single dataset is the interest in the overall influence of the unplugged activities on participants' engagement in computational thinking dispositions as opposed to individual groups. A single case study is used for this study because of the interest in the data as one unit (Yin, 2014). Therefore, the unit of analysis is the whole class as opposed to individual groups within the class. The focus of this case study is on computational thinking dispositions and unplugged LEGO activities. This single case study explains how much unplugged activities facilitate computational thinking dispositions among middle grade students (fourth through eighth) in a STEM camp. The unplugged activities consisted of Lego blocks and Lego sets.

2.2. Research Context

The context for this case is a STEM Camp offered by a community-based non-profit organization that offers STEM camps to students in kindergarten through eighth grade. The STEM camp was in the southeast region of the United States of America at a public title 1 school. The STEM camp was primarily available free or at a discounted rate to students who attended the school but was open to the broader community, including students of all races, ethnicities, and economic backgrounds. The 5-day STEM camp took place from 9 to 3 p.m. from Monday to Friday. Students were provided with breakfast, snacks, and lunch. Participants engaged in unplugged LEGO building activities, devotionals, community building activities, out-door time, and games. The STEM activities of the camp were unplugged LEGO blocks and LEGO sets. The LEGO sets include a LEGO Creator, LEGO Minecraft, LEGO Sonic, LEGO Disney, and LEGO Friends. All these activities are building kits that do not require connection to the internet. From Monday to Thursday, students engaged in an hour and a half morning session and an hour and a half afternoon session of LEGO activities (see Table 1). On the last day, students went on a field trip to a local LEGO-themed amusement park that loosely reflected the designs that participants built in the camp.

Table 1. Overview of the STEM Activities Schedule.

Day	Focus of the Day	Duration	Participation Structure
Monday	Semi-structured LEGO Activities	3 h	Groups of 3–4
Tuesday	Structured STEM Kits	3 h	Groups of 3–4
Wednesday	Structured STEM Kids	3 h	Groups of 3–4
Thursday	Semi-structured LEGO Activities	3 h	Groups of 3–4
Friday	Field Trip to Legoland, specifically LEGO city with the miniature structures and the rides	6 h	Whole Group

Note: 9 a.m.–3 p.m. daily.

There were two types of LEGO building activities offered: structured and semi-structured activities. The structured activities were the LEGO sets. The sets were based on characters from popular youth TV shows and movies such as SONIC, Minecraft, WISH, and LEGO Friends. Participants also built LEGO sets based on structures that you might see in a community (bird houses, benches, and houses). Participants worked in groups of 3–4 to build these sets using the instructions that accompanied the set.

The semi-structured activities were a mix of LEGO pieces, characters, and blocks that participants could use to create a design related to a topic assigned by a camp facilitator. The final project for the camp was a semi-structured activity. Participants worked in groups of three to four to create a design that would be part of the larger amusement park that individual group designs would come together to make. The intent was for the individual design projects to come together to contribute to a large LEGO-themed amusement park. On the last day of camp, participants visited a LEGO-themed amusement park in person and saw the larger sized structures such as government buildings, racetracks, and spaceships. As participants walked around the park, they also saw the large rides that they had built similar models for.

2.3. Participants

After obtaining Institutional Review Board approval from the University (IRB-24-351) and research approval from the organization, participants were recruited from the camp to participate in the study. Students who assented to participate in the study and whose parents consented for them to participate in the study were enrolled in the research. The sampling technique used for this study is purposive, which is, according to Miles et al. (2014), a typical sampling technique used in qualitative research. Instead of studying both the younger (K-3rd) and older (4th–8th) students in the camp, the focus was on the older group in order to obtain thicker descriptions of the phenomenon. Trying to divide my attention between the two groups may have resulted in shallow observations and student responses because of the time and research personnel constraints. Twenty-one students assented to be in the study, and their parents consented for them to be in the study. Table 2 contains the demographic information of the participants.

Table 2. Participant Demographics by Count and Percentage (n = 21).

Characteristic	Count (n)	Percent (%)
Gender		
Female	9	45
Male	11	55
Race		
Asian	0	0
American Indian/Alaskan Native	0	0
Black	3	15
Multiracial	0	0
Native Hawaiian or Other Pacific Islander	0	0
White	17	85
Ethnicity		
Hispanic/Latinx	6	30
Non-Hispanic/Latinx	14	70
Upcoming Grade Level Completed		
4th	8	40
5th	4	20
6th	3	15
7th	4	20
8th	1	5

Note: Percents are rounded to the nearest tenth, so some totals may not equal 100.

