THE EFFECT OF GROUP INTERACTIONS AND GROUP STRUCTURE ON ACHIEVEMENT IN ELEMENTARY SCHOOL ROBOTICS CLASSROOMS

by

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DEDICATION

This dissertation is dedicated to my loving parents, who instilled in me the values and beliefs I hold today. I would never have pursued this degree without their constant support, encouragement, and faith in my abilities to accomplish what I once thought impossible. Also, of equal importance, I would like to dedicate this dissertation to my soon-to-be wife, Penny. Her patience, care, and kindness toward me throughout this process have been extraordinary and one of the primary reasons I persevered through all the challenges that attaining this degree brought. Thank you for still agreeing to marry me after all of this!

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ABSTRACT

Jung and Won's (2018) review of elementary school ER found a lack of understanding of instructional practices for ER with young children. Other researchers have called for further studies into what effective classroom orchestration and interaction look like within ER classrooms (Ioannou & Makridou, 2018; Xia & Zhong, 2019). This study was conducted to understand the effect of group interactions and group structure in terms of gender on achievement in elementary school robotics classes. Knowing the effect that interactions have on students' achievement can help inform instructional practices and pedagogies in educational robotics activities (Kucuk & Sisman, 2017). The study was conducted at a primary school in Nonthaburi, Thailand. The participants included 103 second-grade students (44 male, 59 female). A mixed methods embedded research design was used as a framework to make observations of interactions, conduct a robotics assessment, and analyze the data from the assessment. Cooperative learning (CL) which is the use of instructional small groups to maximize learning (Johnson & Johnson, 1999) was used as a lens for observing the student interactions. Group processing, positive interdependence, promotive interactions are some of the primary elements of CL and used as classifications of student interactions in the robotics classrooms and during the assessment. The robotics assessment consisted of multiple challenges where students were given a score in their skills of generalization, algorithmic thinking, and their Level of Achievement (LoA). The LoA was the sum of all the challenges completed. The mean scores of the students’ assessment results were analyzed using separate one-way ANOVAs to explore the effect of group structure and interaction types on achievement. It was found that the types of interactions in a group can have an effect on achievement depending on the types of robotics challenges. It was also found that gender did not have an effect on the students LoA during their robotics assessment, but it did have an effect on the types of interactions seen among students. It is recommended that for simpler robotics challenges that utilize basic generalization skills, instructors should try to facilitate promotive interactions within the classroom groups. For more advanced robotics challenges that utilize algorithmic thinking skills, instructors should try to facilitate group processing within their classroom groups.

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LIST OF ABBREVIATIONS

ER	Educational Robotics
CL	Cooperative Learning
CLOP	Cooperative Learning Observation Protocol
SIT	Social Interdependence Theory
STEM	Science Technology Engineering Math
DLPS	Denla Primary School

CHAPTER ONE: INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) disciplines in schools are becoming more emphasized worldwide (Thomas & Williams, 2010). Educational robotics (ER) has become a vehicle for delivering valuable STEM education (Hutamarn et al., 2017). With the help of ER activities, teachers can engage students in different types of complex learning environments; provide hands-on experiences for understanding the latest technologies; and create new outlets for students to apply their knowledge and skills in real-world situations (Jung & Won, 2018).

ER provides more than just an opportunity for students to interact with the newest educational technologies, it gives them an additional outlet to interact with their peers. The relationship between educational technology and social interactions has been studied and documented for decades. Svenson (2000) found that children's social interactions doubled in front of a computer. Most of these interactions were regarding the assigned task at hand. Wartella and Jennings (2001) found that children's interactions around computers are similar to those in other play areas. The most exhibited positive behaviors were cooperation, relationship building, and constructive group play (Wartella & Jennings, 2001). Bers (2010) found that computers can facilitate positive interactions between students who speak different languages. The connection between face-to-face social interactions and various educational technologies is well documented. Some may perceive technology as the antithesis of meaningful face-to-face interactions. However, as shown with many educational technologies, this is certainly not the case. In ER, a synchronous blend of social interaction and technology creates a unique learning environment suitable for the needs of the 21st-century learner.

While the STEM fields are growing rapidly, the number of women in the STEM fields is not. Jobs related to engineering are predominantly held by men (Burns, 2019). While there is no clear answer for addressing the gender disparity, the research on gender differences in ER offers possible solutions. It has been found that positive ER experiences help motivate girls to enter the STEM fields (Screpanti et al., 2018). Teachers should understand gender differences and the interactions occurring between their students to create positive and meaningful experiences (Angeli & Valanides, 2020; Kucuk & Sisman, 2017). If practitioners better understand how gender and interactions play a part in achievement in ER, they will be better equipped to provide positive ER experiences for their students.

This dissertation focuses on student interactions and gender as factors for achievement in ER. It provides a framework for observing student interactions in ER activities and analyzes how these interactions affect student achievement.

Background of the Study

The global robotics industry has been proliferating. According to the International Federation of Robotics (IFR) report of 2018, the global production of industrial robotics increased in volume by 30% (De Backer et al., 2018). This production increase was preceded by five consecutive years of all-time high growth in the industry (Gdansky et al., 2020). As the demand for robotics increases, so does the need for employees with the necessary knowledge and skills to be productive in the robotics field.

ER provides students an outlet to learn about a growing industry while developing other valuable STEM skills such as critical thinking, inquiry, innovation, and applying knowledge and skills in a real-world context (Kennedy & Odell, 2014). While the ER field has been around for decades, 50% of all ER research has been conducted in the past five years (Evripidou et al., 2020). The field is still in its infancy and proliferating in terms of research. Further understanding of how to best utilize ER in the classroom is needed.

Denla Primary School in Nonthaburi, Thailand, focuses on the STEM disciplines and values robotics so much that it is a part of the regular, weekly curriculum. The school's administration also allows teachers to conduct research as seen fit by the practitioner. This gave the researcher a unique opportunity to further understand elementary students in the context of the robotics classroom and contribute to an area of ER research that has not been fully explored.

Statement of Problem

Jung and Won's (2018) review of elementary school ER found a lack of understanding of instructional practices for ER with young children. Other researchers have called for further studies into what effective classroom orchestration and interaction look like within ER classrooms (Ioannou & Makridou, 2018; Xia & Zhong, 2019). By establishing the best instructional practices in the ER classroom, teachers will be able to create more positive learning experiences for young children and help the gender disparity in STEM fields. Even at a young age, stereotypes of robotics persist as boys have been found to be interested than girls in robotics (Sullivan & Bers, 2019). These negative stereotypes have become more exacerbated as children get older (Sullivan &

Bers, 2019). However, girls that have positive ER learning experiences at young ages show significant changes in their interests and attitudes toward engineering and even their desire to enter engineering careers (Sullivan & Bers, 2019). Establishing these best practices will help to address the gender disparity.

ER researchers have been calling for a shift away from research on the outcomes produced by robotics technologies and focus more on the implementation and pedagogies used in the robotics classroom (Jung & Won, 2018; Ioannou & Makridou, 2018; Anwar et al., 2019). Understanding how students interact with their peers is essential for developing teaching pedagogies and instructional practices (Jung & Won, 2018). Furthermore, studies on how group structures in terms of gender can affect achievement in ER are lacking (Zhong et al., 2022). More specifically, there is a lack of understanding of what effective cooperation among student ER groups looks like (Xia & Zhong, 2019). Knowing what types of group interactions and group structures produce maximum achievement will help to fill the gaps in understanding how to facilitate successful learning in ER (Xia & Zhong, 2019; Zhong et al., 2022). Successful ER learning experiences can help create a sense of confidence for girls in STEM activities, increasing their interest in entering STEM fields (Sullivan & Bers, 2019). The ER field would benefit from understanding how students interact during group robotics activities. Knowledge of interactions and group structure’s relationship to student achievement helps inform best instructional practices for maximizing learning.

This study’s findings have contributed to a further understanding of the relationship between student interactions, gender groups, and achievement in ER. The results provide practical recommendations for instructional strategies that can be used in ER activities.

Theoretical Framework

The theoretical underpinnings of this study are based primarily on Constructionism, Cooperative Learning (CL), and Social Interdependence Theory (SIT). These frameworks provide the foundation for the research methods of this study.

Seymour Papert's constructionist learning theory posits that children construct their knowledge from building tangible artifacts (Harel & Papert, 1991). It is thought that by constructing personally meaningful artifacts, learners can further construct their cognitive abilities for understanding (Girvan & Savage, 2019). Constructionism has heavily influenced educational robotics design, technologies, and activities (Stager, 2005; Mikropoulos & Bellou, 2013; Gorakhnath & Padmanabhan, 2020). These constructionist activities provide opportunities for collaboration, discussion, inquiry, and interaction among students (Han & Bhattacharya, 2001; Cho et al., 2017).

SIT gives a conceptual framework for understanding how cooperative learning may be best organized, used in various instructional settings, and applied to various issues (Johnson & Johnson, 2002). Social interdependence exists when the outcomes of individuals are affected by each other's actions.

According to SIT, a lesson or activity that is structured cooperatively can create positive interdependence. Positive interdependence contributes to how individuals interact and ultimately determine the group outcomes (Johnson & Johnson, 2005). A cooperatively structured activity means that there are established mutual learning goals among group members (Johnson & Johnson, 1999). When the individual's actions negatively correlate to the group's goals, it creates negative interdependence (Van Mechelen et al., 2014). This theory has been tested for over a century, with hundreds of studies spanning various subject areas and settings (Johnson & Johnson, 2005). Its versatile applicability makes it a useful lens for observing interactions among groups. CL, as an instructional strategy, is based upon SIT.

Johnson et al. (1996) defined cooperative learning (CL) as “the instructional use of small groups so that students work together to maximize their own and each other’s learning” (p.138). CL, as an instructional practice, is based on SIT. CL has been researched for decades and has shown to be an effective tool for helping students develop interpersonal relationships while simultaneously working together to achieve common goals or tasks (Gillies, 2014).

According to Johnson and Johnson (2002), the five key elements of CL are positive interdependence, individual accountability, group processing, promotive interactions, and social skills. The first element of CL is positive interdependence. Positive interdependence is the perception that the group’s goals are intertwined, and that success is only possible if everyone does their part and works towards the collective goal (Kern et al., 2007). When group members perceive positive interdependence, promotive interactions occur. These interactions encourage and facilitate the groups' efforts toward reaching their goal. (Johnson & Johnson, 1996). Some examples of promotive interactions are giving and receiving help, exchanging resources, and encouraging others (Johnson & Johnson, 1996). Individual accountability occurs when each student is given specific jobs, roles, or tasks they are expected to perform to reach the group's goals (Johnson & Johnson, 1999). Group processing occurs when groups reflect upon and discuss their progress toward reaching their goals (Johnson & Johnson, 2002). Social skills of group members determine how students interact with each other and are seen through negotiations, discussions, active listening, and communication among members (Van Mechelen et al., 2014).

CL within ER activities is regarded as a beneficial practice and is commonly used as a method of classroom orchestration within ER (Zhong & Wang, 2021; Xia & Zhong, 2019). Constructionist Theory, SIT, and CL will guide the observation of the different types of interaction seen among groups (Figure1.1)

Within this study, three of the five CL interaction types were observed: positive interdependence, group processing, and promotive interactions. These interactions were specifically chosen because of the conditions of the classroom environment and the format of the Cooperative Learning Observation Protocol (Kern et al., 2007). The following section lists the key terms used throughout this study.

Definition of Terms

Interaction: Any sequence of verbal or non-verbal communication between students

Group Interaction Types

Three types of interactions will be observed in this study: positive interdependence, group processing, and promotive interactions. Groups that predominantly demonstrate these types of interactions will be labeled with the following categorizations:

Positive Interdependence: There is evidence of group cohesiveness for accomplishing the task.

Examples in ER activities:

- Students share ways to solve problems concerning the task, programming, or robotics building.
- Students listen to others' ideas about ways to accomplish the robotics task.
- Students know their roles as needed.
- Students are engaged and have their attention focused on the group's task.

Group Processing: Finding ways to improve the processes team members use to maximize their learning.

- Students discuss ideas about their progress as a group in their robotics tasks.
- Students challenge each other's ideas and propose alternatives to reach their task goals.

Promotive Interactions: Promote one another's success, encouragement, and praise.

- Advocating achievement and encouraging others.
- Speaking positively/complimenting each other.
- Resolving conflicts peacefully.

A*chievement:* Success in robotics activities.

Level of Achievement (LoA): Refers to the specific score received in the assessment portion of this study. It is determined by how many robotics challenges are completed using the Matatalab Challenge Book. Each challenge requires the students to move their robot from one point to another using various configurations. Each challenge had a possible 20 - 40 points. To get a full score, students must complete the challenge in under one and a half minutes on the exact path that is described in the Matatalab Challenge book. If students completed the challenge, they moved on to the next challenge. Points were awarded based on how many blocks were correctly placed. If the students reach the finish point but in a way that does not match the solution in the book, they will only get points for the correctly placed blocks. Students were given a score based on the number of correct blocks.

Group structure: Refers to whether the group gender is heterogeneous (mixed genders) or homogeneous (all male or all female.) There are three gender group structures: all male, all female, and mixed gender.

Purpose of the Study

This mixed methods embedded design study explores the relationship between student group interactions and group structure on achievement in robotics activities in a second-grade elementary school robotics class. In a systematic review of over 147 ER studies from the years 2000-2018, K-12 ER research could be categorized into five different areas of study: "(1) general effectiveness of educational robotics; (2) students' learning and transfer skills; (3) creativity and motivation; (4) diversity and broadening participation; and (5) teachers' professional development" (Anwar et al., 2019, p.1). While there was a substantial amount of literature regarding K-12 ER research, most studies lacked essential details regarding how to implement ER in a school environment (Anwar et al., 2019). This is especially true within the classroom. Yang et al. (2022) noted that there is a lack of established pedagogical practices within the field of ER. Ronsivalle et al. (2018) found that the issue with ER was not the technologies but a lack of practical teaching methods. Ioannou and Makridou (2018) believed that after a review of ER research, there was a need for research to recommend practical guidelines and instructional strategies for delivering ER instruction in the classroom. There is a glaring need in ER research to find effective ways to deliver ER instruction.

Furthermore, Lee et al. (2013) specifically pointed out that “although there is significant research regarding technology in education, relatively little is focused on the foundational early childhood years” (p. 272). In general, there is a lack of curriculum, policies, and frameworks specifically designed to teach young children technology and engineering in the early childhood years worldwide (Sullivan & Bers, 2015). One major barrier preventing widespread adoption and emphasis on teaching such disciplines in early childhood is the lack of knowledge, understanding, and pedagogical approaches (Bers et al., 2002). ER can provide young children with opportunities to learn about technology and engineering, but more research is needed to understand how to teach these skills (Sullivan & Bers, 2015). ER exposes young children to specialized STEM education and programming. This exposure at a young age has been found to break gender stereotypes of STEM careers (Metz, 2007, as cited in Sullivan & Bers, 2013). These stereotypes can play a factor in the gender disparities in the STEM fields (Sullivan & Bers, 2013).

Peer interactions are directly linked to the quality of learning within the classroom for children as young as four years old (Tenenbaum et al., 2019). Xia and Zhong (2019) posit that knowing what effective cooperation and interactions in the ER classroom look like can provide a model for future practitioners to follow when directing their classrooms and implementing their instructional practices. Understanding the types of interactions among different groups of students and the relationship between these interactions and achievement in ER activities will help guide future instructional practices and pedagogies.

In addition to understanding how the interaction variable can be leveraged to create effective classroom instruction, this study will also focus on understanding the effect of group structure on robotics achievement. Gender differences in young children are important to consider when designing ER lessons (Angeli & Valanides, 2020). Some of the most recent research has found that group structure can affect students' learning performance (Zhong et al., 2022). But, while gender differences in ER achievement have been previously investigated (Taylor & Baek, 2018b; Xia & Zhong, 2018; Castro et al., 2018), very few studies of gender differences within young children's ER activities have been conducted (Jung & Won, 2018; Zviel-Girshin et al., 2020). In fact, according to Jung and Won's (2018) systematic review of young children's ER research, only one study looked at the gender differences between boys and girls in early childhood (Sullivan & Bers, 2016). Understanding how these gender differences play a factor in young children's ER learning is important for developing instructional practices for the age group (Sullivan & Bers, 2016). Also, knowing how group structures affect learning is beneficial for developing instructional practices (Zhong et al., 2022). Therefore, understanding the differences and effects of group structures on achievement in ER provides much-needed data to the field.

In the broader context, gender disparities in the STEM fields are a problematic issue. Diversity is an important aspect of the STEM fields, yet women only comprise 15% of the current engineering workforce (Jackson et al., 2021). These choices to enter or not enter the engineering fields have been found to precede college enrollment

(Jackson et al., 2021). More studies on the differences between genders in early childhood robotics education have been called upon to provide a more comprehensive understanding of why the gender gap in the STEM and robotics field is occurring (Sullivan & Bers, 2016). Early childhood is a critical time to affirm young children's views of gender and competency in STEM areas (Sullivan & Bers, 2016). This study adds to the growing body of knowledge in understanding where this divide occurs by providing recommendations for practical implementation of classroom facilitation and instructional strategies in ER. More specifically, this study examines how classroom interactions and gender group structures affect ER achievement.

The research questions are as follows:

RQ1: *How do cooperative learning interactions manifest among the second-grade robotics students at Denla Primary School?*

While the current research gives various interactions found within robotics classrooms, these are not always guaranteed to occur. Different classrooms have different dynamics. While the same general interaction types exist, they presented themselves differently at Denla Primary School. It was important to document exactly what behaviors and interactions were observed among the students within the classroom.

RQ2: *Do the types of group interactions in second-grade robotics activities make a difference to the group's achievement?*

This question focuses on how the different interaction types can affect a groups achievement. This study's three types of interactions are positive interdependence, group processing, and promotive interactions. This research question provides valuable information in understanding how group interaction types affect achievement in ER activities.

RQ3: *Does the group structure in second-grade robotics activities make a difference to the group's achievement?*

This research question focuses on the group's achievement based on group structure. Three different group structures were used: all-male, all-female, and mixed gender. This research question was intended to reveal if there were gender differences in achievement.

Significance of the Study

One of the main focuses of this study is to understand the types of interactions occurring in the elementary robotics classroom and their relationship to robotics achievement. There is a need to understand learners and the types of interactions in the classroom that affect student learning in the ER, especially with young children (Jung & Won, 2018). Few studies focus on the interactions that occur during ER activities (Jung & Won, 2018), and yet it has been found that social interaction is important to robotic education quality and plays a role in the success of ER activities (Chootongchai et al., 2021).

Ioannou and Makridou's (2018) review of current ER literature found that the use of ER in the classroom can create significantly extra work for teachers because there is a lack of practical guidelines to facilitate interactions between students to create successful ER learning environments. The researchers noted that a way to fix this problem would be to document and discuss the details of specific robotics interventions that successfully teach ER skills. By understanding what kinds of interactions and group structures create high ER achievement, the recommendations from this study can help ease the burden of teachers tasked with teaching and integrating ER in the classroom.

Furthermore, gender disparities in the STEM fields and stereotypes favoring men are well documented (Su & Rounds, 2015). Further understanding of how gender differences affect or do not affect achievement in STEM fields can help to transform the preconceptions and stereotypes that may already exist (Leaper, 2015). This is especially true within the field of ER. Sullivan and Bers (2013) note that some of these issues can be addressed by first expanding upon the limited research that has been conducted in understanding the gender differences in early childhood ER. The researchers recommended that studies be conducted examining the gender differences in young children's approach to ER activities. This study explored how different gender group structures interacted and approached ER challenges, and how the group structures and interactions effect on achievement. By providing qualitative and quantitative data on the gender differences in young children's ER activities, this study contributes to the broader understanding of the gender divergence in the STEM fields and ER.

Assumptions and Limitations

The study assumes that the student’s behavior was not altered or influenced by the researcher’s presence. The researcher of the study was the students regular STEM teacher and assistant robotics teacher for over a year at the time of the study. The students were completely familiar with the researcher and their presence in the classroom. It is assumed that because there were no substantial disruptions to regular classroom instruction, students interacted with each other as they usually would during their robotics activities.

It is also assumed that the ER activities conducted during the days of observation were structured to provide and create opportunities for student interaction. Students were participating in “typical” activities for the robotics class. The types of activities were not altered or changed for the researcher's sake but were carefully planned so that the observation and group activities coincided.

The research site is a school in Thailand. Most of the student population speaks Thai as a first language. However, all instruction and student interactions are in English per the school’s policy. If students speak in Thai, the researcher could translate and understand the nature of the interactions based on over ten years of experience living and working in Thailand.

One limitation is that this data depended on obtaining permission from parents. The number of student participants in this study relied upon permission being granted to observe the students because they are a vulnerable population. The researcher found that most of these forms were returned and brought back to allow the on-site study to take place. There were, however, four students whose parents did not want their children to participate in the study. The Head of Denla Primary School offered his help in reaching out to parents by publishing a small paragraph in the monthly school newsletter to inform them of the study. This was intended to assure the parents that the study being conducted was indeed sanctioned by the school and used ethical practices in compliance with the local authorities. These four students’ parents still did not want their children to participate.

Chapter 1 Summary

ER provides students an opportunity to learn about new, proliferating technologies in real-world contexts within the confines of the classroom. There is a lack of studies that provide details on how to implement ER in a school environment (Anwar et al., 2019). Research shows that there is a need to understand effective and established pedagogical practices within the field of ER especially with young children (Yang et al. 2022; Lee et al., 2013). In doing so, this research will help practitioners create more positive experiences for young children in ER, which has been found to help break gender stereotypes and create confidence especially for young girls (Sullivan & Bers, 2016).

Social interactions are an important part of ER (Chootongchai et al., 2021), and understanding interactions is critical for creating success in the classroom (Tenenbaum et al., 2019). Understanding how these interactions affect achievement in the classroom will help to provide a model for future practitioners to follow within their own classroom (Xia & Zhong, 2019).

When establishing effective pedagogical practices for young children's ER, gender differences are also important to consider (Angeli & Valanides, 2020). It has also been found that group structure can affect students' learning performance (Zhong et al., 2022). Knowing how to leverage gender to create success in ER would also be beneficial to developing instructional practices for that age group (Sullivan & Bers, 2016).

The purpose of this study was to explore the relationship between student group interactions and group structure on achievement in robotics activities in second-grade elementary school robotics classes. Using ER in the classroom has created significantly extra work because of the current lack of established pedagogical practices (Ioannou & Makridou, 2018). This study's findings help to ease this burden on teachers by beginning to fill the gaps in understanding what classroom instructional practices produce achievement in ER classrooms. This will be done by answering three research questions. RQ1 first establishes what interactions in various gender groupings look like in young children's robotics classes. RQ2 explores how different interaction types affect a group's level of achievement. RQ3 investigates how group structure affects a group's level of achievement.

CHAPTER TWO: LITERATURE REVIEW

The purpose of this literature review is to explore the relationship between group interactions, gender differences in Educational Robotics (ER), and ER activities in elementary students by examining the field's past, present, and potential future studies. This review includes the following: an overview of the ER field, studies of group interactions in ER, outlines the importance of understanding interactions, gender differences in ER, and the need for developing instructional strategies in ER.

Overview of Educational Robotics

Over the past two decades, research in the field of ER has been rapidly increasing worldwide (Angel-Fernandez & Vincze, 2018). Some estimates project that the international ER market will be worth 3.1 billion dollars by 2025 (Davis, 2019). The ER field is so vast that it is necessary to clarify what exactly is meant by the term “educational robotics."

Angel-Fernandez and Vincze (2018) found that there is yet to be a consensus on the term's exact definition, but that one was needed to help progress the field further. The researchers examined the essential components of the field and considered many factors. They offered a formal definition: "Educational Robotics [is] a field of study that aims to improve the learning experience of people through the creation and implementation of activities, technologies, and artifacts, where robots play an active role" (Angel-Fernandez & Vincze, 2018, np). This definition will serve as the operational definition of ER in this review.

The following section will closely examine the history of ER, popular ER technologies, the theoretical framework behind ER, popular ER technologies, and the role robotics currently plays in the classroom.

History of Educational Robotics

The beginnings of modern ER date back to the 1960s when Massachusetts Institute of Technology's (MIT) Seymour Papert and other professors envisioned and created the programming language LOGO. LOGO was used by children worldwide (Mehmet, 2013). The early versions of this program were made to communicate with a clunky, basketball-sized robot aptly named the "Turtle" (Mehmet, 2013). The Turtle could perform simple commands such as moving forward, backward, left, and right.

In the 1970s, the Turtle was moved to the computer screen and opened up a new world for programming. The Turtle on the computer screen through the LOGO system was more responsive and created a wider variety of shapes than the floor turtle. This new programming language began to change the educational landscape (Mehmet, 2013).

In the 1980s, Papert's Logo Computer system's popularity led to its implementation on various platforms such as the Atari and the Apple II. As the program's popularity increased, so did its prevalence in schools (Ames, 2018). This popularity led to a collaboration with the Lego group, resulting in the LEGO/LOGO system. This system was a computer-based platform that integrated the LOGO programming language with LEGO construction (Blikstein, 2013). Unlike the original Turtle robot, the LEGO/LOGO program required children to make their original creations with LEGO bricks rather than simply programming the already built Turtle. While this created a powerful new form of robotics that appeared to be enjoyable and productive for the students critics cited the requirement of the LEGO/Logo robot to be connected to the computer as a problem (Mehmet, 2013; Blikstein, 2013). A system that provided more mobility for the created objects was needed.

"Crickets" were another ER form that rivaled Lego robotics during this time. These robots provided students with an interface that used sensors to build and design scientific instruments. These robotics followed constructionist theories and provided students with new ways to connect to their interests and demonstrate their knowledge (Alimisis & Kynigos, 2009).

In 1998 the Lego Company released one of the most famous ER today called the LEGO Mindstorms Robotic Invention kit (Mehmet, 2013). The technology behind the LEGO Mindstorms provided a combination of mobility, innovation, and creativity not seen before in ER. Later the Mindstorm NXT was launched in 2006, followed by one of the most popular ER technologies, the Mindstorms EV3. The Mindstorm EV3 has stood the test of time as its robotics kits are still in use today and commonly used in and outside the classroom (Watters, 2015).

<u>Educational Robotics Technologies</u>

There are a variety of ER technologies used around the world. Whether in the classroom, at a robotics club, or even at a worldwide competition, the opportunities for students to engage with ER are plentiful. With so many different types of technologies, it is difficult to know where to begin. Evripidou et al. (2020) proposed categorizing ER technologies into three categories based on the type of programming to operate the robotics: *no code*, *basic code*, and *advanced code*.

No Code Robotics

No code robotics technologies are programmed using a Tangible Programming Language (TaPL) (Evripidou et al., 2020). These technologies will use physical code cards or bricks to initiate commands for their robots to follow. These robotics kits are primarily used to introduce beginning robotics concepts to kindergarten and lower primary schools (Evripidou et al., 2020).

An example of a *No Code* robotics platform is the Bee-Bot. A Bee-bot is a bee-shaped TaPL floor robot designed similarly to the original LOGO turtle. It uses the same commands as the original LOGO: forward, backward, left, right (Evripidou et al., 2020). De Michele et al. (2008) found that the Bee-Bot was useful in helping students develop logical thinking, problem-solving, and topological problems. Cacco and Morro (2014) found that the Bee-Bot effectively initiated teamwork in a study of two first-grade classes based on the outcomes.

Basic Code Robotics

Basic code robotics are categorized through a Visual Programming Language (VPL) (Evripidou et al., 2020). These robots use a programming language that uses ordered pictures to replace commands. Friendly graphics, simple interfaces, and coding blocks make these elementary robotics suitable for students as young as seven years old. VPLs require students to follow simple rules and have an opportunity to explore and experiment with different actions by making simple adjustments to their coding blocks (Evripidou et al., 2020).

A popular VPL robotic platform is Lego's WeDo 2.0 robotics kits. These kits use bricks, motion and tilt sensors, and a simple motor to create a product suitable for children seven and up. Research has found that the WeDo is a hands-on platform that allows students to develop meaningful creative thinking, teamwork, and problem-solving skills (Scaradozzi et al., 2015). Chalmers (2018) also found that the WeDo robotics kits created unique opportunities for students to practice computational skills, problem-solving, and group/team collaboration.

Advanced Code Robotics

Advanced code robotics refers to robotics kits that use Textual Programming Languages (TPLs) that use a combination of text, number, and functional sequences to program their robots (Evripidou et al., 2020). Some of these robotics kits use real-world professional programming languages like Java, C, C++, and Python to program their robots (Evripidou et al., 2020). These are primarily used for older students.

A popular platform used in advanced code robotics is the Arduino Education kit, which uses programmable boards, sensors, accessories, and physical parts to create their robots (Evripidou et al., 2020). Many other companies will use Arduino boards to create their robotics technologies. Makeblock is a popular series of robotic kits that combines Arduino boards with their programmable robotics line called the mBot. Xia and Zhong (2019) found that in a primary school robotics course, students utilizing the mBot platforms preferred cooperative learning rather than competitive learning when using the mBot.

50% of the ER research available has only been conducted in the past five years (Evripidou et al., 2020). This increase is in part because ER technologies have become more affordable and accessible worldwide (Yolcu & Demirer, 2017). A majority of K-12 ER research is conducted in secondary school, followed by primary school, and lastly early years (Yolcu & Demirer, 2017; Elkin et al., 2014). The new technologies offer opportunities for further research in different areas.

The development of no-code ER technologies simplicity now provides opportunities for researching how ER can impact young students in primary and early years schools (Elkin et al., 2014). Research with children as young as four years old is already being conducted to understand the effects that ER can have on education. The creation of TaPL allows young children to engage in ER and programming activities by using physical manipulatives as a medium for teaching students important programming content (Evripidou et al., 2020). The development of these types of technologies have allowed for more opportunities for studies of young children's ER.

With basic and advanced code ER technologies there is no clear distinction between the tools in terms of educational needs or age groups (Sapounidis & Almisis, 2020). But, in general, the type of robotics technology also determines what kind of activities can be conducted (Gürkani, 2018). These categorizations of ER technologies provide a basic classification structure for the plethora of tools available in the classroom. Researchers have cited that one of the challenges for ER technologies is that there is little to no interoperability between systems (Sapounidis & Almisis, 2020). It is suggested that future technologies be designed to make it more convenient and adaptable for younger learners to use to increase continuity across age groups (Sapounidis & Almisis, 2020). In general, basic and advanced code ER technologies are used for upper primary and secondary school students (Evripidou et al., 2020). The progression of difficulty between technologies provides somewhat of an overarching structure for improving skills to advance towards careers in the robotics fields.

This study utilized the Matatalab Robotics Kit which is a no code ER technology that uses tangible coding blocks to teach students basic robotics programming concepts. At the research site this robotics kit is a part of the schools AI and Robotics curriculum and meets all of the requirements for teaching the learning goals and standards of the school.

Regardless of the types of robotics technologies used, all platforms appear to facilitate CL among students. Even with such a wide variety of technologies and age groups, it is no coincidence that there are many commonalities. This occurs due to the overarching framework which has inspired ER, constructionism.

Constructionism

Seymour Papert is widely considered one of the most influential figures in educational computing and robotics. Papert worked closely with famed philosopher Jean Piaget, taking his theory of constructivism and expanding it with his own theory of constructionism (Stager, 2016). The constructivist and constructionist viewpoints focus on a child building their knowledge rather than simply receiving knowledge from their teacher. However, the constructionist viewpoint emphasizes the external artifacts and sharing with others (Mehmet, 2013). Papert believed that the activity of constructing was an iterative process involving constant redesign and reconstruction. Papert's purposeful naming of the theory was to convey the idea that "humans do not necessarily strive for cohesion, but are by nature engaged in questioning their view of the world" (Almisis & Kynigos, 2009, p. 12). Constructionism is one of the guiding theoretical frameworks for ER (Stager, 2005; Mikropoulos & Bellou, 2013; Gorakhnath & Padmanabhan, 2020).

Seymour Papert's (1991) constructionist learning theory posits that children construct their knowledge from building tangible artifacts. By constructing personally meaningful artifacts, learners can further construct their cognitive abilities for understanding (Girvan & Savage, 2019). Constructing is a unique activity because it requires individuals to build and create an object or entity, which is, at its essence, a tangible manifestation of the processes behind thinking (Almisis & Kynigos, 2009). From a constructionist perspective, ER provides an ideal environment for learning because students can interact, manipulate, and solve physical, real-life problems (Kucuk & Sisman, 2017).

Within ER, constructionist learning does not just stop after the robots are built. Alimisis and Kynigos (2009) point out that controlling the robots is integral to the constructionist process, and this is where students can genuinely experiment and manipulate their environment. This second aspect of robotics creates incredible potential and opportunities for constructionist learning. When students have control over their robotics, they can receive instantaneous feedback from the tasks they intend for their robots to perform and what happens (Alimisis & Kynigos, 2009). This approach also allows for less teacher intervention and gives students a path for constructing their own knowledge.

The attributes of the constructionist classroom foster social interaction among students. The constructionist "learning by doing model" creates unique opportunities for young learners to engage in critical thinking, problem-solving, decision making, and collaboration processes (Cho et al., 2017). Teachers take on the role of facilitator rather than provider of knowledge. There is consistent learner collaboration, open inquiry, discussion, development of ideas, and engagement in authentic, real-world tasks (Han & Bhattacharya, 2001).

Lee et al. (2013) conducted a study with a group of kindergarteners in an ER class which hypothesized that by designing an ER activity that followed some of the central tenets of constructionism, more social interactions would be seen. Students were given more time and freedom to explore robotics tools independently rather than having teachers intervene. The results indicated that children who participated in a more open-ended, unstructured learning style had significantly higher collaborative interactions than students who followed a more traditional model of structured activities.

To create a program specifically designed to promote Papert's constructionism, a group of Italian primary and secondary school headmasters came together and created The PIONEER (PIedmOnt Net for Educational Robotics) program. This program used age-appropriate robotics as its vessel for creating cooperative learning environments (De Michele et al., 2008).

Building, constructing, and controlling artifacts inherently creates environments full of interactions among students. Constructionism's foundational precepts are ideal for creating collaborative learning opportunities.

Benefits of Educational Robotics in Schools

The use of robotics in schools is generally classified into two categories: robotics as a learning object and robotics as a learning tool (Almisis & Kynigos, 2009). Robotics as a learning object refers to how robotics is taught as a subject. Typically, this will include educational activities designed to create a learning environment where robotics solves an authentic, real-world problem (Almisis & Kynigos, 2009). Authentic problems in robotics would include robotics constructions, robot programming, and artificial intelligence (Almisis & Kynigos, 2009). Robotics as a learning tool refers to integrating robotics to help teach other disciplines (Almisis & Kynigos, 2009). When used correctly, robotics are valuable in teaching the general STEM subject areas (Xia & Zhong, 2019).

Regardless of which categories the robotics activities fall under, ER has numerous benefits. Anwar et al. (2019) conducted a systematic review of 45, K-12 robotics studies that "unanimously suggested that robotics promotes active learning pedagogy and helps to improve the learning experience" (p.7). The same review found that 32 studies on ER activities provided opportunities to blend coding, scientific theories, and real-world problem-solving experiences. This context helps students recognize and connect deep and abstract content (Anwar et al., 2019). Anwar et al. (2019) also found that dozens of ER studies cited increased creativity and motivation and significantly increased exposure and interest in STEM fields.

In addition to these general benefits, robotics provides a unique opportunity for students to develop specific skill sets needed for the 21st century. The National Academy of Sciences reports defining deeper learning and 21st-century skills found that for students to reach their fullest potential as adults, schools needed to provide opportunities for students to develop interpersonal skills such as leadership, teamwork, and collaboration (Pelligrino & Hilton, 2012; Nemiro, 2020a). The report showed that a critical feature of deeper learning was that teachers must find a way to create situations that help improve interpersonal competencies (Pelligrino & Hilton, 2012). Group ER activities have improved interpersonal skills in a unique setting and context.

In a study focused on the interactive learning environment created by robotics activities, researchers found that students believed they needed to work as a group to complete their tasks (Hwang & Wu, 2014). Students were asked to move a series of dice into a specific area by programming their robots and were assigned specific roles of controllers and coordinators. The study used different configurations of the number of robots used within different groups. This study indicated that the robotics activity created an environment that required students to use and develop interpersonal skills to reach optimal efficiency (Hwang & Wu, 2014).

Nemiro (2020a) found similar results when working with elementary school students in group robotics activities. A study over three years from three different classrooms aimed to understand the processes of team formation, conflict resolution, and behaviors between students. The results showed that the group robotics activities organically fostered an environment where students could practice positive interpersonal skills and strategies such as conflict resolution, collaboration, and teamwork (Nemiro, 2020a). They also found that team members appeared to organize themselves to achieve the best results in accomplishing the tasks, even if this meant changing roles for someone more suited (Nemiro, 2020a).

Taylor and Baek (2018a) also found that having assigned group roles within robotics-based activities such as project manager, data manager, materials manager, and time manager positively impacted student motivation and collaborative problem-solving. This study shows that appropriately structured group robotics activities naturally develop 21st-century interpersonal skills amongst students.

In a study conducted outside of a school setting at a K-8 robotics competition, researchers wanted to understand the effect of team collaboration quality on their performance in robotics activities (Meneske et al., 2017). Teams were given a collaboration quality score through a task that did not require rehearsed or highly coached behaviors. Scoring used a rubric that evaluated the interactions regarding the quality of discussions and participation. Results indicated that teams with higher collaborative behaviors performed substantially better on the robotics task (Meneske et al., 2017). This result demonstrates the critical role that group robotics plays in teaching students the necessary interpersonal skills. This study also demonstrates that the setting, whether in the classroom or at a competition, is not relevant to developing these skills but rather the technologies and structure of activities that help develop students' skills.

ER serves as a facilitator for teaching interpersonal skills. This is done by using complex learning environments and the structure of its activities that mimic what is commonly found in the 21st-century workforce (Pellegrino & Hilton, 2012).

Computational Thinking in ER

Computational thinking (CT) is a term originally coined by Dr. Jeanette Wing (2006). Wing (2006) states that CT is "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" (p.33). CT is considered one of the most fundamental skills within the STEM fields (Grover & Pea, 2013). Research has shown ER to be highly beneficial in developing important CT skills (Chiazzese et al., 2019; Constantinou & Ioannou, 2018). While there is yet to be one single consensus definition of CT, it is widely accepted that CT includes five fundamental skills: decomposition, abstraction, generalization, algorithmic thinking, and debugging (Chalmers, 2018; Ioannou & Makridou, 2018). ER has proved to be a useful tool for teaching primary school students CT skills (Chalmers, 2018). Even children as young as kindergarten can use ER for learning critical CT thinking skills (Bers et al., 2014).

The use of robotics for teaching fundamental CT skills has been researched and recommended by many experts in the field (Angeli et al., 2016; Chalmers, 2018; Kazakoff et al., 2013). Angeli et al. (2016) created a framework using robotics for teaching young children (6-8 years old) CT skills using Bee-Bot robotics.

Decomposition in CT refers to breaking down problems into small parts (Evripidou et al., 2020). An example could be if students were to break a long path down into a set of shorter, simpler paths (Angeli et al., 2016). Bers et al. (2014) had children slowly break down the steps it would take to make their robots do the “hokey-pokey” dance with the use of decomposition and abstraction.

Abstraction in CT is taking the information available and focusing on only the most relevant and important details to understand the problem (Grover & Pea, 2013). Angeli et al.’s (2016) framework for teaching CT to young children recommends having them solve a problem using specific directional and programming language. The example given is telling students a story that refers to the Bee-Bots programming mat. Students would have to design a path that gets the robot to a specific location on the mat based on what occurs within the story.

Generalization in ER could refer to familiar patterns used in previous solutions and applying them to a new problem (Chalmers, 2018). Angeli et al.’s (2016) framework provides the example of assessing students on their ability to recognize and use the same sequence in an old Bee-Bot path and applying it to a new path. This is in line with Atmatzidou and Demetriadis' (2014) guidance for developing CT skills by having students expand on previous solutions to find the solution to new problems.

Algorithmic thinking in ER is the use of creating step-by-step sequences of actions to be taken in a specific order to solve a problem (Selby, 2014). Within the K-2 framework, this could provide students with problems that require solutions that follow a specific sequence of codes or steps to be taken (Angeli et al., 2016). These solutions should allow students to demonstrate their thinking through ordered instructions (Evripidou et al., 2020).

Debugging is a CT skill that comes with the iterative process of testing and retesting during programming (Chalmers, 2018). Debugging is the skill of identifying and fixing problems with any programming or code that may occur (Angeli et al., 2016). During ER activities, this skill can be observed when students can recognize when their robot is doing the actions they would like it to but can identify and fix where in their program things are going wrong.

Group Interactions in Robotics

Constructionist theory has heavily influenced educational robotics activities' design and technologies. ER activities design creates opportunities for social interaction and collaboration amongst students. These guiding principles make social interactions a focal point in ER activities. Further understanding the types of group interactions and their effects within the robotics activities will help develop effective pedagogies and instructional practices.

Johnson et al. (1996) defined cooperative learning (CL) as "the instructional use of small groups so that students work together to maximize their own and each other's learning" (p.138). Technology-assisted CL occurs when technology is integrated into lessons that utilize small groups of students. The use of CL practices has increased over the past thirty years and is beneficial in helping to promote higher-level thinking, reasoning, and interpersonal relationships, amongst many other skills (Gillies, 2014). As demonstrated in the previous section of this review, there are clear connections between constructionism, ER technologies, ER's role in helping to develop skills, and promoting social interaction in ER activities.

Five Elements of Cooperative Learning in ER

It has been found that CL has advantages over independent learning in ER activities, such as increasing the frequency of student interactions (Zhong & Wang, 2021; Xia & Zhong, 2019). While there is a vast range of ER activities, the general structure lends itself to the overarching elements of CL. CL can be broken down into five basic elements: positive interdependence, individual accountability, promotive interaction, social skills, and group processing (Johnson & Johnson, 1999).

Positive interdependence is one of the foundations of CL. This is the perception that students' successes and failures are intertwined. By establishing a mutual learning goal, small groups can create a positive interdependence in the learning environment. Positive interdependence can bring diverse backgrounds together to unite students in a joint effort (Johnson & Johnson, 1999). Xia and Zhong (2019) recommended that robotics activities use a "co-opetition" model in which students are placed into cooperative groups to compete against each other. This model creates positive interdependence where students have a mutual goal in which they all succeed or fail together.

Individual accountability occurs when group members receive their performance feedback results and is reported to the individual and the group. This gives each student a responsibility to learn independently and contribute to the group (Johnson & Johnson, 1999). Yuen et al. (2014) discuss the importance of establishing individual accountability when constructing a robot. Each member has their own assigned roles that others rely on to carry out their task. This appeared to increase motivation amongst the group members. Taylor and Baek (2018a) also recommend assigning specific roles to students in ER group activities, citing that they positively affect student motivation and collaborative problem-solving.

Promotive interaction is the support and encouragement of others within a group. Activities that follow CL models create "interpersonal dynamics that only occur when students get involved in promoting each other's learning" (Johnson & Johnson, 1999, p. 27). This is only possible when working in small groups that provide an environment for students to practice these skills. Group-based ER activities have increased social interactions in small groups (Cheng et al., 2013). For promotive interactions to occur, a catalyst must initiate a general interaction first. ER activities provide an outlet for further understanding of the relationship between the way social interactions occur with the use of technology (Wartella & Jennings, 2001).

Social skills are the fourth element of CL. In a study conducted by Pennsylvania State University, elementary school teachers across six elementary schools rated social skills as a "critical" skill for their students to develop. Failure to develop such skills could lead to an increased risk of unfavorable outcomes within the classroom (Meier et al., 2006). In a systematic review conducted on robotics in young children, one of the overarching themes found amongst the research was that robotics was an effective tool for helping students develop collaborative, social, and teamwork skills (Toh et al., 2016). It has been found that the nature of robotics activities also forces learners to collaborate actively and interact if they are to be successful (Cheng et al., 2013).

Group processing is “a review of a group session to describe the member actions that were helpful and unhelpful and to decide what actions to continue or change” (Johnson et al., 1990, p. 507). This group reflection process is essential for helping maintain group relationships, encouraging social skills, and providing feedback to group members. It gives an additional reminder for students as to the importance of collaborative learning. During robotics activities, it was found that students had to work closely with their peers and “combine their knowledge to construct their robots” (Toh et al., 2016, p.151). Nemiro (2020a) recommends that robotics activities be used to develop and encourage conflict-resolution strategies. This includes listening, empathizing, mediating, and negotiating, which are conducive to group processing.

One of the distinguishing features of CL is that it is based on social interdependence theory (SIT) and its related research (Johnson & Johnson, 2002). Social interdependence is a “generic human phenomenon” that can impact many outcomes (Johnson & Johnson, 2002). SIT has created the foundation for understanding the five main elements of CL. These elements are prevalent throughout ER research. The following will demonstrate specific research that further validates these findings.

Positive Interdependence

As noted earlier, positive interdependence is one of the most important elements of cooperation (Johnson & Johnson, 1996; Johnson & Johnson, 2004). Positive interdependence exists when group members believe they are working towards the same goal; this is known as outcome independence (Johnson & Johnson, 2004). Positive interdependence is demonstrated through interactions when there is evidence of group cohesiveness, such as members designating roles and actively working towards the group goals by sharing their unique knowledge or skills (Kern et al., 2007). Interactions demonstrating positive interdependence have been shown in various studies throughout ER.

Nemiro et al.'s (2017) study of primary school students intended to measure students' creativity in robotics activities. Students engaged in cooperative robotics activities, from making robotics move in specific directions or angles to dancing. Students brought their unique perspectives and skill sets to work toward the group goal of making the robots dance. This cohesiveness as a group is a good representation of positive interdependence.

Chalmers (2018) had similar findings in the study of elementary to middle school students involved in robotics competitions where students must work in teams to complete challenges. It was found that an overwhelming majority of students said they had talked with others about how to solve problems, asked other students to explain their ideas, and felt that other students listened carefully to their ideas. This proved to be an important part of creating an interdependent team.