2.4. Data Collection and Analysis

The data garnered for this study include (a) observational field notes and (b) student reflections. The observational field notes included observations of if and how students were engaged with the computational thinking dispositions. The participant reflections took place at the end of each day after students were engaging in LEGO building activities. Participants reflected on their experience by describing if and how they engaged in computational thinking dispositions. Observational notes and participant reflections were combined into one dataset. The dataset was analyzed using directive content analysis, a coding approach that uses existing theory to guide the coding process (Hsieh & Shannon, 2005). The first step enacted was an initial reading of the dataset. The next step was to read the dataset again and code each individual idea as either tolerance for ambiguity, persistence on difficult problems, or collaboration with others to achieve a common goal. Using guidance from Pérez (2018), each item coded as tolerance for ambiguity was assigned a rating of high tolerance for ambiguity, developing tolerance for ambiguity, or not observed (see Table 3). Each item coded as persistence on difficult problems was assigned a rating of high persistence, developing persistence, or no evidence of persistence. Each item coded as collaboration with others to achieve a common goal was assigned a rating of high willingness to collaborate with others, developing willingness to collaborate with others, or not observed.

Table 3. Summary of Analysis.

Computational Thinking Disposition	Rating
Tolerance for ambiguity	High tolerance for ambiguity Developing tolerance for ambiguity Not Observed
Persistence on difficult problems	High persistence Developing persistence No evidence of persistence
Collaboration with others to achieve a common goal	High willingness to collaborate with others Developing willingness to collaborate with others Not observed

3. Results

This study investigated the potential of unplugged STEM activities to engage students in computational thinking dispositions. The computational thinking dispositions investigated in this study include tolerance for ambiguity, persistence on difficult problems, and collaboration with others to achieve a common goal. The findings are reported in terms of if and how the unplugged LEGO activities facilitated (or not) each of the computational thinking dispositions. The types of unplugged LEGO activities investigated were structured and semi-structured LEGO activities. A summary of the findings is displayed in Figure 1. These findings are reported in more detail in the sections that follow.

3.1. Tolerance for Ambiguity

Participants were observed and asked to reflect on if and how they engaged in tolerance for ambiguity as they engaged in the activities. A total of 27 unique responses were collected from 21 participants. If a participant provided the same response as another participant, the response was only counted once to ensure that only independent ideas were collected.

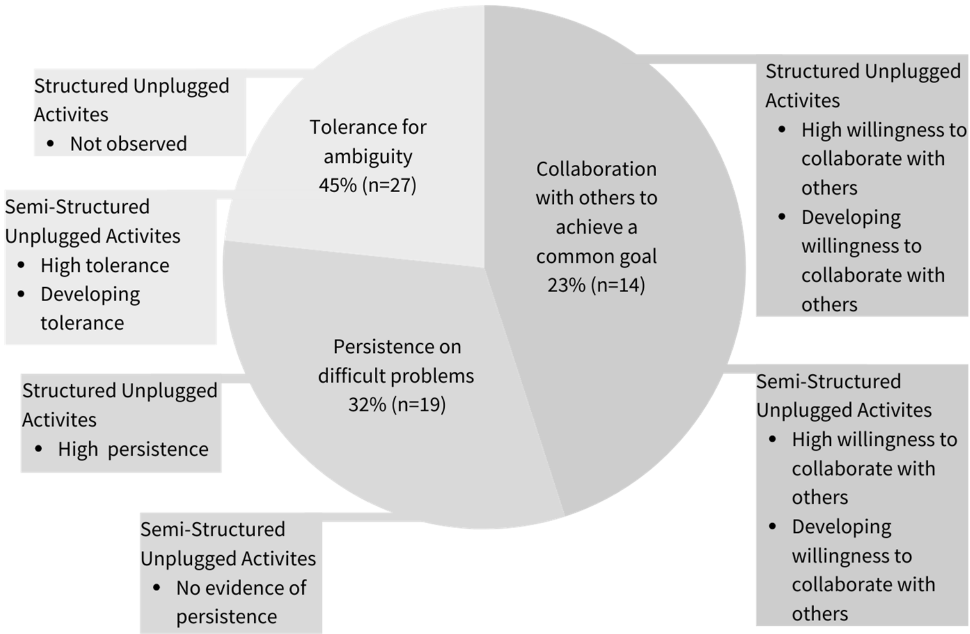

Figure 1. Summary of Findings Based on Participant Reports and Observations.