Denis and Hubert (2001) designed a study to understand the relationship between collaboration and ER activities of students working in small groups (2-4) in primary schools using LOGO robotics. It was found that when faced with the robotics challenge, students organized themselves by creating roles to carry out specific tasks. This cohesive approach was usually led by the student who could delegate tasks and was seen as a leader amongst the students. These interactions form a level of structure and positive interdependence amongst members. Witherspoon et al. (2016), had similar findings when they found that students in robotics competitions primarily categorized themselves as "programmers" or "builders." These roles are in regards to students that either physically build the robots or are students who will be responsible for the mechanical construction.

In a case study that involved elementary school students, LEGO Mindstorm construction kits were used at a summer school camp (Somyürek, 2014). Sixty-two students were placed into different group variations throughout the camp and asked to complete various tasks. Activities were structured cooperatively, and students were given specific goals to accomplish. In the study, only 5 of the 62 students felt that they were always in agreement with their group. Despite this, an overwhelming majority of the students said they could share their thoughts and opinions with group members (Somyürek, 2014).

<u>Individual Accountability</u>

Individual accountability occurs when all group members take responsibility for their efforts and work towards carrying out their roles as established by the team to the best of their abilities (Kern et al., 2007). Students will also hold each other accountable for their actions by providing feedback and ensuring that they are doing their jobs (Gillies, 2014). These interactions have been demonstrated in various ER studies.

Nemiro (2020b) conducted a case study to compare students' collaborative behaviors during robotics activities vs. during math activities with two classes of 4th-grade students. Observers of the two classrooms found that students participating in the robotics activities appeared to provide and accept feedback and assistance from others more often than within the math classes. This feedback was related to the robotics tasks. Students accepting feedback in relation to their robotics role suggests individual accountability. The researchers regarded and noted these interactions as positive (Nemiro, 2020b).

These findings are consistent throughout ER group interaction research. A decade before Nemiro (2020b), Blanchard et al. (2010) specifically noted that during group robotics activities in a Canadian elementary school, students were divided into teams and provided with a scenario in which they had to get their robot into a room to check out a “suspicious box.” Researchers found that students' interactions specifically included immediate feedback to the controllers and programmers of the robots to make changes and adjustments to accomplish their tasks. This feedback was met positively with the understanding that it was provided to meet the group’s goals.

Individual accountability appears to be demonstrated through other types of interactions as well. Nemiro (2020a) talks about students recognizing the persistence needed to accomplish their tasks. In a robotics activity using Lego Mindstorms, a student referred to their group as never giving up and always working hard, doing their best, and moving towards their goal no matter how many times they failed. Students were determined to accomplish their tasks and felt accountable and responsible for not letting their group down.

Individual accountability is a common type of interaction seen in group ER activities. Students appear to engage, contribute, and effectively participate when they know they are responsible for a specific role or task within the group. This occurs when students accept their roles while simultaneously encouraging others to complete their role as well (Gillies, 2014).

Group Processing

Group processing occurs when students take time to reflect as a group upon their progress and functionality (Kern et al., 2007). In terms of interactions, this could look like students talking about what is helpful and unhelpful, making sure everyone knows what they are doing, listening to other members' opinions, and respectfully challenging each other to reach the group's goals (Johnson & Johnson, 1996). In robotics classes, this could look like students respectfully challenging each other's ideas and actions about how to proceed in a task, setting goals or subgoals to carry out a plan, or discussing the progress of their robotics task together.

Chaudhary et al. (2016) conducted a study in several elementary schools in India to evaluate the effectiveness of using Lego Mindstorms EV3 kits to evaluate computational thinking, problem solving, programming, teamwork, and project management for elementary school students. At the end of the study, it was found that 78% of the students said working in a team was more effective than working individually. This effectiveness was due to the group's ability to work together, reflect as a team, and continuously improve.

The theme of group processing is present throughout ER and takes many different forms. In Taiwan, elementary school students designed a robot rat to compete in a race and tug-of-war competition. The focus of the competition was to allow groups to practice cooperation, problem-solving, and the application of collective team knowledge. Students demonstrated group processing journals, and discussions reflected specifically on the team's progress, specific group members' abilities and actions, and ways to increase the quality of the team's work (Hong et al., 2011).

In a 2013 study, students in an Australian primary school classroom were observed to understand the types of speech interactions made during a Lego Mindstorms robotics activity (Mills et al., 2013). Group processing was seen throughout the activity as students constantly proposed solutions, collectively thinking, adjusting and improving their solutions, and providing feedback to each other. Researchers found that students often collectively question and evaluate the proposed solutions with their team and the outcomes (Mills et al., 2013).

Students respectfully challenging each other's reasoning is an important aspect of growth as it helps create critical thinking, motivation to learn, better decision-making, and deeper thinking (Johnson & Johnson, 2005). Group processing requires careful conversation and reflection about the ideas and progress of the group. Stergiopoulou et al. (2017) proposed that ER activities are designed for cooperation and interaction while facilitating critical thinking through conflicts by requiring students to explain, justify, and articulate their point of view.

Group processing is a type of interaction that appears to occur worldwide in ER activities structured cooperatively. Group-based ER activities provide an environment that allows students to be more reflective and apply collective knowledge to accomplishing the group's goals. This is produced by the CL goal structure of ER activities and the positive interdependence created by these goal structures.

Promotive Interactions

Promotive interactions can be defined as "individuals encouraging and facilitating each other's efforts to complete tasks and achieve in order to reach the group's goals" (Johnson & Johnson, 2002, p. 28). Ponticorvo et al. (2020) believe that ER activities are exceptionally beneficial to creating positive relationships amongst students compared to other activities. Research shows ER activities to be beneficial in creating positive relationships through interactions like giving feedback, providing constructive critiques rather than malicious criticism, providing help, exchanging information, working cooperatively, and more. The general nature of robotics activities promotes positive learning environments. Anxiety in robotics activities has been shown to be lessened by the students' playfulness with each other (Hsu & Hwang, 2021). This idea fits well with the central tenets of promotive interactions.

In the previous study by Nemiro (2020b) comparing collaborative behaviors in elementary school students of robotics versus math teams, researchers specifically looked for behavior towards effort or contribution to the team's task. Part of this definition was any behavior that "encourages and supports the efforts of others in the group" (Nemiro, 2020b, p.7). Researchers found that students tried hard to contribute to the knowledge of the group and work hard, but there was no mention of encouragement from other group members. However, the overall "effort" of the group was high.

Nemiro et al. (2017) conducted an explanatory observational study to examine how a School Robotics Initiative (SRI) could foster creative behavior. In the study, researchers conducted weekly observations and analyzed student journals to understand the effects of group-based ER activities. One theme that arose throughout the study was peer assistance. Researchers noted that because of the ratio of students to faculty members, students had to rely on the assistance and help of their peers. Promotive interactions were commonly observed as students often asked, received, and provided help and assistance throughout the various stages of the robotics activities. They were encouraging and helpful in their interactions. Some students were even called “techie” because of their knowledge, skillset, and ability to assist other students (Nemiro et al., 2017).

Jordan and McDaniel (2014) conducted a study that examined how elementary school students managed uncertainty in an ER group activity. In the study, students' interactions were categorized into two broad categories, unsupportive and supportive responses. When one student was uncertain, others could help that group member by “challenging, explaining, or offering information” (Jordan & McDaniel, 2014, p.509). The interactions and responses were most commonly supportive and could be classified as promotive interactions.

In a study that examined teachers' perceptions of the benefits of ER on 21st-century skills in their classrooms, participants cited that robotics activities tended to create a positive environment for students to interact with each other (Khanlari, 2013). Teachers of focus groups noted that students tended to find great interest in giving and receiving help from other students during ER activities. Teachers noted that this type of promotive interaction occurred organically without any prompting.

In a study by Yuen et al. (2014), researchers observed the group dynamics and interactions in elementary and middle school students at a summer robotics camp. One of the findings was that students observing each other appeared not just to be a passive task but rather an important part of the collaboration process. This process of observing was noted as a predictor of on-task behavior. Students observing their groups' robotics testing and other groups' efforts would influence their own reasoning and behaviors.

Promotive interactions are found commonly throughout ER literature. These interactions can take many forms but essentially are interactions that promote others' success, are supportive, and are encouraging. Promotive interactions are commonly seen throughout CL research when positive interdependence is present (Johnson & Johnson, 2002).

Social Skills

Social skills are important to functioning as a group and reaching a goal. Interaction patterns would demonstrate that students trust each other, communicate clearly and precisely, support each other and resolve conflicts constructively (Johnson & Johnson, 1996). Interactions that demonstrate important social skills are found throughout ER activities.

In a study of 10-11year old students comparing different types of group activities in Italy, Ponticorvo et al. (2020) wanted to understand how group activities in an ER laboratory, a coding laboratory, and students involved in an individual activity compared to each other. Lego Mindstorms NXT robotics were used in the robotics activity. Using sociometric tests, ER activities were the most beneficial in improving interpersonal relationships and developing social skills amongst students compared to the other activities.

This theme of social skill development is found throughout the research of ER. Ching et al. (2019) conducted a study involving three elementary schools to understand how STEM-integrated robotics curriculums impact student attitudes towards STEM fields. Students told researchers that it was sometimes difficult to work with other students, as conflicts often occur. However, it was noted that most teams could negotiate and come to a consensus for solutions as their relationships developed over time, resulting in constructive conflict resolution, an important social interaction (Ching et al., 2019).

Social skills are always developing throughout robotics activities. This is seen in interactions as positive engagement, using clear communication skills, paraphrasing, encouragement, and other types of positive interactions. (Kern et al., 2007).

Summary of Group Interactions

Here were some of the major themes found throughout the study of group interactions in ER.

1. The five elements of CL were demonstrated through student interactions in robotics studies.
2. These student interactions were present whenever the study utilized a CL approach to their activities.

This section provided a unique way to classify and synthesize the available literature documenting the types of interactions found in ER activities. These interactions are consistent with what would be expected according to CL, SIT, and the structure of the ER activities.

However, from the research examined above, the observation of interactions among students appears to be merely a byproduct of other research aims and goals. There is little research directly focused on the interactions found within ER activities. Of the 17 studies reviewed, only three (Jordan & McDaniel, 2014; Mills et al., 2013; Yuen et al., 2014) were specifically designed to focus on the types of interactions occurring in group-based ER activities. There appears to be a gap in the research that should be more thoroughly investigated.

Interaction patterns are well documented throughout research in CL and are the product of positive interdependence. However, there are few studies whose objective is to thoroughly understand these interactions and their broader implications for the field of ER. It is clear from the group robotics research reported in this literature review that there needs to be more research that directly focuses on the types of interactions occurring amongst group members in group ER activities.

Interaction Patterns in Educational Robotics

As demonstrated in the preceding section, there is no shortage of literature that documents interactions that occur within ER activities. This section will demonstrate a need to understand how these interactions occur and their wider implications for classroom instruction and orchestration.

Kucuk and Sisman (2017) studied the behavioral patterns of elementary students and teachers in one-one robotics instructions in an elementary school robotics classroom. Researchers observed various behaviors among the students and teachers in one-to-one situations revealing that students frequently liked to share ideas and experiences with the instructor. The researchers concluded that future research on interaction patterns of students and their peers would benefit from understanding the types of behaviors that are occurring in ER activities. Kucuk & Sisman (2017) note that understanding these behaviors will help inform and improve instructional practices in ER activities.

Nemiro (2020b) found that there is a lack of research that has been done to understand how students work and collaborate during robotics activities. Moreover, Nemiro (2020b) points out that most ER studies that explore team collaboration among students will typically fall into three categories: studies that describe teamwork in robotics programs, studies that describe the process that students and teams make in ER activities, and studies that assess teamwork as an outcome. These categories do not consider the interactions occurring during collaboration or team activities, their effect on the robotics activities, and how they can affect outcomes.

Lee et al. (2013) conducted a study in a kindergarten robotics workshop. They wanted to understand the interactions between students using structured and unstructured robotics curricula. While the researchers measured the number of interactions recorded during the robotics activities, they did not measure the types of interactions occurring. The results showed more interactions between students in unstructured robotics activities, but they did not explain the type of interactions occurring. Lee et al. (2013) noted this gap and specifically suggested that future studies look at the different interactions occurring in robotics activities.

Observing Interactions in Group ER

Yuen et al.'s (2014) study is one of the few studies whose intentions were to document the types of group dynamics and interactions occurring during robotics activities. Researchers designed a "Group Observation Form" (GOF) based upon the following categories: on-task behavior, current task, hands-on, grouping, exclusion, and interaction (Yuen et al., 2014). These categories were created based on previous classroom observations for approximately three weeks. Researchers felt these categories captured the types of interactions occurring within their camp. Each student was observed for 10 minutes while working within their robotics group during the activities. Their behaviors and interactions were documented during this time.

Cheng et al.'s (2013) study on the impacts of group formation on interaction and achievement developed a frequency interaction table to count the number of interactions occurring amongst students during their robotics activity. This interaction table is based upon the idea of group learning which stems from social constructivism. The researchers do not define interaction, but each time students interacted, it was recorded as an occurrence in the table. This study only considers the frequency of interactions and not the type of interactions occurring.

In a study of collaborative behaviors in ER activities, researchers developed a "Collaboration Assessment Rubric" (Nemiro, 2020b). The rubric was developed by Nemiro and three other university students. It was reviewed by university faculty members who had exceptional skills and experience in ER, math education, and collaboration methods. The rubric was tested in a university classroom first and adjusted further to reflect more accurate aspects of collaboration for observation. The final rubric consisted of seven behaviors: focus on team tasks, effort, communication, problem-solving, engagement, attitude, and responsibility towards team tasks (Nemiro, 2020b). Observers watched students for six weeks and gave students a 0-4; zero was no behavior observed, and four was exemplary behavior observed.

Jordan and McDaniel's (2014) study on uncertainty management during a robotics engineering activity in elementary school students utilized a retroactive approach to observing interactions. Researchers recorded videos and created rough transcriptions of the conversations had between students. These transcriptions were further refined, condensed, and annotated with the video of the class activities to report gestures and interaction with physical objects. Jordan and McDaniel used four categories to understand students' ability to manage uncertainty through their interactions: reduce, ignore, maintain, or increase. This data was further corroborated through student interviews. The work of sociolinguist Frederick Erickson influenced researchers' data sampling framework.

Blanchard et al. (2010) observed students' strategies elementary school children used for solving robotics-based tasks. To do this, they wanted to observe how they work in groups directly. They transcribed video-recording "while looking at how children develop strategies to overcome obstacles in the process of problem-solving while utilizing situational awareness from their collective work" (p.2853). While many interactions, strategies, and behaviors were observed, this was the extent of their understanding of what was happening during the group robotics activities.

Although many types of interactions are observed throughout ER, few were observed as a part of a deliberate study designed for categorizing or analyzing the types of interactions occurring. Understanding the types of interactions occurring and their effect on students' achievement in the classroom will provide an alternative perspective to students' engagement in robotics technologies (Jung & Won, 2018).

Interactions to Observe

The five elements of CL are present throughout ER research. This was demonstrated through the student interactions. Table 2.1 provides specific examples based on the literature of what CL interactions can be seen within elementary ER activities.

Table 2.1 Observational Guide for Interaction Patterns in ER Activities

Cooperative Learning Elements and Examples of Interactions in ER Activities	
Positive Interdependence: *There is evidence of group cohesiveness for accomplishing the task.*	• Students share with each other ways to solve problems in relation to the task, programming, or building of robotics. • Students listen to others' ideas about ways to accomplish the robotics task. • Students know their roles as needed.
Individual Accountability: *Individual group members take responsibility for individual efforts and contributions towards the team.*	• Students engaging, participating and contributing to their group by carrying out their roles. • Students provide feedback to each other about the work that they are doing and holding each other accountable.
Group Processing: *Use ways to improve the processes team members use to maximize their learning.*	• Students discussing ideas about their progress as a group in their robotics tasks. • Students challenge each other's ideas and proposing alternatives to reach their goals of the task. • Journaling or writing down reflections about their activity or task.
Promotive Interactions: *Promote one another's success through a supportive, encouraging, and praising environment.*	• Advocating achievement, encouraging others. • Speaking positively to each other. • Resolving conflicts peacefully.

The nuances of these interactions are subtle but important. The more detailed interactions can be studied and understood, the more insights can be provided about how a particular activity produces interactions and is structured, affecting overall quality.

If an ER activity is cooperatively structured, then it is highly like that these types of interactions will be seen within the activity. Interdependence is considered the most important aspect of CL (Johnson & Johnson, 2004).

Gender Differences in Educational Robotics

The under-representation of women within STEM fields has been well documented and is an important topic of study (Kahn & Ginther, 2017; Blickenstaff, 2005). The primary causes of this inequality have been debated, but the study of gender in robotics has shown great potential to understand further why this imbalance is occurring (Hartmann et al., 2007). Further understanding of gender groups within the ER field will not only help understand important variables in dealing with the development of effective instructional practices but also contribute to the growing body of knowledge surrounding the gender gap within the STEM fields.

The research on the effects of gender groups and the effect on robotics has mostly agreed with the idea that there appear to be little to no differences in performance between males and females in ER with some exceptions (Jung & Won, 2018). Sullivan and Bers's (2013) study of young children found that boys had higher mean scores than girls in completing tasks, but few of these scores were statistically significant. This demonstrated to the researchers that both boys and girls could have successful learning experiences at young ages. Sullivan and Ber's (2016) continued studies found that young children performed equally well on most tasks; however, the boys seemed to perform significantly better on advanced programming tasks. Researchers suggest that further studies should be conducted on why boys performed better on these tasks.

Other studies have noted the non-impact gender has on groups' robotics performance. Taylor & Baek (2018b) found that the gender composition of groups had no impact on the group's robotics performance in 4th and 5th graders. Other forms of ER assessment, such as a questionnaire on basic robotics also demonstrated no gender differences in terms of achievement (Castro et al., 2018).

Xia and Zhong (2019) also came to the same conclusion that the available research has found few differences between performance within genders in robotics-based tasks, but there were differences in how girls approached their tasks. Boys were often less inclined to follow instructions, while girls were dedicated to following written tasks. Cheng et al. (2013) also found that gender had no impact on final learning outcomes in elementary school students. However, they did find that groups of the same gender interacted at significantly higher rates.

This pattern of nuanced differences is consistent in older students as well. Ardito et al. (2020) found that girls and boys did not show significant differences in computational thinking within middle school robotics groups. However, girls tended to reflect more in journals and discuss themselves more often in groups. Girls also tended to share more, even in mixed-gender groups, during robotics activities. This difference in the social dynamics of robotics groups was also noted by Burns (2019) when it was found that females enjoyed the social aspects of robotics more than males. Males enjoyed the technical aspects more than females. Atmatzidou and Demetriadis' (2016) findings nearly replicated Ardito et al. (2020) in their study of junior high and high school students. It was found that there was no significant difference between computational thinking scores between genders. However, it was found that girls scored higher in teamwork and communication than boys. Also, mixed-gender groups showed higher levels of discourse, with girls leading much of the discourse. Zhong et al. (2022) found that mixed-gender groupings outperformed single-gender pairs in robotics tasks where the students had no prior knowledge or experience.

Other studies have found that general attitudes towards robotics between genders is positive; however female students appear to be less confident in learning about robotics than male students (Kucuk & Sisman, 2020). This finding was consistent with students in robotics competitions. It was found that from 5th-12th grade, mentors of students generally thought there were no differences between male and female students in terms of performance (Sullivan & Bers, 2019), but they did find that boys were significantly more confident in their general technical abilities, and their abilities to put things together than the females. This finding was also consistent with younger students. Zviel-Girshin et al. (2020) found that young boys felt significantly more confident than girls when asked about building larger and more advanced robots. But, when examining performance, desire to study robotics, and perception of having fun with robotics, there were no differences between the two groups.

Instructional Strategies in Robotics Teaching

One of the emerging patterns found in the calls to research throughout ER research is a need to understand what is occurring within the robotics classroom and develop the best instructional practices. In a systematic review, Jung and Won (2018) found that much of the current research on robotics activities focuses on technologies and outcomes. There needs to be more focus on understanding children’s learning and engagement processes. They conclude that understanding how students engage with the technologies, teachers, and peers will help to create grounds for creating effective new pedagogies (Jung & Won, 2018).

While there is a need to improve instructional strategies, there have been studies that have made some important contributions to ER teaching practices. Xia & Zhong (2019) recommends using small group sizes to help eliminate some common problematic issues in ER, such as “free-rider” issues where a student in the group does not contribute. Another common instructional strategy has been to assign roles to students. Zhong and Wang (2021) found that using paired learning and assigning roles to group members is important to success. Taylor and Baek (2018a) recommend that assigning specific roles to students in ER group activities is beneficial to collaboration. Yuen et al. (2014) found that assigning roles also helped to increase motivation among students. Nemiro (2020b) recommended assigning team roles based on the students' interest. These instructional strategies are helpful and based on peer-reviewed research methods, but there is a need for more.

Ioannu and Makridou (2018) called for further research to understand classroom orchestration. They found a need for more research to understand ways to facilitate interactions between students within the class and in small groups. In order to create this understanding, further research must be conducted to understand the current student interactions occurring during ER activities. These findings are similar to Anwar et al.'s (2019) systematic review of ER studies, which found that most ER studies lacked important details about pedagogical methods inside the learning environment. They felt a need to connect the theoretical basis of robotics with its implementation.

Xia and Zhong (2019) studied student pair learning in robotics education to explore its effectiveness. They concluded that although CL is the presiding format in ER, there is “still a lack of detailed research and successful experience in promoting effective cooperation among students" (Xia & Zhong, 2019, p. 292). In order to improve effective cooperation, studies must be conducted that aim not only to understand the types of interactions occurring amongst students in different groups but also to measure their effect on success in the classroom.

The gap in the research is clear, along with a need for further progress and improvement in our understanding of how students interact in robotics activities. The themes noted above demonstrate a need to shift toward ER studies focusing on what is happening in the classroom. Understanding the relationship between interactions and success in the ER classroom would help to inform instructional practices and improve robotics education.

Chapter 2 Summary

ER has been used for over fifty years. Seymour Papert and other professors developed some of the first ER and programming languages in the 1960s (Mehmet, 2013). The prevalence of ER in various settings has been steadily increasing over the years, along with advances in ER technologies. ER provides an environment for students to practice vital interpersonal skills in modern and complex learning environments (Peligrino & Hilton, 2012).

The primary theoretical framework behind ER is constructionism (Stager, 2005; Mikropoulos & Bellou, 2013; Gorakhnath & Padmanabhan, 2020). Developed by Papert (1991), constructionist learning theory posits that children construct their knowledge by building external artifacts. The structure of a typical ER activity includes the use of cooperative learning, which is the use of small groups working towards a common goal to maximize learning.

The five elements of CL are positive interdependence, individual accountability, face-to-face promotive interaction, social skills, and group processing (Johnson & Johnson, 1999) are routinely seen throughout ER research.

This chapter revealed that there is a minimal number of studies that are specifically designed to understand the interaction patterns that are occurring in ER activities. Concurrently, there is a call to research to understand what is happening within the classroom during ER activities in student interactions (Kucuk & Sisman, 2017; Nemiro, 2020b; Lee et al., 2013). Understanding these interactions will help to develop instructional practices for positive outcomes and effective pedagogy. See Figure 2.1 for a summary of the findings.

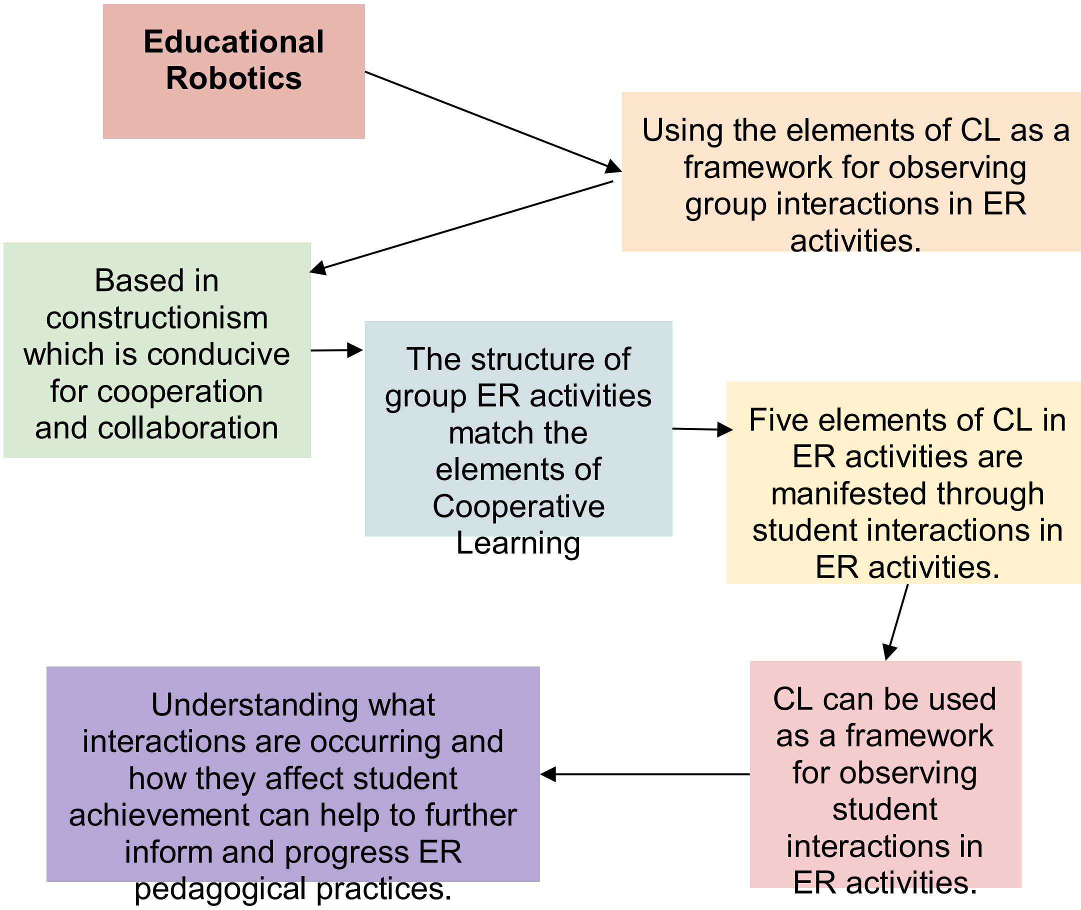


Figure 2.1 Summary of Findings

One of the most valuable products of this literature review is that it justifies using elements of CL as a lens for observing interactions in cooperatively structured group-based ER activities. It was also found that there is a need for further understanding the effect of interactions and gender differences in young children's ER to help develop instructional practices (Jung & Won, 2018).

CHAPTER THREE: METHODOLOGY

The purpose of this mixed methods embedded design study was to explore the relationship between student group interactions and group structure on achievement in robotics activities in a second-grade elementary school robotics class. Cooperative Learning (CL) is used throughout Educational Robotics (ER), and its elements are a viable lens for observing future interactions. CL provides a framework for categorizing the interactions occurring during group robotics activities. This study provides a methodology for exploring this relationship.

This study focused on 50 groups (103 students) of 2nd-grade students in their regular primary school robotics class. It used a mixed methods embedded design (Creswell & Clark, 2018). A preliminary observation of the classrooms was conducted to observe and document specific interactions, which was later used to help categorize interaction types during the students robotics assessment. One-Way Analysis of Variance (ANOVA) tests were conducted to test the difference between student achievement in different groups of students based on gender and interactions seen within the group. This chapter includes the study's research questions, participants, settings, design, data collection processes, observation protocols, instruments, and data analysis.

Rationale for Methodology

This study utilized a mixed methods embedded design (Creswell & Plano Clark, 2006). Creswell and Plano Clark (2006) stated,

> The embedded design mixes the different data sets at the design level, with one type of data being embedded within the methodology framed by the other type…The embedded design includes the collection of both quantitative and qualitative data, but the one of the data types plays a supplemental role within the overall design (p. 67-68).

Preliminary observations were conducted in the classroom to provide context and background to the study. The observations helped to provide a secondary account of the classroom environment, and specific information on the interactions among students within the classroom in terms of the interaction type and group structure. The quantitative analysis was the primary method for answering the research questions about the effects of gender and group interactions. Doyle et al. (2009) note that with embedded design method, qualitative data is needed to explain and understand the findings of the dominant quantitative methods (Figure 3.1).

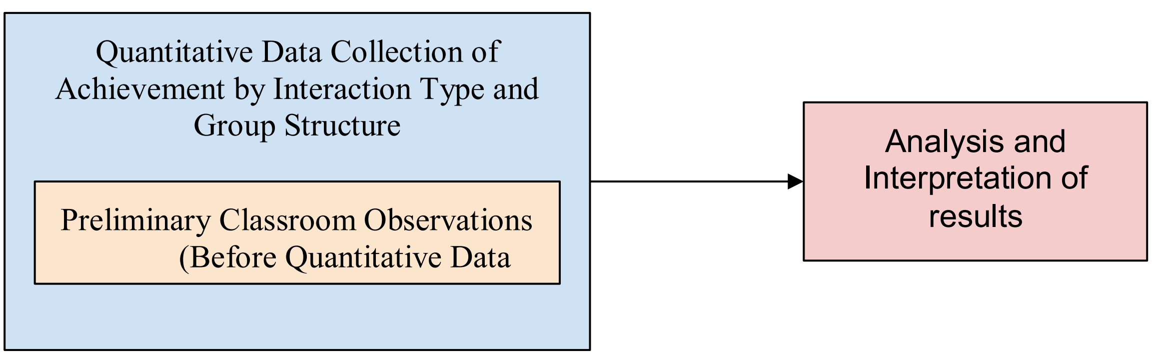


Figure 3.1 Mixed Methods Embedded Design

As noted by Edmonds and Kennedy (2017), this "approach is appropriate when one type of data plays a secondary role and would not be meaningful if not embedded within the primary data set" (p. 189). The preliminary observations of the classroom provided contextual data to this study that helped categorize and classify group interaction types.

This study was conducted with young children in the natural setting of their regularly scheduled classes. There needed to be as little disruption to this environment as possible. Researchers should always consider the situation and setting in which they are trying to obtain the data (Tracy, 2020). Proper situational ethics entailed quick and efficient data collection to allow participants to carry on with their regularly scheduled activities. One of the advantages of using a mixed methods embedded design is that there is only one phase in which data is collected, causing little disruption to students (Creswell, 2013).

Participants and Research Context

Researchers say there are many benefits to children being exposed to robotics at an early age (Cejka et al., 2006). However, there is a need for more research to understand teaching pedagogy and student engagement during robotics lessons, particularly for young children (Jung & Won, 2018; Castro et al., 2018). This study addressed a younger demographic that needs a further understanding of delivering meaningful and effective ER instruction.

Denla Primary School (DLPS) is located in Nonthaburi, Thailand. This small private school is in its third year of operation. The school prides itself on its curriculum, which centers around STEM skills and regular AI and Innovation classes (Bangkok Post, 2019). This is made evident by the student's schedule, which includes three science periods, one computer literacy, one AI and Innovation class, and one STEM period per week. The robotics curriculum was developed and designed by a local Thai university to fit the needs of the learners at the school. The robotics program's comprehensive curriculum begins with students using Matatalab robotics kits in first and second grade. In third grade, students begin using Lego WeDo kits. In the fourth and fifth grades, students begin their use of Lego EV3 Mindstorm robotics kits.

The robotics classroom at Denla Primary School (DLPS) is well-equipped. Students from each grade level use different age-appropriate technologies that gradually progress in difficulty throughout the comprehensive curriculum. The curriculum utilizes robotics as a learning object approach (Almisis & Kynigos, 2009). This focuses on the programming and construction of robotics themselves rather than attempting to integrate it across disciplines. In the DLPS robotics program Grade 1 and Grade 2 students use no code robotics (Evripidou et al., 2020), which utilizes a tangible programming language in the form of plastic direction blocks to move the robots. These Matatalab Robotics kits come fully equipped with all the necessary pieces to carry out the most basic coding movements. The classroom has eight Matatalab with robotics kits with class sizes ranging from 15 - 24 students. This structure provides ample opportunities for the students to practice using the robotics kits while working in small groups (2-3 students.) No construction is required for these kits, only a basic setup for turning on the robots and organizing the coding blocks. These robots are the precursor to more advanced robotics used in later grade levels. Students at Denla Primary School learn how to construct and program Lego WeDo robots and Lego EV3 Mindstorms in Grades 3-6. This study is intended to help build the program and practices of the school.

The researcher is normally the participant's STEM class teacher and a regular assistant in the student's AI and Robotics class. The student participants for this study consisted entirely of the 2nd-grade cohort of students at DLPS. This study included 103 students (44 male, 59 female). The average class size for this grade level is 21 students. These students have all had one year of experience in the robotics classroom with each other. Although most students speak English as a second language, it is school policy that the language of instruction in the classroom always remains in English. Students are expected to speak in English with their teachers and peers.

The robotics teacher created the groups that were observed in the study. The robotics teacher usually has students in groups of 2-3. These groups depend on how many students attend on a particular day. The researcher did not influence whom the robotics teacher chose to be in a particular group. This parameter prevented any researcher bias from occurring with the groupings.

Before the challenges began, a one-way ANOVA was used to see if the groups were homogenous in their robotics abilities. This was done by taking the groups of students' final scores from their previous year in robotics class in the first grade. These scores were comprised of a year's worth of assessment, formative observations, and regular quizzes within the student's robotics class. This comprehensive score accounts for all students' robotics knowledge and abilities. These scores were recorded only one month prior to the assessment.

Levene's test resulted in a *p-value* > .05 (*p=.086)* based upon the mean score, indicating that the groups were homogenous and that the error variance based on the prior score was equal across all groups. The null hypothesis was accepted, making it appropriate to check for significant differences among the various groups. The data also met the assumptions of normality. Hatcher (2013) states that to conduct an ANOVA the group's data must meet the underlying assumptions of homogeneity and normality, retain the independence of observations (not using repeated measures from the same participant), and use continuous data types. The data obtained from the second-grade students at Denla Primary School met all of these requirements. Levene's Test can be seen in Table 3.1.

Table 3.1 Levene's Test of Students Prior Robotics Class Scores by Groups

	Levene Statistic	df1	df2	Sig.
Prior Score Based on Mean	2.58	2	47	.086

The ANOVA resulted in a *p-value* >.05 (*p*= .058), indicating no significant differences between groups regarding prior robotics knowledge. With no significant differences between the group's prior robotics knowledge or abilities, the differences produced post-assessment provided an accurate indication of the effect of group structure and interactions on the student's achievement. This ANOVA can be seen in Table 3.2.

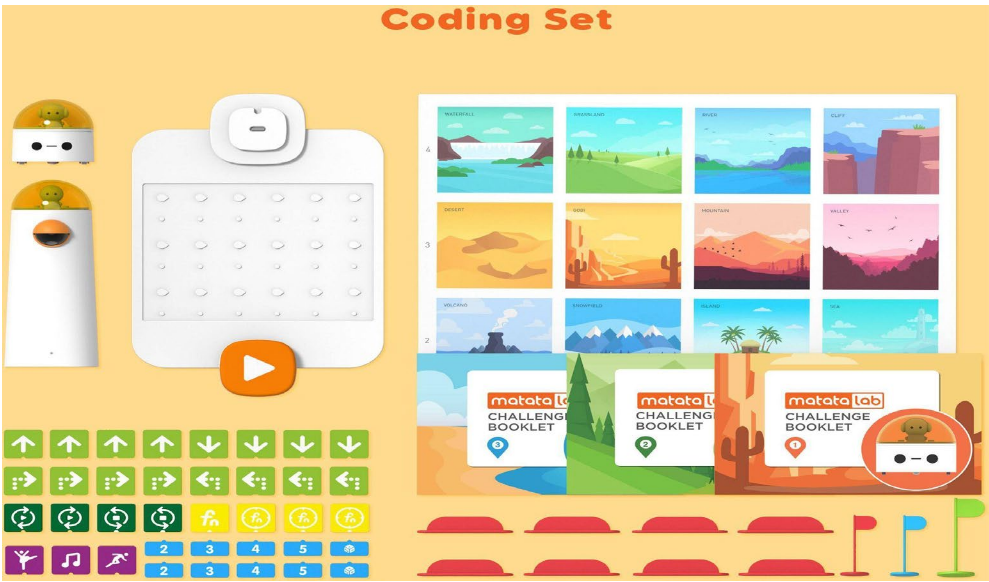
Table 3.2 One-Way Analysis of Variance of Prior Robotics Class Scores by Groups

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	268.25	2	134.13	3.03	.058
Within Groups	2084.09	47	44.34		
Total	2352.34	49			

Robotics Equipment

The assessment will be conducted using the Matatalab robotics kit. Each Matatalab kit comes with a series of challenge books. The robotics kits consist of a grid board, robot, tangible coding blocks, and obstacles. Challenges can be as simple as programming the robot to move from one space to another or as complex as exact programming degree turns to draw automated pictures using a marker. For the assessment of achievement, students worked from the official Matatalab Challenge Book. A challenge consists of students moving their robot from one spot on the grid to another spot designated by a plastic flag marker. Students met with the researcher during the class one group at a time and were required to see how many challenges their group could fully complete. The Matatalab Challenge Book provided the challenge's best possible solution to reach the designated point. During this time, the researcher observed and recorded the group's interactions and successes within the classroom. Challenge Book 1 includes simple movement patterns that utilize basic generalization skills, while Challenge Book 2 integrates new variables such as obstacles and utilizes more algorithmic thinking skills. There is a natural progression of difficulty written into the challenge books. The

Matatalab kits have been used in previous studies and are structured in a way that makes them suitable for teaching and assessing algorithmic thinking and generalization skills (Yang et al., 2022). The full Matatalab set can be seen in Picture 3.1.



Picture 3.1 Matatalab Robotics Lab Kit

Research Design

Qualitative data was collected to help support the study's quantitative data. The data helped provide support and context for the data analysis and interpretation. Preliminary classroom observations were collected and included detailed examples of how various interactions manifested within the different groups. These observations provided valuable information on how to categorize the groups interaction type during the assessment. Quantitative data on student achievement was concurrently collected with observations of the student's interactions during their assessment. The preliminary observations were taken into consideration during the analysis and interpretation of the quantitative data. A mixed methods approach to this research was necessary to understand the relationship between interactions and achievement. A mixed methods approach provides a more comprehensive and robust understanding of the problem than if one single approach were to be used (Creswell & Creswell, 2018).

One-way ANOVAs were conducted to understand the relationship between group structure and interactions on achievement during robotics activities. This data helped to further reveal best instructional practices for classroom orchestration within second-grade ER classrooms.

This design helped answer the three research questions guiding this study:

RQ1: *How do cooperative learning interactions manifest among the second-grade robotics students at Denla Primary School?*

RQ2: *Do the types of group interactions in second-grade robotics activities make a difference to the group's achievement?*

RQ3: *Does the group structure in second-grade robotics activities make a difference to the group's achievement?*

RQ1 provided a qualitative record of understanding the classroom environment and how the interaction types show themselves within the second-grade robotics classroom at Denla Primary School. While the ER literature provides a lot of data and information about what types of interactions should be seen, it may not include other types of interactions that are unique to the classroom environment at the research site. This information will be invaluable to gaining a more thorough and accurate understanding of the interactions exhibited in the particular robotics classrooms. This embedded qualitative portion also provides context and more understanding of the quantitative results produced by RQ1, RQ2, and RQ3.

RQ2 and RQ3 provide quantifiable data to understand the differences between group structures, interaction types, and the effects of both to understand how these variables influence classroom student interactions and are the primary justification for the findings of the study.

Research question one asks: *How do cooperative learning interactions manifest among the second-grade robotics students at Denla Primary School?* This question was answered through the initial preliminary observations conducted over approximately 4 hours and 20 minutes of class time. It revealed important supporting data to help the researcher understand how the interactions within the CL framework are shown in the second-grade classrooms at DLPS. These interactions were documented and used as a guide to categorize groups as specific group interaction types. The observations provided context and information to help answer RQ2 and RQ3.

Research question two asks: *Do the types of group interactions in second-grade robotics activities make a difference to the group's achievement?* A one-way ANOVA that tests the three different types of group interaction types with the group's level of achievement determined if there were significant differences between groups. This data was collected through an assessment conducted with 50 groups of students. In these assessments, student groups were categorized into one of the following interaction types: positive interdependence, group processing, or promotive interactions. The Level of Achievement (LoA) was calculated for each group and tested for significant differences amongst the various interaction types.

Research question three asks: *Does the group structure in second-grade robotics activities make a difference to the group's achievement?* Another one-way ANOVA was conducted to determine if there were significant differences between group structure and the student's LoA. This study had three group structures: all-male, all-female, and mixed-gender groups. This data was collected through the assessment with the same 50 groups of students. SPSS version 28.0 was used for all quantitative analyses.

Table 3.3 summarizes the research questions and the methods used to answer each question.

Table 3.3 Summary of Research Questions and Methods

Aim of Research Question	Type of Analysis	Method of Analysis
RQ1: *Document how interactions manifest in the ER classroom.*	Qualitative	Five, 2nd-grade ER classrooms were observed. Student interactions in accordance to CL interaction types and group structures were documented.
RQ2: *Analyze the effect of group interactions on ER achievement.*	Quantitative	A one-way ANOVA testing the three different CL interaction types by the group's achievement was conducted.
RQ3: *Analyze the effect of group structure on ER achievement.*	Quantitative	A one-way ANOVA testing the three different group structures by the group's achievement was conducted.

The assessment portion of the study took place in the robotics classroom. Students were asked during class time to sit with the researcher and conduct the test. The students' lead robotics teacher pre-determined the groups, and the researcher did not influence how the groups were chosen. The robotics teacher's only instructions were to try and evenly distribute the students by gender if possible. All the challenges given to the students were problems they had already done in the past. All students had completed one year of robotics classes in the first grade with the same teacher in the same classroom. This assessment took place in the 1st quarter of the new school year, which begins in May and ends in July.

Students sat down at a table together and were provided with a challenge book containing all the challenges and the relevant Matatalab set and pieces. The set included the following blocks: four forward, four backward, four right, four left, two “2” blocks, two “3” blocks, a start loop block, and an end loop block. These blocks were not set up in any particular order, and students were required to find the quickest and most efficient way to their goal.

The furthest that any group was able to get was six challenges. These six challenges were categorized into two sections. The first three challenges are considered the “generalization” challenges. The second set of three challenges was considered the “algorithmic thinking” challenges. These challenges are normally used to meet the curriculum requirements of the DLPS robotics curriculum. The robotics teacher of the classroom uses these challenges as assessments of these skills. The Level of Achievement (LoA) was equal to the sum of all the scores of the completed challenges within the time frame of one and a half minutes for each challenge. This could include challenges in both the algorithmic thinking and generalization categories.

Research Tools

This study observed students to understand the types of interactions occurring in robotics class. Based on what was learned in the literature review, CL is commonly found throughout ER research. CL structures are often used in ER activities and are a suitable lens for viewing the interactions commonly found within ER activities.

Cooperative Learning Observation Protocol

The literature review demonstrated that the elements of cooperative learning are prevalent throughout ER. The Cooperative Learning Observation Protocol (CLOP) is an observational instrument used to measure students' classroom interactions (see Appendix A). Kern et al. (2007) originally developed this instrument for measuring "cooperative learning skills used by students as they engage in cooperative tasks in the classroom" (Kern et al., 2007, T1D-6). When tested for reliability and validity, researchers simultaneously observed four separate cooperative learning groups. The CLOP was deemed a reasonably reliable instrument with a calculated Cohen's Kappa of $\kappa = 0.67$, a "substantial agreement."

Previous studies have used this same observation protocol and adapted it to fit the needs of an elementary school engineering classroom (Luo, 2014). Yang and Liu (2005) conducted a study observing the interactions of elementary school students using a cooperative learning approach. Researchers utilized categories of cooperative learning and recorded the frequency of each type of interaction seen under that category. Behaviors seen as the antithesis of the specific cooperative behavior were recorded as a negative reaction. The researchers then totaled the scores and labeled the group as a specific interaction type. The four categories they used were: individual, authoritative, argumentative, and consolidated (Yang & Liu, 2005).

A version of the CLOP was adapted for use in this study while maintaining the CLOP's central integrity of evaluating most of the elements of cooperative learning: positive interdependence, group processing, and promotive interaction a combination of Kern et al., (2007). Table 3.4 demonstrates the information section of the original CLOP as produced by Kern et al. (2007).

Table 3.4 Information Section of CLOP

<table>
<tr><td colspan="7">Cooperative Observation Learning Protocol</td></tr>
<tr><td>Course/Level</td><td colspan="3"></td><td>Date</td><td colspan="2"></td></tr>
<tr><td>Observer</td><td colspan="3"></td><td>Instructor</td><td colspan="2"></td></tr>
<tr><td colspan="2">Number of students in class</td><td colspan="2"></td><td colspan="3" rowspan="2">Whole Class Demographic Information:</td></tr>
<tr><td colspan="4">Instructional context:</td></tr>
<tr><td colspan="7">Group Specifics</td></tr>
<tr><td colspan="2">GROUP #/Name</td><td colspan="2"></td><td colspan="2">Seating Arrangement</td><td></td></tr>
<tr><td colspan="2">Group Composition</td><td colspan="2"></td><td colspan="2">Length of Class</td><td></td></tr>
<tr><td colspan="2">Number of Students in Group</td><td></td><td>Female</td><td></td><td>Male</td><td></td></tr>
<tr><td>Other:</td><td colspan="6"></td></tr>
<tr><td colspan="7">Cooperative Tasks</td></tr>
</table>

Note. Adapted Table from *Cooperative Learning: Developing an Observation Instrument for Student Interactions* by Kern, A. L., Moore, T. J., & Akillioglu, F. C., p. T1D-4, (2007) The second part of the sheet provides an area to mark the level of interactions seen within each interval. Positive Interdependence (P), Individual Accountability (I), Group Processing (G), and Promotive Interaction (F) represent the interactions that are actually observed. Social skills are the final element of CL but were excluded in this form by researchers through the validation process and thought to be redundant in the observations. The form will be adapted to measure the frequency of each interaction.