3.1.1. Structured Activities

Tolerance for ambiguity was not reported or observed because the unplugged structured activities were not deemed ambiguous. As such, based on my observations, the context of the activity did not facilitate an environment where students could develop a tolerance for ambiguity.

3.1.2. Semi-Structured Activities

Findings revealed that participants' engagement in unplugged, semi-structured LEGO activities facilitated both high and developing engagement in tolerance for ambiguity. Participants demonstrated high tolerance for ambiguity by embracing the activity as a creative endeavor. Most of the participants reported that they liked the more ambiguous activity because it (a) provided more leeway in developing a design. Most of the participants reported that by not having detailed instructions, they had more leeway to use their imagination, creativity, and be innovative. One participant wrote, "I like the instructions, but I also like the creativity of building without instructions... it's like freedom... and then when I am done... it's like... I made this!" (participant quote). Several participants explained that engaging in this way is fun. Three participants demonstrated developing tolerance for ambiguity in the way that they engaged with the ambiguous designs. For instance, the participants expressed that they preferred the less ambiguous designs (the structured activities) because they found them to be easier, knew that they would have all the pieces they needed to build the design, and they knew exactly what they were building. They expressed that they did not like the more ambiguous designs because it required more thought to create a design from scratch and that it is too open ended.

3.2. Persistence on Difficult Problems

Participants were observed and asked to reflect on if and how they persisted on difficult problems. A total of 19 unique responses were collected from 21 participants. If a participant provided the same response as another participant, the response was only counted once to ensure that only independent ideas were collected.

3.2.1. Structured Activities

Findings revealed that participants' engagement in unplugged structured activities facilitated high persistence. Participants identified several difficulties with the structured activities, which include challenges with transferring what was on the image to the actual build, difficulty finding the pieces, and breaking the build down after completing it. Participants demonstrated high persistence on difficult problems by enacting strategies to persevere through the activity. These strategies included being patient, not wanting to give up, discussing it with their peers, helping each other, sorting the pieces by color to better identify them when it was time to use them, conversing and socializing while building, and switching roles. Participants also mentioned that being interested in LEGOs, interested in building their design, and the desire to see the finished product helped them to persist on the problem even though it was difficult. For example, one participant wrote, "We are almost done, so why give up now?" (participant quote) and another participant wrote that they "wanted to see how it was going to function" (participant quote).

3.2.2. Semi-Structured Activities

Participants' engagement in unplugged, semi-structured activities did not facilitate persistence. Most of the participants' responses related to persistence on difficult problems related to the structured activities. The comments made about the semi-structured activities related to it being easy. For example, one of the participants indicated that the unstructured activity was "interesting but not challenging" (participant quote), and another participant explained that the semi-structured activities are "easier because the instructions slow you down" (participant quote).

3.3. Collaboration with Others to Achieve a Common Goal

Participants were observed and asked to reflect on if and how they engaged in working well with each other to achieve the common goal of building a LEGO structure together. A total of 14 unique responses were collected from 21 participants. If a participant provided the same response as another participant, the response was only counted once to ensure that only independent ideas were collected.

3.3.1. Structured Activities

Participants' engagement in unplugged structured activities facilitated both high and developing willingness to collaborate with others to achieve a common goal. Most of the participants demonstrated a high willingness to collaborate by engaging in division of labor by taking on roles and engaging in turn taking (see Figure 2). For example, even though roles were not assigned, one group naturally engaged in roles. A group was observed, and one person was observed searching for pieces, another person was building, and another person was reading the instructions. After seeing one group doing this, facilitators recommended this structure to others that were struggling to collaborate.