It is important to note that three interactions were observed in this study: group processing, promotive interactions, and positive interdependence. Individual accountability was not observed because, within this particular activity, students were not assigned roles. Based on the literature review, students working within their assigned roles was revealed to be one of the primary manifestations of individual accountability interactions seen within robotics research (Yuen et al., 2014; Taylor & Baek, 2018). Each group was classified by one of the three interaction types. Table 3.5 demonstrates the categories created by Kern et al., (2007) along with how they might be manifested in CL groups.

Table 3.5 CLOP Interactions in Robotics Class

(P): There is evidence of group cohesiveness for accomplishing the task.	**(I):** Individual group members take responsibility for individual efforts and contributions towards the team	**(G):** Use ways to improve the processes team members use to maximize their learning.	**(F):** Promote another's success, through a supportive, encouraging, and praising environment.
Examples: - Roles as needed: Facilitator, encourager, timekeeper etc. - Contributing unique background & skill	**Examples:** - Participation - Contribution - Engagement - Ability to articulate & justify group procedures and results. - Group makes sure all understand task & procedures.	**Examples:** - Feedback to one another about team effectiveness. - Setting goals or sub-goals. - Reflection on success. - Key sayings "what we have so far?" "Does everyone understand where we are?"	**Examples:** - Eye contact - Name use - Appropriate interruptions. - Celebrate success - Student suggestions respected - Conflict is managed

Note. Adapted Table from *Cooperative Learning: Developing an Observation Instrument for Student Interactions* by Kern, A. L., Moore, T. J., & Akillioglu, F. C., p. T1D-6, (2007)

Previous ER research have noted examples of the three different CL interaction types. Table 3.6 shows a summary of how the three different interaction types have been previously seen throughout the studies reviewed in Chapter 2 and were used as a general reference for observing interactions at the research site.

Table 3.6 CLOP Interaction Examples from Research

Cooperative Learning Elements and Examples	
Positive Interdependence: *There is evidence of group cohesiveness for accomplishing the task.*	• Students share ways to solve problems related to the task, programming, or building of robotics. • Students listen to others' ideas about ways to accomplish the robotics task. • Students know their roles as needed.
Group Processing: *Use ways to improve the processes team members use to maximize their learning.*	• Students are discussing ideas about their progress as a group in their robotics tasks. • Students challenge each other's ideas and propose alternatives to reach their task goals. • Journaling or writing down reflections about their activity or task.
Promotive Interactions: *Promote success through supportive, encouraging, and praising environment.*	• Advocating achievement, encouraging others. • Speaking positively to each other. • Resolves conflicts peacefully.

The CLOP provides a method for categorizing and observing interactions. This protocol led to the collection of some of the most valuable findings. To answer RQ2, it is first essential to know the types of interactions occurring in the robotics activities. The CLOP gives a lens for observing the students' interactions but also a method for categorizing the group interactions. The interactions recorded in the preliminary observations helped to inform the interactions recorded within the CLOP by giving specific examples of what types of interactions are commonly seen within the classroom, essential contexts of the interactions, and a general understanding of the types of behaviors seen within the classroom.

Data Collection

Data collection was conducted for approximately three and a half weeks. Ethics dictate that as little disturbance to the natural setting of participants is created as possible (Tracy, 2020). Previous studies of elementary school robotics classes typically observed students from between 8-15 hours (Nemiro, 2020b; Yuen et al., 2014; Lee et al., 2013). The researcher observed each classroom once for the full 50 minutes to document the classroom's general context, atmosphere, interactions, and activities. These observations took a total of 4 hours and 20 minutes. The second phase of data collection required the researcher to assess each group to record their level of achievement and types of interactions. These assessments took over two weeks of class time to complete, taking approximately 10 hours. This gave a total observation and assessment time of approximately 14.5 hours.

Preliminary Field Observations

During the first week of observations, the researchers took field notes to document the types of interactions seen in the classroom and useful research context information. The researcher acted as an observer and participant, meaning they were able to observe and interact with participants with their full knowledge of why the researcher was there (Kawulich, 2020). These observations included general information on specific student interactions within the CL framework during ER activities, general observations of achievement, gender grouping of students, and other information on the classroom environment. Field notes help create thick, rich descriptions of the research context and are valuable as secondary data in mixed methods research (Phillippi & Lauderdale, 2018). This data collection is consistent with embedded design research methods, which give priority to one approach and supports the findings with secondary research methods (Almeida, 2020). These field notes were organized and included in the final report of information.

The observations provided valuable information about how the interactions were specifically shown in the second-grade classrooms. There is general knowledge of what types of interactions to expect from the students, but this can vary and show itself in different ways. The observations documented common behaviors and interactions shown by the students through the lens of CL. Notes were taken not only on the interaction types, but also on the various group structures.

Assessment of Achievement

Students completed a series of tasks using Matatalab robotics kits. Matatalab robotics kits utilize a *no-code robotics* technology (Evripidou et al., 2020). Students attempted to move their robots into a designated area using physical coding blocks. Each task builds upon the previous task and becomes progressively more challenging.

Here are the following parameters for obtaining and calculating the level of achievement score for all groups.

- For each challenge, groups were given a score. The level of achievement (*LoA)* was equal to the sum of all the scores earned in each challenge throughout the assessment.
- Students were given one and a half minutes to complete the challenge. (This time limit was created due to limitations of classroom time and

recommendations from the robotics teacher.) If they reached the designated point within this time, they moved on to the next challenge. If they did not, the assessment was concluded, and the students' accumulated points were calculated as their final LoA score.

- If the students reached the designated point within one and a half minutes and used the best possible solution as provided by the Matatalab Booklet, they earned a possible 20 points for generalization challenges and 40 points for algorithmic thinking challenges.
- If the students reached the designated points within the one and a half minutes but did not use the same solution as shown within the Matatalab Booklet, they earned the number of correct blocks (CB) divided by the total number of correct blocks needed to complete the challenge (TB). This number was then multiplied by 20 for generalization challenges or 40 for algorithmic thinking challenges.
- On the final assessment, which the students cannot complete within the time limit, only correctly placed blocks were counted towards the student's level of achievement (*LoA*). See formula for calculating *LoA* below.

Level of achievement formula

LoA= Sum of all challenges

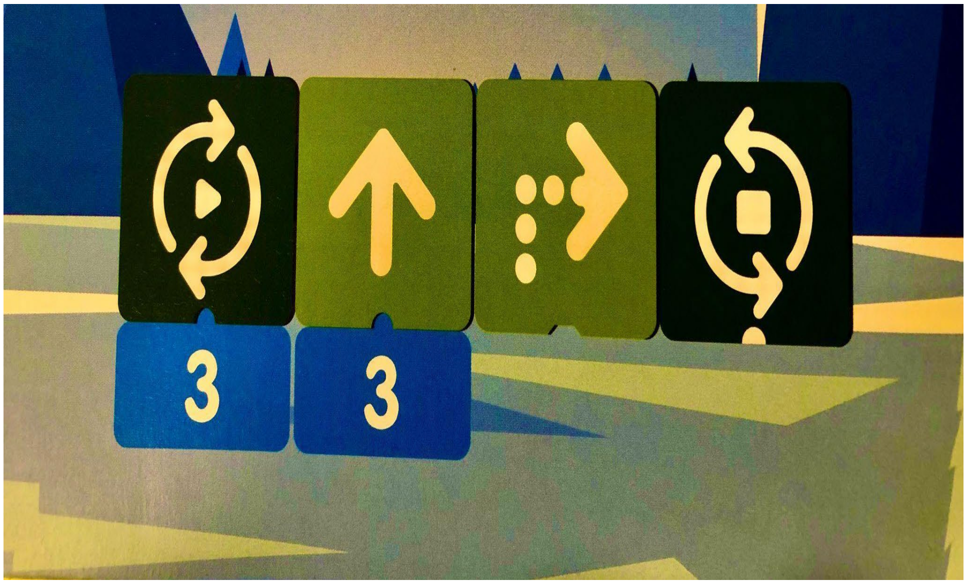
$$\textit{Generalization Challenge Score} = (CB \div TB) \ x\ 20$$

$$\textit{Algorithmic Challenge Score} = (CB \div TB) \ x\ 40$$

This formula provided the researcher with scores to compare amongst groups. This continuous variable was used to answer the research questions in understanding the relationship between interactions and gender groups and achievement in ER activities. An example of a challenge can be seen in Picture 3.2.

Picture 3.2 Matatalab Coding Challenge

The solutions in the Matalabs robotics kits are always displayed using pictures of the actual coding blocks in the kits. Picture 3.3 demonstrates how the solutions are shown within the challenge books.



Picture 3.3 Solution to Matatalab

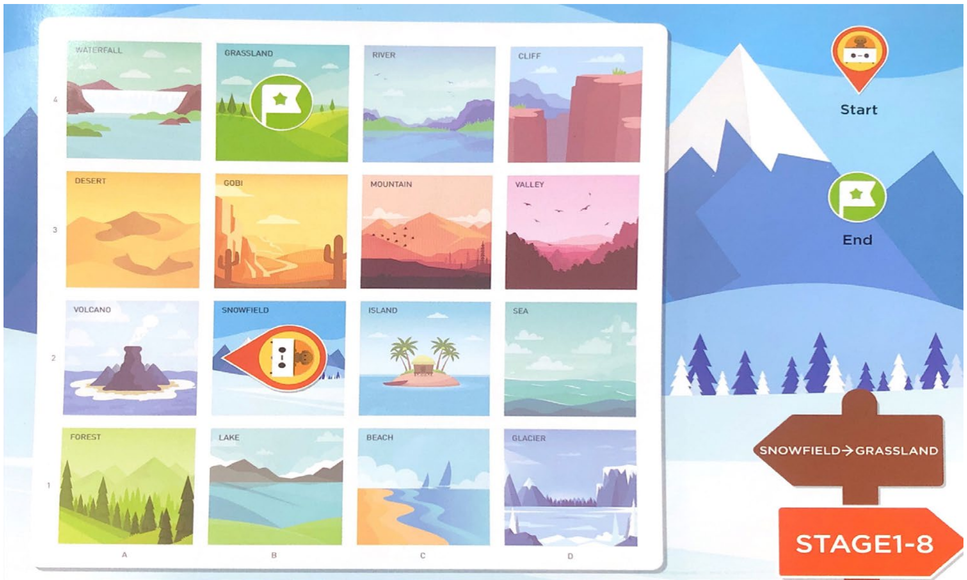
Within the robotics assessment, there are two main types of challenges. The first three challenges are considered generalization challenges based on the framework for teaching computational thinking skills with robotics to K-6 students by Angeli et al. (2016). The next three challenges are algorithmic thinking challenges based on the framework and approach in which students have to solve these challenges. Students are taught to approach the problem by using step-by-step actions and sequences to reach their goal.

With the varying difficulty levels, it is important to note that the algorithmic thinking challenges were worth more points than the generalization challenges. The Matatalab challenge books are divided into three levels. The generalization challenges come from the challenges in Challenge Book 1. Each of these challenges do not have specific sequences that need to be followed. They require basic movements and pattern recognition. Within the algorithmic thinking challenges students are introduced to a new piece, the obstacle barrier. Students are not allowed to touch this piece on the board and therefore are required to move in a specific sequence. Students have been taught in their robotics class to clear the obstacle and then move to the flag. The algorithmic thinking challenges come from Challenge Book 2 of the Matatalab.

Generalization Challenges

Atmatzidou and Demetriadis (2014) defined generalization as the "transferring [of] problem-solving process to a wide variety of problems" (p. 46). Angeli et al. (2016) provide a framework for teaching and assessing elements of computational thinking in young children. They suggested providing challenges that require the identification of common patterns between problem-solving tasks and using sequences for solving new problems. The beginning challenges of this robotics assessment begin with simple challenges that can be easily solved using common patterns to get to their goal.

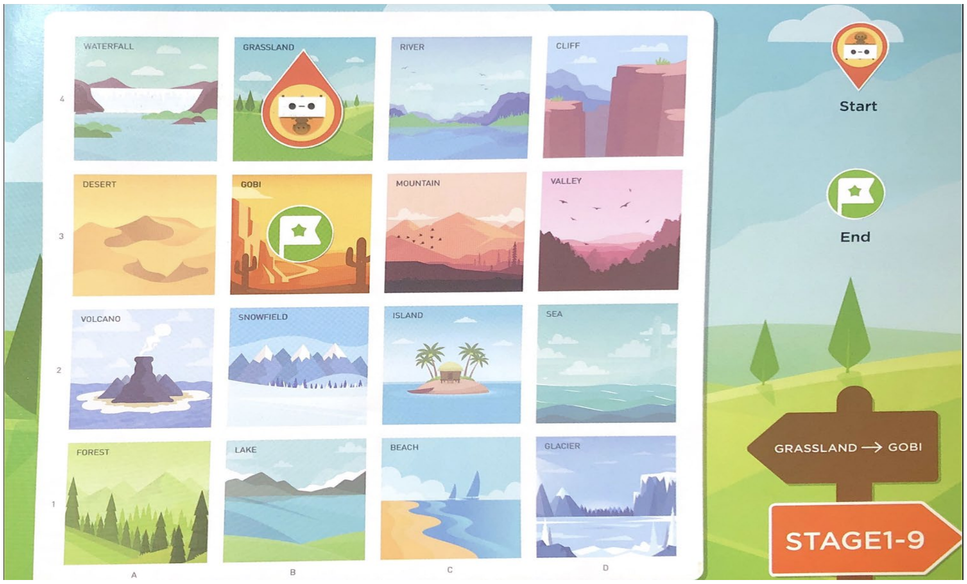
The first generalization challenge requires students to recall some basic movements. They must be able to use basic movements in order to reach the flag. This challenge can be seen in Picture 3.4.



Picture 3.4 Generalization Challenge 1

The correct solution to this challenge is *right, forward, forward.* This sequence gets the robot to the flag in the number of steps. Students will have to build off this pattern using their generalization skills to recognize familiar patterns.

Generalization Challenge 2 appears to be quite simple, but it proved to be one of the most difficult to solve with the solution prescribed by the Matatalab book: *move backward.* This challenge only requires one programming block. Students had to recognize the patterns from their previous lessons on basic robotics movement. This type of movement was not seen in Generalization Challenge 1; however, students' prior knowledge from the classroom and work with simple one-space movements had been previously practiced. This problem uses generalization because of the required recall and implementation of basic patterns of the Matatalab movement. It does not require any specific sequence because there are no other pieces on the board. This challenge is depicted in Picture 3.5.



Picture 3.5 Generalization Challenge 2

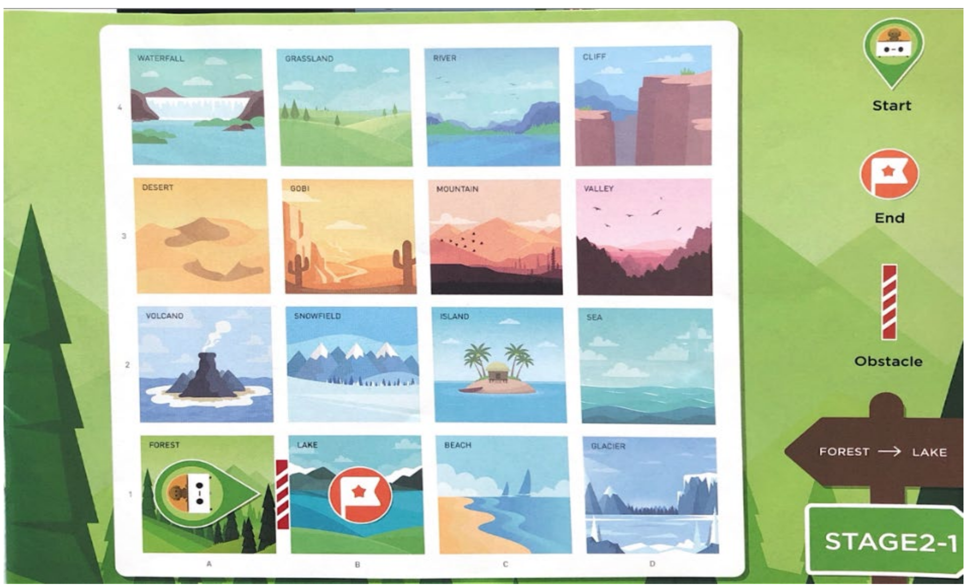
The third challenge of the assessment required students to use their generalization skills in recalling some of the same patterns used in the first challenge. Generalization is the act of students reusing previous methods to solve similar problems (Noh & Lee, 2019). In this challenge, students must use the same pattern as in the first challenge but with an additional forward piece. Generalization Challenge 1 required students to move *right, forward, forward,* while Generalization Challenge 3 required students to move *forward, right, forward, forward.* This challenge solution took direct programming sequences from previous problems. Student's generalization skills were put to the test in this challenge. If they were able to recognize that this challenge almost exactly follows previous sequences they were successful. This challenge can be seen in Picture 3.6.

Picture 3.6 Generalization Challenge 3

Algorithmic Thinking Challenges

In the second set of challenges, students needed to utilize their algorithmic thinking skills. Algorithmic thinking requires students to define steps that must be taken to solve a problem (Selby, 2012). In the following Matatalab Challenges, the "obstacle" piece is introduced. This piece creates a new variable within the challenge. Students must take specific and defined steps to reach their goals. In their regular robotics class, students were taught to clear the obstacle and then get to the flag. As recommended by Angeli et al. (2016) framework for teaching and assessing computational thinking in robotics, students should be able to understand what steps should be taken for a solution and put commands in a specific sequence to carry out that action. Creating step-by-step actions in a specific order demonstrates algorithmic thinking (Selby, 2014). These challenges are worth double the generalization challenges because they require students to move within a specific sequence. They are no longer able to just move freely to the ending flag. They must navigate around an obstacle. This is the first challenge in the second series of books for the Matatalab challenges.

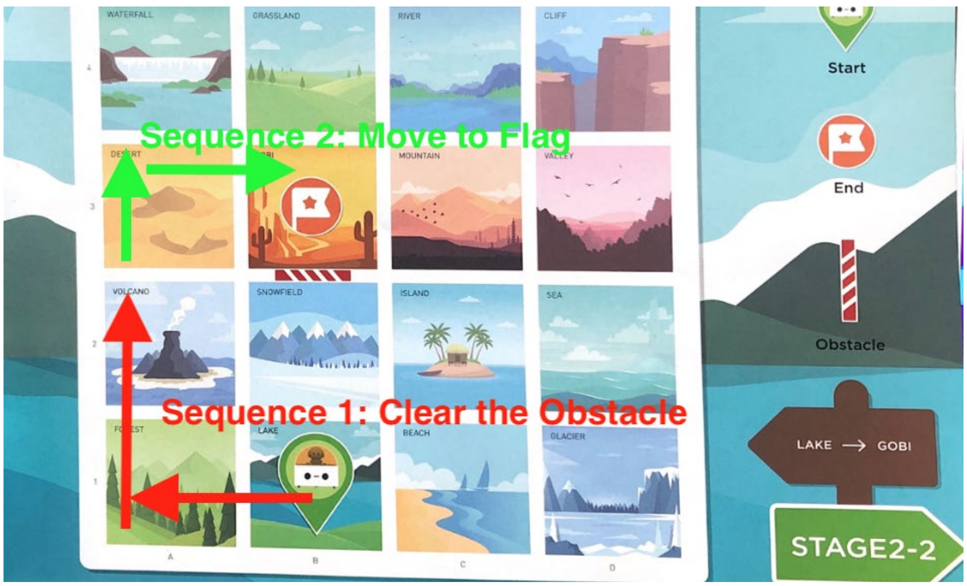
In Algorithmic Thinking Challenge 1, a new variable was introduced. The obstacle required students to use a specific sequence rather than simply being able to move freely around the board, like in the previous challenges. This challenge can be seen in Picture 3.7.



Picture 3.7 Algorithmic Thinking Challenge 1

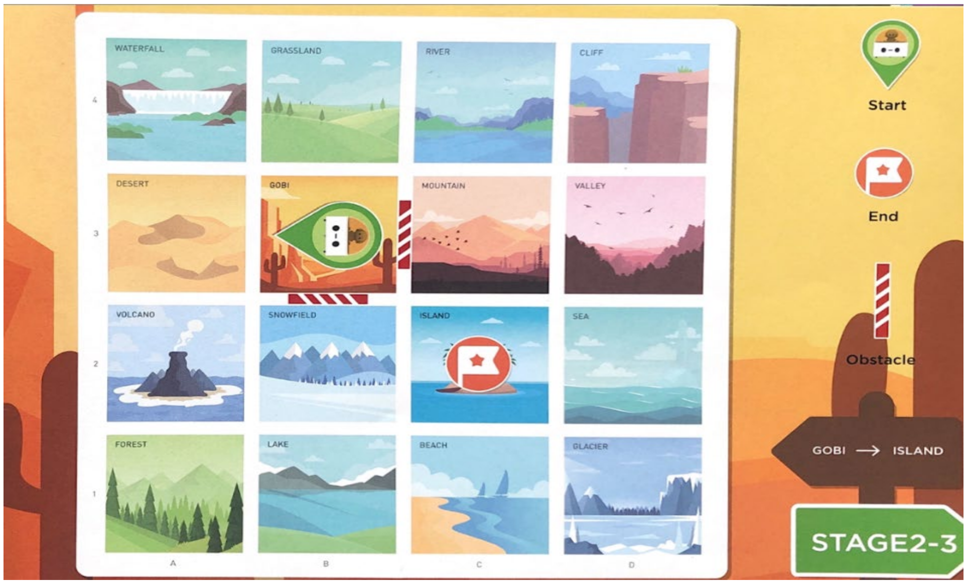
The solution for this challenge is *left, forward, right, forward, right, and forward.* At this point in the assessment, this challenge had the most steps, and the difficulty increase impacted the group's achievement.

In Algorithmic Thinking Challenge 2, students demonstrated their algorithmic thinking by breaking the challenge into two parts. The first was to make a move to clear the obstacle. Sequence two requires students to reach the flag. Algorithmic thinking requires breaking down problems into small solvable pieces (Chalmers, 2018). Students had been previously taught in their regular robotics classes to approach the challenge with this mindset. This challenge and sequence can be seen in Picture 3.8.



Picture 3.8 Algorithmic Thinking Challenge 2

Algorithmic Thinking Challenge 3 was the most difficult for the students. Students had been taught algorithmic thinking techniques for challenges like these before by breaking the problem down into smaller, sequenced pieces. For this challenge, the initial sequence was to clear the obstacle effectively by first moving into Column A and moving in a straight line down the path. The second sequence was to move to the flag. Students had to put the instructions in the correct sequence, or else they hit the obstacle. Defining the steps needed and placing these steps in the correct sequence is a hallmark of algorithmic thinking activities in robotics (Angeli et al., 2016). This challenge can be seen in Picture 3.9.