Participants demonstrated a developing willingness to collaborate by their challenge with being stuck in a role. The facilitators had to intervene to support students on strategies to overcome the challenge. The facilitator recommended that in addition to engaging in roles, the roles should change every couple of pages of the instruction manual. The facilitators adopted this strategy from another group that had enacted this strategy. In this way, each participant would have a chance to play the builder role. That was the main source of complaint. That is, the person who played the role of reading the instructions also eventually wanted to build something with their hands. It was also observed that when a significantly younger group member was grouped with two older group members, they tended to stray off to a group that was considered their peers. For example, in Figure 2, only two of the group members are collaborating on the project, and the other group member wandered off and was chatting with peers. However, after redirecting him back to the group and supporting the group with collaboration strategies, they completed the project together (see Figure 3).

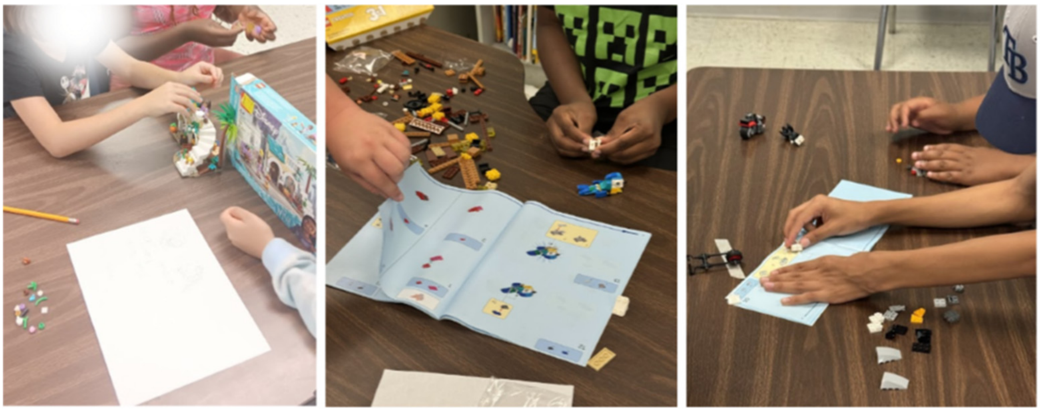

Figure 2. Participants engaging in division of labor.

Figure 3. Participants collaborating on the structured unplugged activity.

3.3.2. Semi-Structured Activities

Findings revealed that engagement in unplugged, semi-structured activities facilitated both high and developing willingness to collaborate with others to achieve a common goal. Most of the participants demonstrated a high willingness to collaborate by collaboratively deciding on a design and contributing to the building of the design (see Figure 4). Participants demonstrated a developing willingness to collaborate by arguing over what the common goal would be. For example, participants had to negotiate what the actual building would be. In fact, one of the groups had to be split up because they could not come to an agreement on what their own build would be. Within that group, the two participants decided to stay and agree on a common goal. They did so because, according to them, they were able to work well together because they were best friends.

Figure 4. Participants engaging in the semi-structured activity.

4. Discussion

4.1. Reflection on Findings and Implications

The current study investigated the potential of unplugged STEM activities to engage students in computational thinking dispositions. The computational thinking dispositions investigated in this study include tolerance for ambiguity, persistence on difficult problems, and collaboration with others to achieve a common goal. Findings revealed that unplugged structured LEGO activities (a) did not facilitate tolerance for ambiguity, (b) facilitated high persistence on difficult problems, and (c) high and developing willingness to collaborate with others to achieve a common goal. Findings also revealed that unplugged, semi-structured LEGO activities (a) facilitated high and developing tolerance for ambiguity, (b) facilitated no evidence of persistence, and (c) high and developing willingness to collaborate with others to achieve a common goal.

It may have been harder to collaborate on the structured activities and persist on difficult problems because participants were expected to follow complicated steps to finish their design. For example, one of the participants indicated that it was challenging transferring what was on the three-dimensional image to the physical design. What the participant is describing is a spatial reasoning challenge. This may indicate that stronger spatial reasoning skills are needed to be able to translate what is on an image into a physical structure. This is similar to research by Brosnan (1998) who found that spatial ability is related to the ability to construct LEGO models. Spatial ability plays a vital role in predicting STEM success in STEM fields and disciplines (Dawson, 2019; Wai et al., 2009). Thus, instead of trying to make the instructions less complex, facilitators should continue to engage participants in complex designs. However, before engaging participants in complex designs of this nature, they should first do a brief overview of spatial reasoning and how it connects to LEGO building.