Picture 3.9 Algorithmic Thinking Challenge 3

All quantitative data was collected and interpreted together in a single phase. This procedure is consistent with the mixed methods embedded design. This information was necessary for answering RQ2 and RQ3. The level of achievement was the primary dependent variable in this study. It was critical for all data findings. It was during this time that the observations of students' interactions were used as a reference to understand any questionable interactions between students. RQ1 provided the necessary information to make distinctions between interactions.

Categorizing Interactions

Yang and Liu's (2005) method for studying group interactions was essential to this study. Researchers in this study used overarching categories for observing student interactions and created detailed types of behaviors to be observed in each category. By tabulating the frequency of the interactions, Yang and Liu then created broad interaction labels for each group based on these interactions.

This method, in conjunction with the CLOP, provided the structure for categorizing observations in this study. While students were completing the robotics assessment, the researcher was observing and taking notes on the way the students interacted with each other. Based on each CL category, specific interactions were observed and noted for frequency.

The types of interactions seen most frequently informed the categorization of the interaction types. Each instance where interaction was observed was valued as one interaction and recorded on the CLOP sheet. Based on the preliminary observations, the researcher thoroughly understood how positive interdependence, promotive interactions, and group processing manifested between the students. An interaction was counted when direct exchanges of information or communication between the students fell into one of the three interaction categories. This interaction can come in the form of physical or verbal exchanges between the students. This was seen in the form of short dialogues between students or physical exchanges. Some examples of this are students high-fiving each other, hugging, celebrating each other’s success, or even physical demonstrations of knowledge such as students moving the robot or pieces around to discuss a plan or carry out a role. In the event of equal levels of interaction frequency between categories, the researcher had to use the knowledge and understanding of the class and group dynamics to determine what interaction types most accurately described the group as discovered in the preliminary observations. The data gathered to answer RQ1 provided even more examples of the types of interactions seen in each category among the class groups.

Here is a sample interaction and how it would be categorized using the method described.

One of the students begins by asking everyone how they think the robot should go. The other student responds by saying that they should start by moving the robot to the right then forward and up. The students then pick up the robot to map out each step that the robot will take and physically demonstrating to the other students. The students put in their code and run it. It is successful. The students high five, and tell each other good job.

In this interaction, the students would be categorized as a group processing type of group. The first note that was made was when the student asks everyone which way they think the robot should go. The other student responds by offering a solution for the direction they should go. This is one group processing interaction. The student then physically picks up the robot demonstrating to the group members how the robot will move across the board. This is a second group processing interaction. After the students are successful, they promote and celebrate each other's success with compliments and high-fives, this counts as one promotive interaction. Therefore, the final tally of this group is two group processing interactions and one promotive interaction. Based upon the frequency and types of interactions, this group would be categorized as a group processing group.

Here is another example of a group interaction that was commonly seen and how it would be categorized.

Students begin by setting up their pieces. They quickly establish roles for themselves. The girl says she will set up the board, and the boy organizes the coding blocks.

The girls says "Ok, I will tell you what pieces to put."

She then begins calling out coding directions as the boy places the pieces. They run the code and it doesn't work. She says "Ok, let's try it again."

The boy says "You can do it! You're smart! Maybe we should go left instead of right? That will bring us to the flag." She gives the boy another sequence of coding instructions and he places them. It works this time. The boy tells the girl "Wow, you are so good at this!"

In this situation, there are many interactions shown. First, as the students begin, they quickly establish roles for themselves by each doing separate jobs that are working towards the goal. The girl says that she will tell the boy which pieces to place, and he places them in a sequence. This counts as a positive interdependence interaction. After the first failed attempt, the boy encourages her, and offers a possible solution. This counts as one promotive interaction for encouragement and one group processing interaction for evaluating and discussing possible solutions. The girl then gives out another series of commands for the boy. This is another positive interdependence interaction. The boy celebrates the girl and her success, this is a promotive interaction.

This group would be categorized as a positive interdependence interaction type. There were two positive interdependence interactions, one group processing interaction, and two promotive interactions. In this situation there was a tie between positive interactions and promotive interactions. However, primarily the group had established roles for themselves throughout the challenge and carried out jobs within their roles toward the goal.

Data Analysis

This study used a one-way Analysis of Variance (ANOVA) to understand the relationship between groups and achievement in robotics activities. ANOVA tests are used to compare the means of more than two groups (Levin & Fox, 2011). An ANOVA may be used when the researcher wants to investigate the effect of more than one factor on a response variable (Beyer, 2021). one-way ANOVAs were conducted for group structure and interaction types. For each of these factors, the dependent variables were the LoA, generalization challenge scores, and algorithmic thinking challenge scores.

The first independent variable, group structure, had three possible categories: all-male, all-female, and mixed. The second independent variable was the group interaction type, with three possible categories: positive interdependence, group processing, and promotive interactions. The dependent variable is the level of student achievement. All results were analyzed using SPSS 28.

The one-way ANOVA was used to reveal if there is a significant difference among means but is unable to tell where those differences are (Hatcher, 2013). Post hoc tests are a type of multiple comparison procedure "that allows researchers to determine which specific conditions are significantly different from one another" (Hatcher, 2013, p.368). When there were significant differences among groups in student achievement, a post hoc test was initiated. Tukey's Honest Significant Difference (HSD) is a post hoc test that reveals what group means are significantly different from each other and is commonly used after an ANOVA test (Haynes, 2013). Tukey's HSD was designated as this study's post hoc test when a significant difference was found.

Ethical Considerations

Ethical considerations have been made before, during, and after the study. Before beginning the study, permission forms from the parents (Appendix B), permission forms signed by the head of school (Appendix C), and the deputy head of school (Appendix D) who is responsible for operations were issued to ensure compliance with local education department guidelines.

During the study, no names were recorded of the students; only numbers were assigned to participants to retain anonymity. No personal data that would make any individual identifiable was collected. All data collected throughout this study was kept confidential and accessed only through a virtual private network (VPN). This VPN allowed access to a secure drive on the Boise State University network.

It is important to note that the teacher read a verbal assent form to ensure that the students understood that participation in the study was optional. Whether they chose to participate or not, students' classroom activities and grades were not affected. However, all students that were given permission by their parents to take part in the study all agreed.

Chapter 3 Summary

This mixed methods embedded design study was conducted in the 2nd-grade robotics classes in Nonthaburi, Thailand. Parent permission, site permissions, and student permission were obtained for the researcher to conduct the study. Data collection for this study was conducted in a single phase using adapted formats of the CLOP (Kern et al.,

2007) and Yang and Liu (2005) observation methods. Data was collected and analyzed using two, one-way ANOVAs. It was stored on a secure drive provided by Boise State University. This data was then interpreted to answer the research questions proposed in the study.

CHAPTER FOUR: RESULTS

This chapter documents the results from the observations and assessment, and provides an analysis of those results. First the results from the observations of student interactions are revealed. Then there is a review of the robotics assessment results in terms of group structure and interaction types. Finally, the chapter finishes with a summary of the results. The following research questions were answered:

RQ1: *How do cooperative learning interactions manifest among the second-grade robotics students at Denla Primary School?*

RQ2: *Do the types of group interactions in second-grade robotics activities make a difference to the group's achievement?*

RQ3: *Does the group structure in second-grade robotics activities make a difference to the group's achievement?*

Student Interactions in Robotics Class

Preliminary observations were conducted to give information on specific student interactions within the CL framework during ER activities, general observations of achievement, gender grouping of students, and other information on the classroom environment and learning context to help make more informed group categorizations when assessing the students. These observations proved to be incredibly useful during the assessment phase in that they gave the researcher a full understanding of how students in various classes and groups interacted with each other. It also provided a foundation for understanding how the interactions fit into the overarching CL framework for observing interactions. The following is a report of these observations.

Observational Context

During the week of observation, the robotics lessons began with students lining up at the door. The robotics teacher briefly summarized what they would do in the robotics class and then let the students into the classroom in groups of two to three, assigning them to specific tables. Eight tables were set up around the classroom with enough distance and spacing that students could work with their groups without interacting with other groups. This classroom layout is important because students typically only interact with the students in their group, which the teacher had created.

The teacher then connected to a TV in front of the classroom with his iPad. After going over some of the more basic movements, he introduced the concepts of functions, loops, and using sound blocks. He then put a picture on the screen of how he would like the class to set up their board and gave them some time to solve the day's first challenge. A picture of the front of the classroom setup can be seen in Picture 4.1.

Picture 4.1 Front of Robotics Classroom Setup

According to the robotics teacher, students had just begun learning about repeats and loops but had difficulty understanding the concept. The teacher went through a methodical step-by-step tutorial on placing their coding blocks to reach their goal. After completing this task together as a class, he presented students with a new problem that used the same concept but presented a different challenge. The solution required a loop and repeat numbers to reach their goal. The robotics teacher considered this a more challenging concept than the students usually did.

The teacher went around the classroom checking the different group's solutions, providing feedback, and answering any questions. After the students completed their assigned challenge, they were free to work through the Matatalab challenge books and attempt more complex problems. The assigned challenge of the day can be seen in Picture 4.2.

Picture 4.2 Challenge Given to Students During Robotics Class

Group Interactions

One of the primary focuses of the preliminary observations was to understand how group processing, positive interdependence, and promotive interactions were shown in the second-grade classrooms at DLPS. The other focus was to understand how the various group structures interacted with each other. Overall, students in the classrooms were very familiar with each other and comfortable interacting. The noise level in the classrooms was high. Students primarily stayed in their groups, but if they did stray to another table, they would be quickly prompted to return to their table by the teacher. The interactions within the CL framework became visible once the students began their challenge.

Promotive Interactions

The CLOP defines promotive interactions as interactions that “promote one another’s success through a supportive, encouraging and praising environment” (Kern et al., 2007, np). These types of interactions are often seen within the DLPS robotics classrooms. The following interactions were noted within the field notes of the researcher.

This interaction occurred within one of the all-male groups. This example shows an instance of students encouraging each other even when others failed. This type of promotive interaction occurred quite often throughout the observation.

> *One of the members chose the wrong programming piece, making the robot not only move in the wrong direction but actually off the table. The boy who made a mistake put both hands on his head and screamed, "Oh no, I did it again!" (translated from Thai). The other boy in the group picked up the robot and said, "Never mind, it's ok, try it again!" (translated from Thai.)*

Encouragement and praise occurred quite often within the classroom. One of the all-female groups demonstrated this promotive interaction.

> *The students appeared to be stuck in getting their robot around one of the obstacles. One girl said, "let's just make the robot go backward." The students tried her plan, and it worked. The three of them jumped up and down cheering and told the girl "Wow! You are so smart!" (translated from Thai.)*

While these types of promotive interactions were ubiquitous throughout the classrooms, they primarily appeared to occur amongst the all-male and all-female groups. There was evidence of peaceful conflict resolution in another group of three boys.

Two boys in one group were trying to place the same pieces down simultaneously to the point where they were nearly fighting over who would place the piece. The third boy in the group told them both to stop and said, "No, it's ok. We are all working together!" (translated from Thai.)

These types of verbal interactions were prevalent throughout the different classrooms. There were also many examples of non-verbal promotive interactions where students would celebrate each other's successes and the groups' successes. Here is an excerpt from the field notes.

Groups of students commonly encourage each other through non-verbal communication. It was common to see students cheering when they reached their goal, patting each other on the back, giving each other high-fives, physically jumping up and down, and even doing "victory dances" when their team would reach the end of their challenge.

Promotive interactions were commonly exhibited throughout the various classrooms. Students were quite supportive of each other and rarely had conflicts. These types of interactions appeared primarily in the homogenous gender groups. These groups had high levels of interaction and playfulness. The classroom and lessons were structured in alignment with common CL research and practices. The lesson structures allowed for ample interaction. One of the other essential tenets of CL is positive interdependence.

Positive Interdependence

Within the CLOP, positive interdependence is evidence of group cohesiveness in accomplishing a task (Kern et al., 2007). Positive interdependence in ER group interactions has been seen through students organizing themselves into roles to carry out specific tasks, asking each other questions about their tasks, and sharing opinions about their tasks (Denis & Hubert, 2001; Somyürek, 2014; Chalmers, 2018). These types of interactions and others were seen throughout the observations.

Throughout the observations, positive interdependence interactions showed in various verbal and non-verbal ways. One interesting observation was that many of the groups organized themselves into roles. The instructor often unprompted this and formed organically among the group members. This non-verbal interaction from a mixed group of students demonstrated this interaction quite well after completing a challenge and preparing for the next one.

> *After completing a task, the students began to clear off their board. One student began getting the pieces to set up the board for the next challenge; The other student took each piece off one at a time and began handing them to the next student. This student began re-organizing all the pieces by direction, putting all the left, right, forward, and backward blocks together. Students showed group cohesiveness by establishing roles with each other unprompted by anyone.*

This self-organization and role assignment is consistent with other ER studies (Denis & Hubert, 2001; Nemiro, 2020a). These types of interactions also demonstrated themselves during the challenges. Take this example within a group of two males.

> *Two boys saw the challenge come up on the board, and one of the boys immediately asked for the forward block. "Ok, give me the forward block…Ok, now the left block…number 2 block…" This pattern of "supply manager" and leader continued throughout their challenge without any objection from either boy or request to change positions. They both immediately assumed roles and began working within their roles.*

Students commonly took on the role of leaders within the group and would even decide to switch roles. In this group of females, the girls agreed about who would get to press the play button to run the program.

> *After the two girls both placed some of the pieces and they both tried to press the big, orange, play button at the same time. One of them said, "Ok, this time you can press the button, I will put the pieces and next time I will press the button and you can put the pieces" The girls agreed, and they began taking turns on who would be the one to press the play button.*

These types of group cohesion examples seemed commonplace in the different classrooms. Positive interdependence exists when group members believe their success is intertwined and work together toward a common goal (Johnson & Johnson, 2004). In some cases, this was demonstrated by both verbal and even physical interactions. This is an observation of an all-female group.

> *Three girls were going through a trial-and-error method of changing pieces out one at a time. Every time they reset their robot they would all hold each other's hands or squeeze each other while the program ran through its code. "PLEASE, PLEASE, PLEASE!" they said as they watched their robot go on the programmed path. The girls would do this repeatedly, each time squeezing or hugging each other harder as they got closer and closer until their robot finally reached its flag, where they all let out a giant "YAAAYYYYY!"*

While this interaction might not seem like much, it demonstrates a sense of group cohesiveness, where everyone in the group was working towards a single goal together. This was made evident not only by their body language but also by their confirmation of reaching their final goal together.

In a mixed, positive interdependence interaction type group, the girl had taken on the role of a programmer while the boy worked on physically placing the pieces and resetting the board.

> *The boy in the group reset the board and placed the new pieces on the challenge. The girl looked at the new board and said that the new challenge was "easy." She told the boy that they had to just go around the obstacle, and turn right. The girl*

proceeded to give the instructions for placing the new programming pieces on the board. The boy followed the directions, placed the pieces, and ran the program. The program worked on the very first challenge. They both cheered when the robot reached the flag.

Self-organization into roles was one of the most common practices by the students that fell into the positive interdependence categories.

Group Processing

This occurs when students take time to reflect as a group upon their progress and functionality (Kern et al., 2007). Discussions specifically focused on the team's progress toward a task, adjusting to reach their goals, facilitating critical thinking through respectful conflict resolution, and collectively proposing solutions have been noted throughout ER research (Hong et al., 201; Mills et al., 2013; Stergiopoulou et al., 2017). These types of interactions were also found throughout the second-grade classrooms at DLPS.

Even though these students were only 6-7 years old, it was quite remarkable how much discussion would occur for even the most minor movements on the robotics board. Students would get into lengthy discussions about what move should come next and even plan many moves ahead to try and reach their goals. When the students were first shown their challenge a mixed group (one female, one male) had this interaction.

After students set up their board, both students began moving the robot without placing any pieces square by square to see what route would be the best way to go.
The boy said, "Ok lets do like this, forward, forward, left, forward."
"Wait, no we have to look at it from the robot's nose" (a reference to strategy taught to the students) "we go left, forward, forward" the girl replied.
"Ohhhh, ok, correct." the boy confirmed. (Translated from Thai.)

The student's careful planning and processing were commonplace among the second graders. This type of thoughtful discussion effectively reviewed what was occurring in their challenge and found solutions to problems. This example from a mixed group demonstrates how students could stop and use group processing to achieve their goals.

The students found they did not have enough pieces to get to their flag and kept going back and looking at what they were doing wrong.
"We don't have enough pieces to get there," said the girl.
"We need to get one more forward piece," said the boy.
"Maybe we have to use the numbered pieces?" said the girl. Both students looked at the board.
"Right, we need to use the number piece here!" (pointing to the area where there were two repeating directional blocks.) Students ended up using the number pieces and then had enough to make it to the flag. (Translated from Thai.)

Throughout the observation, students even weighed different options and decided to go in one direction as a group. In this all-male group, each student had a different idea of how to get to the flag. The students' discussion led to their eventual path.

> *Students began their challenge by discussing their options for getting to the flag. One boy suggested that the group go straight in line using multiple arrows. The other boy said that they should use the function piece. The boys eventually decided to try and use the function piece. When they neared the end of the board, they came to another crossroads where they were running out of straight pieces. One of the boys suggested that they start all over again, but the other came up with the idea that they could "turn left and then go backward."*

This interaction demonstrates how the students had thoughtful discussions before the start of the challenge and when looking at their progress, made another conscious decision not to start over but instead go with another solution. Group processing was used before and during the challenge bringing the students to their final goal. A similar type of interaction was also present in another all-female group.

> *As the girls began their challenge, they made the simple mistake of not resetting their robot to the starting position and always going in the wrong direction. One girl said, "Why is it going this way?"*
> *"Ahooo, we need to reset it back to the start! Ok, let's test it now." Girls tested their new setup. "Ok! Now it's good, let's see if this works." (Translated from*

> *Thai.) Girls continued and began to reset their robots to their starting position after every attempt.*

This interaction was a great example of group processing because they assessed their progress midway through the challenge, found out where the problem was occurring, and then made corrections.

The self-organization of roles and group processing was common in the preliminary observations and the assessment. Group processing in planning and discussion was also prominent throughout this challenge. This interaction occurred in an all-male group processing type.

> *Both boys looked at the board together and began systematically moving the robot around in a sequence that avoided the obstacle and moved towards the flag. The boys called out each direction that the robot would have to take and placed each piece one by one. There was not much discussion other than one point where one of the boys said the robot needed to turn right instead of left as they were moving it. The other boy agreed, and they continued on. They only needed to run the program once to get to the goal.*

Some general interaction patterns emerged within the different gender groups during the preliminary observations. Ardito et al. (2020) found that within middle school robotics, boys tended to focus more on the operational aspects of coding and building, while girls tended to focus more on group dynamics. Witherspoon et al. (2016) note that gender stereotypes affect the roles they adopt on their team as children get older. Other interaction patterns were noticed between the different group structures.

All-Male Groups

Throughout the initial preliminary observations of the study, it appeared that all-male groups exhibited promotive interactions and group processing as their primary interaction types. The students were usually playful, polite, friendly, and accepting of mistakes. While the male groups showed high promotive interactions, they also focused on their challenges. This is an excerpt from the observational field of a male promotive interaction group.

> *The boys were given their initial challenge by the teacher. They immediately began mapping out their route and where they would go. One boy made a suggestion, and the other very politely (within the context of the Thai language) objected, stating they should start differently. They seemed to resolve their differences of opinion very quickly and peacefully, attempting one route. This route failed. Students did not get upset with each other. They told each other it was ok and tried the other one. One boy complimented the other and said they were so smart (translated from Thai.)*

These types of mixtures of both group processing and promotive interactions seemed to be quite common amongst the all-male groups. The boys appear to have an almost competitive edge when they were attempting challenges. They seemed to be focused on the tasks at hand, and conversations often took almost too long. Based on the preliminary observations, it is reasonable to say that the all-male groups demonstrated primarily promotive interactions and group processing interactions.

This interaction between an all-male group processing type accurately represents the interactions and discussions seen.

The group begins a discussion on which way to go. One boy suggests moving towards the waterfall, into the desert, and then to the flag. The other boy says that this way will take too long and that they should simply "turn left twice, and then move forward." They both agree to carry out this planning thinking that it is the best way to move to their goal. They both cheer when they reach their goal.

<u>All-Female Groups</u>

The all-female groups also showed promotive interactions as one of their primary interaction types. The girls were very supportive, caring, and playful with each other, no matter the outcomes of their challenges. The all-female groups showed a lot of promotive interactions through non-verbal mediums. It was common to see physical interactions such as hugging, holding hands, dancing, jumping, and high-fives amongst the girls when there were successes. The girls would often cheer each other on during their challenges. The following example of an all-female group is a good illustration of common interactions among all-female groups.

The girls immediately begin grabbing pieces and placing them on the board. One girl tells the other she has no idea what she is doing. The other two girls tell her *not to worry. It is no problem. The girl who did not know what to do began chanting the other girl's names and telling them to keep fighting (translated from Thai, this is a ubiquitous Thai expression and form of encouragement to not give up.) As the other two girls worked, she kept cheering for them until they reached their goal where they all jumped up and down, hugging each other.*

These types of promotive interactions were most common amongst the all-female groups. The interactions above, however, were rarely seen amongst the all-male and mixed-gender groups.

The all-female groups were never discouraged easily. They always kept trying and encouraging each other even when they failed multiple times. They seemed to go with a more relentless trial-and-error approach.

<u>Mixed Groups</u>

The mixed interaction groups showed more group processing and positive interdependence. This pattern was contrary to the observations in all-male and all-female groups. This may be because students may have felt more comfortable being with their gender group and did not feel that same sense of camaraderie felt with their own gender groupings. Amongst these groups, it seemed like much more verbal discussions, planning, and processing was being conducted compared to the all-male and all-female groups. The following interaction in a mixed group of one girl and one boy is a good example of commonly seen interactions amongst mixed groups.

> *At the start of the challenge both students began actively setting up their board immediately organizing themselves into roles. One began organizing the pieces and the other began setting up the board. The students began moving the robot and discussing what directions they will need to take to get to their flag. One student asks about how to use the repeat pieces and says they can't remember. The other student shows them, and they incorporate this into their strategy for getting to the flag. Through trial and error both students work through multiple iterations of their program continually talking to each other and discussing what is going wrong showing good group processing. They finally reach the flag after many attempts but don't seem too excited. One of the students just says, "Ok!"*

It was most common to see the mixed groups having a lot of verbal discussions during the challenges. They showed more positive interdependence by organizing themselves into roles or group processing through many thoughtful discussions. There did not seem to be consistent patterns in the types of roles the boys or girls took. Some of the conversations were even surprising for students at such a young age. These groups also wanted to be faster than other groups in the room, even though there was no actual competition. The students in these groups often looked around at the others in the class to check their progress.

These observations provided invaluable information on what types of interactions should be seen during the assessment. The literature review of this study provided information on some of the basic types of interactions that should be seen in the classroom. These observations provided what interactions are seen amongst the research participants at DLPS. Table 4.1 provides a summary of the types of interactions seen in each category of the CLOP.