Participants also struggled to collaborate on unstructured activities when it came to deciding on a design and sharing roles. Consequently, it is recommended that before engaging students in unstructured activities, they are provided with collaboration strategies. It may be beneficial to provide participants with real world examples of how collaboration takes place in some of the STEM disciplines and how they are expected to enact that in the context of engaging in unstructured activities.

A few participants also struggled with collaborating with older group members. For example, two participants frequently wandered off from their groups to go and engage with individuals that were in their same age group. Based on my observations, this was in part due to the older members of the group “taking over” leaving the younger members with nothing to do. This also may be because the younger members did not take the initiative to take on a role and engage with their group. This suggests that mixed grade groups may need support with engaging all members of the group when collaborating to achieve a common goal. This goal is valuable, as collaboration among mixed-grade groups has demonstrated positive outcomes (e.g., Roberts & Eady, 2012), with students expressing a desire for more of these experiences (Taylor, 2020).

The findings of the current study have similar findings to other studies on computational thinking and the use of LEGOs in STEM camps. First, Hadad (2024) focused on the extent to which pedagogical practices could support students' engagement in and development of computational thinking dispositions. The current study adds to the literature by focusing on the extent to which certain curriculum materials support students' engagement in and development of computational thinking dispositions. In both Hadad's (2024) study and the current study, we found that computational thinking dispositions were developed to some extent by the approach being studied and were not successful to some extent. For example, Hadad (2024) found that tinkering on it did not facilitate computational thinking dispositions. Findings in the current study revealed that structured activities did not facilitate tolerance for ambiguity, and semi-structured activities did not facilitate persistence on difficult problems. Second, in a study of high school intervention studying students' computational thinking dispositions, Pratidhina et al. (2023) found positive evidence of participants' persistence when working with difficulty and skills to work collaboratively to achieve a common goal. In the current study, there was also evidence of participants persisting on difficult problems and collaboratively working together to achieve a common goal. However, there was also no evidence of persistence when students were working on the semi-structured activities.

The overall findings of this study suggest that when using unplugged LEGO activities: (a) it is better to use unplugged structured LEGO activities to promote the computational thinking disposition of persistence, (b) it is better to use semi-structured activities to promote tolerance for ambiguity, and (c) it is better to use either or both to promote collaboration with others to achieve a common goal.

4.2. Limitations

Data that participants report about themselves is self-reported data and is a limitation when used in research. The reason that self-reported data are a limitation is because participants may not comprehend what is being asked and respond to a question that they may have misinterpreted (Cohen & Berlin, 2020). In the current study, I asked students to report if and how they engaged in computational thinking dispositions as they engaged in unplugged LEGO activities. To mitigate this limitation, I defined each of the computational thinking dispositions to participants before asking them to respond to them. Additionally, to further address this limitation, I followed Moore and Rutherfurd's (2020) guidance to include observational data when conducting studies that involve self-reports. Having observational data addressed the limitation in part because the data was not only based on participant reports. Despite these limitations, the findings of this study contribute to the field because it provides an empirical example of the extent to which the use of LEGOS as an unplugged activity can be used to facilitate computational thinking dispositions in middle grades students. Having this information is important because it can support STEM educators in modifying and adapting unplugged LEGO activities to develop students' computational thinking dispositions.

4.3. Suggestions for Further Research

Future research could explore how a learning environment designed to integrate unplugged or plugged LEGO activities and engage students in computational thinking dispositions could impact students' engagement in computational thinking practices as defined by the International Society for Technology in Education and The Computer Science

Teachers Association (2011). Such a study would be significant because, according to the International Society for Technology in Education and The Computer Science Teachers Association (2011), computational thinking dispositions are supposed to support computational thinking practices. As such, empirical evidence to support or refute this claim could advance the field's knowledge of how computational thinking dispositions impact computational thinking skills. Furthermore, a longitudinal study could investigate how students' computational thinking dispositions and skills develop (or not) over time and what factors supported (or not) that development.

Another area of future research is the use of a quantitative instrument to investigate students' computational thinking dispositions within the context of a STEM camp that uses unplugged LEGO activities. For example, Pratidhina et al. (2023) used a self-report Likert scale checklist that asks participants to respond to questions that assess their CT dispositions.

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