Table 4.1 Summary of Interactions Seen Within Preliminary Observations

Cooperative Learning Elements and Examples Found in Observation	
Positive Interdependence: *There is evidence of group cohesiveness for accomplishing the task.*	• Students were clearing their boards and preparing for the next challenge. • All students were involved in the process even with little interaction. • Some students even take on their own roles of collecting pieces, placing pieces, and resetting the robot. • Each student took on a physical role or was involved in setting up their robots. • All students involved in cleaning up and resetting the board. • Team asking teacher for additional challenges for the group to complete. • Students squeezing each other or holding hands together. when they are running their robots through their test course.
Group Processing: *Use ways to improve the processes team members use to maximize their learning.*	• Students were planning out their route. • Students offered multiple solutions to each other. • Students respectfully rejected some suggestions and went with another one. • Students going over the steps together that they had already taken. • Students moving the robot before programming to predict what blocks they will need.
Promotive Interactions: *Promote one another's success through a supportive, encouraging, and praising environment.*	• Students pat each other on the back. • Students physically dance with each other. • Students compliment each other. • Students jumping up and down and cheering YES! • Students comfort each other when they fail at something. • Not getting upset with one another for obvious mistakes. • Students cheering for their teammates. • Using very polite language (in Thai) with each other when completing their challenges. • Telling each other we are on the same team

Cooperative Learning Elements and Examples Found in Observation	
All-Male Groups	• All-male groups appear to demonstrate more group processing and promotive interaction type interactions during the robotics class. • The male groups often have long discussions about which way to go, to the point where they are using almost too much time. • Male promotive interactions appeared to be more verbal, and in the form of celebrating with each other and encouragement. Failures within the group are often brushed off. • In a vast majority of the groups, members all participated and were very friendly with each other. • High interaction levels.
All-Female Groups	• All-female groups appeared to demonstrate more promotive interaction types during robotics class. The girls were very physical with each other, often hugging, high-fiving, dancing, cheering, and encouraging each other during the robotics challenges. • The female groups appeared to be less concerned about pre-planning and discussions about the paths of their robots. Seems more willing to go with a trial-and-error approach. • All-female groups seemed to have a lot of success by not giving up. • High interaction levels.
Mixed-Gender Groups	• Mixed-gender groups seemed to show more positive interdependence and group processing interaction types. Groups would often self-organize with a leader and a peace placer. • These groups seemed more focused and serious about the challenges than some of all-male or all–female groups. • Mixed-gender groups appeared almost competitive and were faster than the other groups. • Lower interaction levels when compared to same-gender groups.

Group Structure and Robotics Achievement

Based on the group structure and achievement, three areas were analyzed. Students' LoA, generalization, and algorithmic thinking. The results were as follows.

Level of Achievement

Blanca et al. (2017) found that the ANOVA test is still a valid option even with uneven sample sizes because of its robustness. Therefore, the differences in sample size should not be a factor in the results of this study. The effect of group structure based on gender and robotics achievement was evaluated. There were three categories of group structure: all-male (n=14), all-female (n=20), and mixed-gender groups (n=16). Table 4.2 shows the descriptive statistics for the LoA by group structure.

Table 4.2 Descriptive Statistics for Level of Achievement by Group Structure

Group Structure	*N*	*Mean*	*Std. Deviation*	*Std. Error*	*Lower Bound*	*Upper Bound*	*Minimum*	*Maximum*
Male	14	56.31	32.82	8.77	37.36	75.26	13.3	138.8
Female	20	49.46	28.08	6.28	36.32	62.61	7	117.56
Mixed	16	52.54	34.7	8.67	34.05	71.03	14	135.86
Total	50	52.37	31.11	4.40	43.52	61.21	7	138.80

A one-way ANOVA was conducted to understand the effect of group structures on students' level of robotics achievement. The one-way ANOVA revealed that there was no statistical difference in mean LoA scores between group structures (F (2, 47) =[3.025], (p=.825) (Table 4.3).

Table 4.3 One-Way Analysis of Variance of Level of Achievement by Group Structure

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	386.65	2	193.33	.193	.825
Within Groups	47046.19	47	1000.98		
Total	47432.83	49			

Generalization

While there were no differences between groups for the LoA, it was necessary to check if there were any differences in achievement amongst the category of generalization and algorithmic thinking. Table 4.4 provides the descriptive statistics for the Generalization challenge scores based on the group structures.

Table 4.4 Descriptive Statistics for Generalization Scores by Group Structure

Group Structure	*N*	*Mean*	*Std. Deviation*	*Std. Error*	*Lower Bound*	*Upper Bound*	*Minimum*	*Maximum*
Male	14	37.65	22.58	6.03	24.62	50.68	5.3	75
Female	20	39.53	17.03	3.81	31.56	47.5	2	67.2
Mixed	16	23.86	16.88	4.22	14.87	32.86	0	49
Total	50	33.99	19.62	2.77	28.42	39.56	0	75

When looking at the challenges that specifically focused on generalization, the one-way ANOVA revealed that there was a significant difference in mean generalization challenge scores between at least two groups (F(2,47)=[3.498], p=0.038). (Table 4.5).

Table 4.5 One-Way Analysis of Variance of Generalization Scores by Group Structure

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	2442.43	2	1221.22	3.5	.038
Within Groups	16410.82	47	349.17		
Total	18853.25	49			

Tukey's HSD Test for multiple comparisons found that the mean generalization challenge scores were significantly different between all-female and mixed-gender groups (p=.042, 95% C.I. = .5, 30.84). There were no statistically significant differences between all-male and all-female groups, and all-male and mixed-gender groups.

The all-female groups demonstrated primarily promotive interactions. During the assessment, the all-female groups exhibited many of the same interactions seen in the preliminary observations. These students were able to complete the challenges quite easily. This example of one of the highest-performing all-female groups characterizes much of what was seen during the assessments.

> *The group begins their new challenge. As they begin placing their pieces, one of the girls says, "no, no, we did this one already!" One of the girls flips back into the challenge book and says "no, look it is not the same" referring to the first challenge shown to the students in the assessment book. "Ohhhh, wow, you're very smart!" [translated from Thai]. Girls continue with their plan and get to the flag. The girls cheer, hug, and then complement each other.*

The lowest-performing group in the generalization category was a mixed group, with a mean score of 23.86 (n=7). This example comes from one of the lowest-performing groups demonstrating one of the common interactions.

> *One of the boys says that he knows how to do the challenge. The girl says ok, and says she will do the pieces and press the play button. They set up the board and begin to place their pieces. The boy gives directions but is going the opposite way. The girl is cheering for him. They only need to use the same pattern as before to get to the flag. After a few attempts they ran out of time.*

This interaction shows how the group organized themselves into roles, were focused on the goal but were unable to reach their goal within the time limit. The same programming blocks and patterns as the last challenge would be needed. The students simply needed to recognize the previous pattern. However, because of the nature of the roles which the group established, only one student was taking on the cognitive load of solving the problem. This student could not make that connection to their previous code, which they had done just two challenges before.

Algorithmic Thinking

Algorithmic thinking challenges was the second skill assessed. Table 4.6 provides the descriptive statistics for the algorithmic thinking challenge scores based on the group structure.

Table 4.6 Descriptive Statistics for Algorithmic Thinking Scores by Group Structure

Group Structure	*N*	*Mean*	*Std. Deviation*	*Std. Error*	*Lower Bound*	*Upper Bound*	*Minimum*	*Maximum*
Male	14	18.66	18.6	4.97	7.92	29.40	0	63.8
Female	20	9.93	18.53	4.14	1.26	18.61	0	62.56
Mixed	16	28.68	26.21	6.55	14.71	42.65	8	106.86
Total	50	18.38	22.34	3.16	12.03	24.73	0	106.86

A one-way ANOVA revealed a statistically significant difference in mean algorithmic thinking challenge scores between at least two groups (F(2,47)= [3.44], p = .04) (Table 4.7).

Table 4.7 One-Way Analysis of Variance of Algorithmic Thinking Scores by Group Structure

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between	3125.478	2	1562.74	3.44	.04
	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Within Groups					
Total	24451.121	49			

Tukey's HSD Test for multiple comparisons found that the mean algorithmic thinking challenge score was significantly different between all-female and mixed-gender groups (p=0.031, 95% C.I.= [-36.04, -1.45]. There was no statistically significant difference in mean algorithmic thinking challenge scores between all-male and all-female groups (p= 0.47) and all-male and mixed-gender groups (p= 0.41).

The highest performers in the algorithmic thinking categories were the mixed-gender groups. They had the most success by breaking the problem into two parts. They cleared the obstacle first and then moved to the flag. Here is an example of a mixed-gender group type that utilized their algorithmic thinking early in the challenge.

> *Group looks at the challenge and one of them says they need to go around the obstacle on the snowfield first. Students recognized it was quicker to clear the snowfield first rather than the obstacle in the Gobi desert. "Ok, we need to go this way first, just forward, left, forward…easy." The group moves around the obstacle first completing the first sequence. One girl says that it is no problem now, they just need to go straight. The group completes the second sequence with the correct forward and number block pieces.*

The group recognized the two sequences and then executed the correct directions for the robots to get there. This demonstrated not only group processing but also algorithmic thinking.

High performers were in the all-male and mixed groups for the algorithmic thinking challenges. The all-female groups were amongst the lowest performers in the algorithmic thinking challenges. This interaction demonstrated where things went wrong.

Girls begin challenges by turning into obstacles. The girls say they need to move in a different direction. The girls cleared the board and started over again. Girls laugh not worried about the failure. They move the robot forward and then turn it in the wrong direction. Girls are cheering for their robot. "No we can't go that way! Lets try go left! " (translated from Thai.) The girls reset their board completely again and try another iteration cheering for their robot again. The girls begin to run out of time. Time expires with one piece placed correctly.

The primary factor in this incompletion was that the girls could not recognize that they needed to break the challenge down into two separate sequences as they were previously taught to do. This created issues when developing a plan for their robot to move.

Interaction Types and Robotics Achievement

Interaction types were evaluated in three categories: Level of Achievement, generalization skills, and algorithmic thinking skills.

Level of Achievement (LoA)

The next variable that was examined was the various interaction types. Table 4.8 shows the descriptive statistics for the LoA scores by interaction types with *N* being the number of groups that were categorized as the corresponding interaction type.

Table 4.8 Descriptive Statistics for Level of Achievement by Interaction Type

Interaction Type	*N*	*Mean*	*Std. Deviation*	*Std. Error*	*Lower Bound*	*Upper Bound*	*Minimum*	*Maximum*
Group Processing	13	63.3	35.09	9.73	42.09	84.5	13.3	135.86
Promotive Interactions	19	59.05	32.44	7.44	43.41	74.68	15	138.8
Positive Interdepen-dence	18	37.42	20.72	4.88	27.12	47.73	7	71
Total	50	52.37	31.11	4.4	43.52	61.21	7	138.8

A one-way ANOVA was performed to compare the effect of interaction types on group robotics achievement. The ANOVA revealed a statistically significant difference in the LoA between at least two groups ($F(2,47)= 3.679$, $p = 0.03$) (Table 4.9).

Table 4.9 One-Way Analysis of Variance of Level of Achievement by Group Structure

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	6420.61	2	3210.30	3.68	.03
Within Groups	41012.23	47	872.6		
Total	47432.84	49			

Tukey's HSD Test for multiple comparisons found that the mean value of interaction types was significantly different between group processing and positive interdependence groups ($p= 0.049$), 95% C.I= -.1475, 51.89). There was no statistically significant difference between promotive interactions and group processing (p=0.916) or promotive interactions and positive interdependence (p=0.77).

Generalization

The next category was the generalization skill-based challenges. Table 4.10 shows the descriptive statistics for the generalization challenge scores by interaction type.

Table 4.10 Descriptive Statistics for Generalization Scores by Interaction Type

Interaction Type	*N*	*Mean*	*Std. Deviation*	*Std. Error*	*Lower Bound*	*Upper Bound*	*Minimum*	*Maximum*
Group Processing	13	30.59	14.76	4.09	21.67	39.51	5.3	52
Interaction Type	*N*	*Mean*	*Std. Deviation*	*Std. Error*	*Lower Bound*	*Upper Bound*	*Minimum*	*Maximum*
Promotive Interactions	19	42.75	18.2	4.18	33.97	51.52	15	75
Positive Interdepen-dence	18	27.2	21.47	5.06	16.52	37.88	0	62
Total	50	33.99	19.62	2.77	28.42	39.56	0	75

Another one-way ANOVA was conducted to compare the effect of group interaction types on achievement in generalization challenges. The ANOVA revealed a statistically significant difference in interaction type and achievement in generalization categories between at least two groups ($F (2, 47) = 3.489$, $p = 0.04$) (Table 4.11).

Table 4.11 One-Way Analysis of Variance of Generalization Scores by Interaction Type

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	2437.09	2	1218.54	3.49	.04
Within Groups	16416.16	47	349.28		
Total	18853.25	49			

Tukey's HSD Test for multiple comparisons found that the mean value of generalization challenges was significantly different between promotive interactions and positive interdependence (p= 0.04, 95% C.I.= .67, 30.42).

In this challenge, the promotive interaction group could recognize and distinguish similar patterns demonstrating generalization skills and the ability to complete challenges within their time limit quickly. Here are the notes from another one of the group's assessments.

Girls are all very polite with each other. They are always using "ka" [this is a formal Thai modifier, which makes the language polite.] All of the girls are working together nicely. Each time they make a mistake, they laugh and smile at each other. They reset their pieces and try again. Not much discussion of the progress of robots. Just a lot of trial and error. Girls are not annoyed or upset with each other. Girls jump up and down and hug each other when they get to the flag.

One of the lower-performing groups was the group processing group with a mean score of 27.6. Here is an example of one of the mixed, group processing types that were intelligent but got so caught up in their planning that they ran out of time and received a zero for the challenge.

> *Group begins by talking about which way they go. One of the girls thinks that they should start by turning right, then forward, and forward. The other boy thinks they should go forward first. The girl moves the robot around, planning out each route. They are in deep discussion about which route they should take. They keep going back and forth about where to start without ever placing the pieces. The boy begins placing the pieces, but decides to go a different route halfway through. The time expires.*

During the preliminary observations, it seemed that situations like this would be inevitable. Some groups became so focused on discussing which way to go that they could not decide within their time constraints. The assessment mean scores and interactions during the assessment demonstrated this as well.

<u>Algorithmic Thinking</u>

The final category to be looked at was the Algorithmic Thinking challenge scores by interaction types. Table 4.12 shows the descriptive statistics for the Algorithmic Thinking challenges by interaction type.

Table 4.12 Descriptive Statistics for Algorithmic Thinking Scores by Interaction Type

Interaction Type	*N*	*Mean*	*Std. Deviation*	*Std. Error*	*Lower Bound*	*Upper Bound*	*Minimum*	*Maximum*
Group Processing	13	32.7	30.19	8.37	14.46	50.95	2	106.86
Promotive Interactions	19	16.3	22.69	5.2	5.37	27.23	0	63.8
Positive Interdepen-dence	18	10.22	4.24	1	8.12	12.33	5	15
Total	50	18.38	22.34	3.16	12.03	24.73	0	106.86

The final one-way ANOVA conducted was to compare the effect of group interaction types on achievement in algorithmic thinking challenges. The ANOVA revealed a statistically significant difference in interaction types and achievement in algorithmic thinking categories between at least two groups ($F(2, 47) = 4.52$, $p = 0.02$) (Table 4.13).

Table 4.13 One-Way Analysis of Variance of Algorithmic Thinking Scores by Interaction Type

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	3947.09	2	1973.54	4.52	.02
Within Groups	20504.03	47	436.26		
Total	24451.12	49			

Tukey's HSD Test for multiple comparisons found that the mean value of algorithmic challenges was significantly different between group processing and positive interdependence (p= 0.01, 95% C.I.= 4.08, 40.88).

The types of interactions that were seen during their assessment were similar to what was seen in the preliminary observations. For example, this interaction is taken from one of the highest performing group processing interaction type groups in the classroom during the assessment.

> *Students begin planning out where they have to go. One student proposes moving up into the snowfield and then moving around the obstacle. The other student says, "no, we don't need to do that, let's just move like this first." The girl makes an "L" shape with her hand, showing the correct sequence. "We just have to do it like this, it's easy" (Translated from Thai.) Students reach the obstacle using the number piece. Students demonstrate thoughtful discussion and meaningful actions.*

This type of discussion was commonly seen in the preliminary observations within the classroom as well. As noted in the previous section, discussions of the challenges and actions that should be taken to reach the goal were quite common.

Here is an example of one of the lower-performing groups. This group was a positive interdependence group.

The first girl in the group says, "Ok, easy…turn left, turn left, forward." She tells the boy to start placing the pieces. Boy starts putting the pieces down and runs the program. The robot goes the wrong way. Girl says "Ooooo…try go right first." The boy changes the pieces. Robot goes the wrong direction again. Cannot reach the goal.

In this group, the members demonstrated positive interdependence by making roles for themselves. The girl acted as the programmer while the boy was the engineer placing the pieces. These interactions were consistent with what was seen in preliminary observations, but in the end, they were unable to complete the challenge.

Summary of Results

The mixed methods embedded design was used to help answer the four research questions. This was done using a set of preliminary observations, followed by an assessment of group achievement. The student's overall LoA, achievement within generalization challenges, and achievement within algorithmic thinking challenges were recorded. These scores served as a dependent variable and were assessed through separate One-Way ANOVAs with group structure by gender and interaction types as independent variables. Here is a summary of the results.

RQ1: *How do cooperative learning interactions manifest among the second-grade robotics students at Denla Primary School?*

Through tedious observation of over 100 students interacting with each other in their normal robotics class over the course of a week, an interaction chart was created to document how group processing, positive interdependence, and promotive interactions manifest within the second-grade robotics classroom.

RQ2: *Do the types of group interactions in second-grade robotics activities make a difference to the group's achievement?*

Through a one-way ANOVA, it was found that there was a statistically significant difference between the group interaction types and LoA within the second-grade robotics classroom.

Post hoc tests revealed that the mean score of group processing interaction type groups ($\bar{x}$= 63.3) was significantly higher than positive interdependence groups ($\bar{x}$= 37.42). There were no other significant differences between promotive interactions and positive interdependence or group processing.

In terms of achievement in group generalization challenges, it was found that the mean difference between promotive interactions ($\bar{x}$=42.75) and positive interdependence groups ($\bar{x}$=27.20) was statistically significant. There were no other statistically significant relationships in this group.

Algorithmic thinking challenge scores revealed the mean difference between group processing ($\bar{x}$=32.7) and positive interdependence ($\bar{x}$=10.22) was statistically significant. There were no other statistically significant relationships in this group.

RQ3: *Does the group structure in second-grade robotics activities make a difference to the group's achievement?*

It was found that in terms of the LoA, there was no significant difference between the different types of group structure and the level of achievement. There was a statistically significant difference between group structures and generalization skill challenges. It was found that the all-female groups ($\bar{x}$= 39.3) performed significantly better than the mixed-gender groups ($\bar{x}$= 23.86). There were no other statistically significant relationships in this group. There was also a statistically significant difference between group structures and algorithmic thinking challenges. It was found that mixed-gender groups ($\bar{x}$= 28.68) performed significantly higher than the all-female groups ($\bar{x}$= 9.93)

CHAPTER FIVE: CONCLUSION AND IMPLICATIONS

This chapter consist of a summary of the study, discussion of key findings from the data collection in Chapter 4, and important conclusions, implications, limitations, and suggestions for future research.

Summary of Study

The purpose of this mixed methods embedded design study was to explore the relationship between student group interactions and group structure on achievement in robotics activities in second-grade elementary school robotics class. Understanding the relationship between student group interactions and achievement will help to inform classroom instruction and teaching pedagogies in Educational Robotics (ER). The results of this study also contribute to a further understanding of the broader narrative of the gender gap within the STEM field. Three research questions guided this study. They were answered using an embedded mixed methods research design. This chapter will discuss some of the key results and how they relate to current research in the ER field, and their implications for future practice.

Research question one aimed to understand what types of cooperative learning interactions occur within the elementary school ER classroom. The literature review revealed that the Cooperative Learning (CL) framework was an appropriate lens for observing interactions within ER activities. This was because the primary theoretical framework behind ER is constructionism (Stager, 2005; Mikropoulos & Bellou, 2013; Gorakhnath & Padmanabhan, 2020). Constructionism is conducive to cooperation and collaboration. The five tenets of CL can be seen throughout ER activities, making it an ideal framework for observing student interactions. Understanding what specific types of interactions are occurring within the classroom helped classify and categorize the different types of group interactions and provided the data needed to make connections between achievement and interactions.

Research question two addressed the connection between group interactions and level of achievement. It is already known that social interaction is important to robotics educational quality (Chootongchai et al., 2021). However, what has yet to be seen is how the types of interactions in the classroom affect student learning, especially among young children (Jung & Won, 2018). By understanding how the different types of interactions differ in terms of achievement, this study has helped to fill in some of the gaps noted by researchers in developing practical instructional strategies and pedagogies (Jung & Won, 2018; Ioannou & Makridou, 2018; Anwar et al., 2019).

Research question three explored the differences between group structure in terms of gender and the level of achievement in robotics activities. This question helped to further expand our understanding of effective cooperation and interactions in ER classrooms (Xia & Zhong, 2019). Knowing what types of group structures can contribute to high achievement levels can guide future instructional practices (Tenenbaum et al., 2019). This question also addressed one of the broader topics, the lack of gender diversity in the STEM fields. Further understanding how gender differences affect or do not affect achievement in STEM fields will help to transform the preconceptions and stereotypes that may already exist (Leaper, 2015).

There is a lack of research regarding technology in education for the early childhood years (Lee et al., 2013). Few studies have focused on interactions during ER activities, and even fewer focus on young children. Gathering as much comprehensive information on student interactions and achievement help to create an important foundation for future research.

Discussion

First, this study investigated and created a table of specific interactions among second-grade students in their robotics classroom. The table lists various types of interactions seen in the classroom that are directly related to ER activities. The observations of the second-grade students also detail what types of interactions are seen amongst the various group structures regarding gender. These are useful for understanding gender differences in the ER classroom and developing instructional practices.

Next, this study found a significant difference between group interaction types and the Level of Achievement (LoA) within the second-grade robotics classroom students. There was also a significant difference between group processing and positive interdependence interaction types when looking at algorithmic thinking challenge scores. The study also found no significant difference between the LoA and group structures regarding gender. However, there were significant differences between group structures and generalization skill challenges. There were also significant differences between the mixed-gender groups and algorithmic thinking challenges.

Student Interactions in Second-Grade Robotics Classrooms

Using the Cooperative Learning Observation Protocol (CLOP) (Kern et al., 2007) three types of interactions were observed: promotive interactions, positive interdependence, and group processing. These types of interactions have been seen in previous studies (Xia & Zhong, 2019; Cheng et al., 2013; Nemiro et al., 2017; Nemirob 2020; Chalmers 2018; Denis & Hubert, 2001; Somyürek, 2014; Chaudhary et al., 2016). They were also present in this research study as well.

Promotive Interactions

Previous studies have noted promotive interactions within ER, such as when students are encouraging, celebrating each other's success, praising, peacefully resolving conflicts, and advocating achievement for others (Jordan and McDaniel, 2014; Nemiro et al., 2017, Nemiro 2020b; Khanlari, 2013). These studies draw close comparisons of the results produced from this study as well (Table 5.1).

Table 5.1 Summary of Promotive Interactions

Promotive Interactions: *Promote one another's success through a supportive, encouraging, and praising environment.*	• Students pat each other on the back. • Students physically dance with each other. • Students compliment each other. • Students jumping up and down and cheering! • Students comfort each other when they fail at something. • Not getting upset with one another for obvious mistakes. • Students cheering for their teammates. • Using very polite language (in Thai) with each other when completing their challenges. • Telling each other we are on the same team • Celebrating each others success

The structure of the challenges presented to the students throughout the study were consistent with the central tenets of CL (Johnson & Johnson, 2002). Students had to work together to program their robot to reach their flag. Promotive interactions have been found to occur when students' goals and learning are intertwined (Johnson & Johnson, 1999).

Table 5.1 documents the many different promotive interactions seen throughout the study. During the ER classroom observations, many groups of students supported each other's success. The interaction levels between students were high as is consistent with research conducted with group-based ER activities (Cheng et al., 2013). The environment was supportive, gleeful, and positive. Throughout the entire observation period, students never seemed to get mad with each other, and appeared to feel wholly intertwined with the goals of the classroom. Previous research has found that ER activities are beneficial for creating positive working relationships (Ponticorvo et al., 2020). This same type of consistent positivity was consistent within the second-grade classrooms of the study and shown in the promotive interactions.

This study found a contrast in the physical nature of many interactions. Throughout the observations, students were constantly high-fiving, hugging, cheering, patting each other on the back, and even dancing when completing their activities to celebrate each other's success. Much of the previous research notes students helping and creating positive and supportive environments (Nemiro, 2020b; Jordan & McDaniel, 2014; Khanlari 2013), but there are few mentions of promotive interactions in the way of physical interaction. Thus, this study documented the physical types of promotive interactions that are not discussed in other related studies.

Group Processing

Group processing may look like individuals in a group talking about what is helpful and unhelpful, sharing each other's opinions, respectfully challenging each other's opinions, reflecting on the progress of the group's goals, and discussing of reaching goals (Johnson & Johnson, 1996; Kern et al. 2007). These types of behaviors can be seen in their own ways within ER activities. Table 5.2 briefly describes what group processing interactions looked like within the second grade ER classroom.

Table 5.2 Summary of Group Processing Interactions

Group Processing: *Use ways to improve the processes team members use to maximize their learning.*	• Students were planning out their route. • Students offered multiple solutions to each other. • Students respectfully rejected some suggestions and went with another one. • Students going over steps together that they had already taken. • Students moving the robot before programming to predict what blocks they will need.

Throughout the observations, students were seen adjusting their robots programming to reach the flag. It was common to see students talking out possible solutions before taking action or going over the steps that they had already taken. Students had genuinely thoughtful discussions about what paths they should be taking, and would often take substantial time to come to solutions before even placing pieces for their program. Mills et al., (2013) note similar behaviors when they found that during primary school ER activities, students would often collectively evaluate proposed solutions, give feedback to each other, and adjust and improve their solutions.

ER activities are often designed in ways that are good for facilitating discussion by having students explain, justify, and articulate their points of view (Stergiopoulou et al., 2017). These same behaviors were noted during the observations of this study. Students often proposed a direction to go and justify themselves by physically moving the robot and calling out programming commands step by step to create group buy-in.

Positive Interdependence

Positive interdependence occurs when group members work towards the same goal (Johnson & Johnson, 2004). Positive interdependence interactions are demonstrated when there is evidence of group cohesiveness, such as members designating roles and actively working towards the group goals by sharing their unique knowledge or skills (Kern et al., 2007). The observations in this study showed numerous examples of positive interdependence between groups, as can be seen in Table 5.3.

Table 5.3 Summary of Positive Interdependence Interactions

Positive Interdependence: *There is evidence of group cohesiveness for accomplishing the task.*	• Students were clearing their boards and preparing for the next challenge. • All students were involved in the process, even with little interaction. • Students take on their own roles of collecting pieces, placing pieces, and resetting the robot. • Each student took on a physical role or was involved in setting up their robots. • All students involved in cleaning up and resetting the board. • Team asking teacher for additional challenges for the group to complete. • Students squeezing each other or holding hands together. when they are running their robots through their test course.

One of the primary positive interdependence interactions in this study was students organizing themselves into roles. Students appeared to primarily place themselves as what could be defined as the "programmer" or the "engineer." The programmer is the person that calls out the directions for the program, and the engineer is the person who physically places the pieces on the board. There were many situations throughout the different classrooms where, without prompting, students would organize themselves into these types of roles. These roles appeared to come naturally to students as they fit their specific skill sets. This type of interaction is also consistent with observations from previous studies. Denis and Hubert (2001) found that students would delegate themselves to carry out specific tasks within LOGO robotics activities, often with one primary leader directing the others. Nemiro et al. (2017) said that primary school students appeared to contribute to their groups based on specific skill sets and perspectives. In elementary schools in Canada, students would organize into "programmers" that write the code and "controllers" to direct their robots to make adjustments (Blanchard et al., 2010). Witherspoon et al. (2016) also had similar findings when they found that students would normally establish two roles for their team within robotics competitions "builders" or "programmers."

Other positive interdependence interactions were also seen in this particular ER classroom context. Students appeared to be wholly involved in accomplishing their goals. Positive interdependence is the perception of students' successes and failures being intertwined (Johnson & Johnson, 1999). The interactions observed showed a manifestation of such perceptions. This was seen in various forms: students clutching each other's hands as the student's robot ran through its course; students working together to quickly clear boards and prepare for the next challenge; students becoming involved in the programming process even though there was very little verbal interaction. While these interactions were not explicitly documented in previous studies, they fall under the CLOP definition of positive interdependence.

All-Male Groups

There were some general observations of the students in all-male robotics groups. Within the all-male robotics groups, group processing and promotive interactions were the primary types of group interactions seen. The male groups often had long conversations and discussions before even beginning to start their programs. The male promotive interactions were primarily verbal. They celebrated and encouraged each other using their words. Failures were easily brushed aside, and there was no animosity or resentment toward others within the group for making the wrong decisions. The general level of interaction amongst the all-male groups seemed to be very high. There appeared to be very rarely a lapse in conversation. Students were almost always interacting with each other. Table 5.4 lists some general themes from the all-male groups.

Table 5.4 Summary of All-Male Robotic Group Interactions

All-Male Groups	• All-male groups appear to demonstrate more group processing and promotive interaction type interactions during the robotics class. • The male groups often have long discussions about which way to go, to the point where they are using almost too much time. • Male promotive interactions appeared to be more verbal, and in the form of celebrating with each other and encouragement. Failures within the group are often brushed off. • In a vast majority of the groups, members all participated and were very friendly with each other. • High interaction levels

Some of these findings are consistent with prior research. Studies have found that groups of the same gender commonly have higher levels of interaction and communication in ER activities (Cheng et al., 2013). The all-male groups appeared to be very open with each other and were rarely exclusionary with each other. This is consistent with general interactions of students in ER activities found in another study of students from elementary (as young as 3rd grade) to middle school (Yuen et al., 2014).

Something unusual that occurred was that during the actual assessment time, the all-male groups primarily demonstrated positive interdependence and group processing types of interactions. When the actual assessment began, boys tended to change the way in which they interacted. This could be due to the confidence that all the boys seemed to have in themselves. During the assessment, members of all-male groups seemed to all have opinions or ideas about how to approach the problem. Previous studies have shown that boys have been found to feel significantly more confident than girls in their robotics abilities (Sullivan & Bers, 2019; Zviel-Girshin et al., 2020). Perhaps the boys' confidence, in combination with the nature of homogenous gender grouping high levels of interaction (Cheng et al., 2013), caused the boys to demonstrate more group processing and positive interdependence when the assessment took place.

All-Female Groups

The all-female groups demonstrated primarily promotive interactions during robotics class. The girls often displayed this in very physical forms. They were less concerned about any sort of pre-planning approaches and would often use a persistent trial-and-error style approach to their robotics challenges. The general interaction level of the students was high, and like the boys there was rarely any lapse of interaction amongst all the groups. Table 5.5 lists some of the common themes seen in the all-female groups.

Table 5.5 Summary of All-Female Group Interactions

All-Female Groups	• All-female groups appeared to demonstrate more promotive interactions types during robotics class. The girls were very physical with each other, often hugging, high-fiving, cheering, and encouraging each other during the robotics challenges. • The female groups appeared to be less concerned about pre-planning and discussions about the paths of their robots. Seems more willing to go with a trial and error approach. • All-female groups seemed to have a lot of success by not giving up. • High interaction levels.

The all-female group's ability to be persistent and use trial-and-error approaches to reaching their robotics goals was consistent with other research at the same age group. Sullivan and Bers (2016b) found that second graders were able to go through material with little instruction and help. The girls in the classroom had little intervention from the teacher and, through their methods, could get through the challenges together. This persistence could also be due to the fact that the challenges the girls were given were "written" in the form of a challenge book. Xia and Zhong (2019) found that when girls approached robotics-based tasks they appeared to be more dedicated than boys when following written-based objectives. This could have played a factor in the girls' approach to solving the challenges.

Mixed-Gender Groups

Mixed-gender groups showed more positive interdependence and group processing interaction types. The general level of interactions, when compared to the same-gender groups, appeared to be lower. Some interesting observations about these groups were that they seemed more serious and focused on the challenges than some of the all-male or all-female groups. There were much fewer physical interactions in the all-female groups and less joking and playfulness than in the all-male groups. Table 5.6 lists some of the common themes of the mixed-gender groups.

Table 5.6 Summary of Mixed-Gender Interactions

Mixed-Gender Groups	• Mixed-gender groups seemed to show more positive interdependence and group processing interaction types. Groups would often self organize with a leader and a peace placer. • These groups seemed more focused and serious about the challenges than some of the all male or all–female groups. • Mixed-gender groups appeared almost competitive and were faster than the other groups. • Lower interaction levels when compared to same-gender groups.

Some of these results are consistent with current research. As noted previously, same-gender groups have been found to have higher levels of interaction than mixed-gender groups in elementary school robotics (Cheng et al. 2013). It was interesting to see that the mixed-gender groups appeared to be faster than the homogenous-gender groups during the challenges. This is consistent with a study by Zhong et al., (2022), who found that mixed-gender group pairings outperformed single-gender pairs. However, Taylor and

Baek (2018) would argue that the gender composition of a group would not contribute to the group's robotics performance.

Perhaps the only real surprises were how girls and boys demonstrated promotive interactions. The all-female groups were much more physical and playful with each other, whereas the male groups were more verbal with their promotive interactions and encouragement with one another. This is contradictory to some studies on older students that have found boys to be more playful than girls (Hwang & Hsu, 2021).

One explanation for this could be found in a previous study of FIRST (For Inspiration and Recognition of Science and Technology) robotics teams, where it was found that female students enjoyed the social aspects of robotics more than males. In contrast, the males enjoyed the technical aspects slightly more (Burns, 2019). This was shown through the all-girl groups' very playful interactions.

This is one of the first studies to intentionally document specific interactions in early childhood robotics classes. The CL framework proved to be a suitable lens for observing ER classes, and the interactions recorded will be useful for building upon in the future. Overall, the observed interactions' results align with previous research documenting the interactions within robotics activities.

Group Structure and Robotics Achievement

LoA

In terms of the LoA, which is essentially, the overall score in robotics achievement the all-male groups appeared to be the highest performers ($\bar{x}$= 56.31), followed by the mixed gender ($\bar{x}$= 52.54), and finally, the all-female ($\bar{x}$=49.46) categories. However, these mean differences were not statistically significant. These findings were similar to other research studies. Sullivan and Bers (2013) also found that boys had higher mean scores than girls in completing robotics tasks, but the scores were not statistically significant. Taylor and Baek (2018b) found that the gender composition of groups had no significant effect on robotics performance in 4th and 5th graders. This is also similar to Cheng et al. (2013) study that found that gender, among other factors, did not appear to have an effect on students' learner outcomes. According to these previous studies these results were unsurprising, however, when looking at the sub-categories of data, there were some interesting results.

Generalization

In this category of generalization, it was found that there were statistically significant results between the mean score of the all-female groups ($\bar{x}$=38.53) and the mixed-gender groups ($\bar{x}$=23.86). However, between all-female and all-male groups the differences were not statistically significant.

During the preliminary observations, it was noted that the all-female and all-male groups seemed to be more relaxed with their interactions and showed higher rates of interaction. This is consistent with previous research (Cheng et al., 2013). The mixed-gender groups did not seem as comfortable with each other. They would either not talk enough about their thoughts or talk too much about what paths they would take, causing time to expire or students to move their robots in unnecessarily complicated sequences.

The generalization challenges were considered easier than the later algorithmic thinking challenges. The initial challenge required students to use simple movement patterns. The second challenge solution was a single backward movement that would be recognized if students could recall the patterns of previous challenges. The final challenge required students to recognize the first challenge sequence's movement pattern and add to it.

Entering into these challenges, the students had all of the prior knowledge necessary to complete the challenges; they just needed to be able to recognize the patterns, movements, and paths that the robots needed to take. It seemed like the all-female groups could easily recognize the paths that needed to be taken. This could be because the general nature of their interactions was light, positive, and comfortable. Burns (2019) found that female students tended to enjoy the team social aspects of robotics more than males. Enjoyment and playfulness can lead to lower anxiety in robotics activities which has the potential to lead to higher levels of achievement (Hsu & Hwang, 2021). In these early challenges, it could be argued that the all-female groups (who were primarily classified as promotive interaction types) demonstrated higher levels of playfulness and enjoyment than the all-male groups and mixed-gender groups. The all-female groups were dancing, laughing, cheering, hugging, high-fiving, celebrating each other's success, and encouraging each other. The combination of playfulness and the relatively simple nature of the generalization challenges that only required simple recalling of patterns and sequences could explain the higher scores in the all-female groups.

Algorithmic Thinking

In the algorithmic thinking categories, it was found that there was a significant difference between mixed-gender and all-female categories. The mean score of mixed-gender groups ($\bar{x}$= 28.68) was significantly higher than the all-female groups ($\bar{x}$= 9.93).

While this score was also higher than the all-male groups ($\bar{x}$= 18.66), it was not statistically significant.

Sullivan & Bers (2016) conducted a study with a similar format in which groups of students worked together to solve robotics challenges. Similarly, to this study, the challenges began with three simpler sequencing or generalization challenges, followed by increasingly more difficult challenges that required loops and additional parameters, much like the algorithmic thinking challenges in this study that introduced obstacles and repeated patterns. The study found that all genders' scores appeared to decrease. This could explain the drop in the scores from the previous generalization challenges, but it does not explain why suddenly the mixed-gender groups outperformed the all-female groups.

Looking back at previous research can help to explain why this result may have occurred. Zhong et al. (2022) found that during paired learning robotics activities, girls, whether they were in mixed-gender groups or all-female groups, maintained a "continuous attitude and engagement with their peers during the learning process" (p.16). As noted within this study, the girls appeared to be much more playful and relaxed during the beginning challenges. While this level of group engagement served the all-female teams well in the beginning challenges, this same level of engagement was not as suitable when the challenges became more difficult. This could explain why the mixed-gender groups progressed further within the assessment, as their interactions were much more reserved and focused. A deeper look at how the interactions affect the students may help answer this question.

Interaction Types and Robotics Achievements

Three types of interactions were analyzed during this study: promotive interactions, positive interdependence, and group processing. There were significant differences in the mean scores of the overall LoA, generalization score challenges, and algorithmic thinking score challenges between groups.

Level of Achievement

The mean score of the overall LoA was significantly higher in group processing interaction type groups ($\bar{x}$= 63.3) than in positive interdependence groups ($\bar{x}$= 37.42). However, the difference between the group processing and promotive interactions ($\bar{x}$= 59.05), and promotive interactions and positive interdependence groups was not statistically significant.

During the assessment, group processing groups were often seen discussing routes, re-evaluating decisions, creating plans, having thoughtful discussions about group progress, and more. Previous studies have noted the benefits of students utilizing this collective knowledge. Hong et al. (2012) found that the quality of students' work increased when discussions focused on the team's progress toward reaching their goals. Chandhary et al. (2016) study revealed that elementary students that felt their team was working together and reflecting as a team were more effective than those working individually. This study shows that group processing’s effectiveness appears to carry over into young children's ER activities as well.

The significant result of group processing groups scoring higher than the positive interdependence groups was revealing. Positive interdependence is one of the primary foundations of CL (Johnson & Johnson, 1999). It is the perception of failures and successes being intertwined. Groups demonstrated positive interdependence primarily through the self- organization of roles within a group. Groups frequently establish roles within the group where one student is the "engineer" and places all the pieces, while the other student is the "programmer" and directs the student. While studies have found that established roles positively affect robotics achievement (Taylor & Baek, 2018b; Nemiro 2020a; Nemiro 2020b), it seemed that within this study, it was not the case. It was common to see the engineer not contribute or contribute very little to the actual programming of the robots. They would often strictly deal with the pieces. This meant that while the engineer helped place pieces and was fully engaged in the challenge, they could not contribute knowledge to the solution. Cognitively speaking, this disadvantaged the group because, essentially, one student was thinking for the group. There was no collective knowledge being applied. This could be one explanation for the significant differences between the mean scores.

Generalization

The results showed that the mean difference between the scores of promotive interaction type groups ($\bar{x}$=42.75) and positive interdependence type groups ($\bar{x}$=27.20) was statistically significant. During the assessment and observations, it was noted that the positive interdependence groups appeared to have fewer verbal interactions, especially when compared to the group processing and promotive interaction type groups. Cheng et al. (2013) found that more interactions between group members during programming activities resulted in higher achievement. Promotive interaction groups also seemed to interact more than the positive interdependence group. This could be a contributing factor to the higher scores in the generalization category.

Another attribute of promotive interaction group types was that they tended to use a trial-and-error type approach. These groups did not have many discussions about the robotics task, but still had much success. Blanchard et al. (2010) found contradictory results when dealing with a group of elementary students in robotics activities. They found that groups that discussed and implemented classroom instructional strategies performed better than groups that would take a trial-and-error approach. These early challenges lacked complexity, and it could be a combination of the levels of interaction, the relaxed nature of the group, and the simplicity of the problem combined for higher achievement scores.

Algorithmic Thinking

In the algorithmic thinking challenge groups, the mean difference between group processing ($\bar{x}$=32.7) and positive interdependence ($\bar{x}$=10.22) was statistically significant. Group processing groups appeared to use more of the strategies taught in the robotics classes. Algorithmic thinking was taught to the students by telling them to think of the problem as two defined steps and sequences. In the first sequence, groups had to clear the obstacle, then move to the flag after the obstacle was cleared. Group processing groups had these types of discussions, as seen in Chapter 4, and were successful. As noted above, positive interdependence groups often did not have as much collective knowledge applied to the problems. Xia and Zhong (2019) also had similar findings in their primary school student robotics study. The researchers felt that it was difficult for primary school students to solve the more complex tasks independently, and they would be more successful if they could discuss and work with other students. The results from this study further demonstrate the effectiveness of group processing with more complex problems.

Implications

This study was conducted to understand more about the interactions between young children in ER, the relationship between these interactions and achievement, and the relationship between group structure and ER achievement. By understanding these aspects of ER, recommendations for instructional practices and pedagogies for teaching ER can be made. These recommendations can be used to create more positive experiences for young girls in ER, which is important for breaking down gender stereotypes and motivating women into entering the STEM fields (Sullivan & Bers, 2012; Screpanti et al., 2018). The findings from this study have led to some important implications.

Cooperative Learning Framework Suitable for Observation in ER

One important product of this study is that it has justified, documented, and piloted a suitable framework for observing interactions in elementary school ER classes and activities. Although other studies have observed interactions (Yuen et al., 2014; Cheng et al., 2013; Nemiro, 2020b; Jordan & McDaniels, 2014), few have deliberately sought to document, categorize, and analyze them. There is a need to understand the interactions occurring within the ER classroom to help inform instructional practices (Jung & Won, 2018; Lee et al., 2013; Kucuck & Sisman, 2017). The research conducted in this study has helped to fill this need.

This study has successfully utilized a new framework for observing interactions in young children's ER classes. The observation table and interaction documentation produced from this study provide a foundation for future research on group interactions. Using these interactions and frameworks, researchers and practitioners can further investigate interventions that could potentially impact the teaching and instructional practices of ER activities and classes.

Interaction Types Matter Depending on Task

The various types of interactions seen amongst the students affected the student's level of achievement. However, it is not as simple to say that one interaction type is more effective than another. There is nuance in the interaction types that should be encouraged depending on the activities.

Positive interdependence is one of the key elements of CL (Johnson & Johnson, 2002). These interactions were primarily seen through group self-organization into roles. In comparison to other interaction types, it did not appear to be a factor in achievement. Although studies with older elementary students have found roles to be effective (Taylor & Baekb, 2018; Witherspoon et al., 2016; Nemiro, 2020a; Neimiro, 2020b), they did not seem to have the same effect on younger students.

Promotive interactions were very effective when doing simpler, generalization-based challenges. Groups that were encouraging, polite, positive, providing praise, and playful had the highest achievement scores. A common method amongst the promotive interaction groups was trial and error approaches to solving robotics challenges. The students did not seem to be worried about failing a task because the nature of their group interactions was so positive and encouraging. This would imply that promoting young children to have fun, not be afraid to fail, and encourage and praise each other would be beneficial to increase achievement in simple robotics tasks that require generalization skills. Instructors and practitioners should try to create positive environments and find ways to facilitate young children to encourage, praise, and support each other when teaching basic generalization skills.

Group processing interaction groups performed the best in more difficult challenges that required algorithmic thinking. Groups that made planned out routes before even beginning their programming, had thoughtful discussions, tracked their progress, reflected upon their successes and failures, and adjusted were the most successful. As challenges become more difficult, promotive interactions do not affect achievement as much. This would imply that encouraging young children to talk and discuss their challenges before they begin would benefit achievement. Also, having children stop and discuss their progress during higher-level robotics activities that require algorithmic thinking could also be a beneficial instructional strategy. Instructors should find ways to create planning or reflection periods where children can evaluate their group's progress with higher-level challenges and designate time for group discussion. A summary of these recommendations can be found on Table 5.7.

Table 5.7 Recommendations for Teaching ER Skills

Type of Robotic Skill Being Taught	**Interaction Type to Facilitate**	**Recommendations**
Simple generalization skill challenges.	Promotive Interactions	*ER instructors should emphasize a positive atmosphere in the ER classroom that is fun, playful, encouraging, and freedom to fail.*
More advanced algorithmic thinking skill challenges	Group Processing	*ER instructors should emphasize and encourage group discussions, pre-planning before programming, having students pause and reflect upon their progress, and adjust their programming.*

Gender Groupings Affect Interactions, Not Achievement

As has been consistent with previous research, group structures in terms of gender does not seem to effect overall achievement in elementary school (Taylor & Baek, 2018b; Castro et al., 2018; Xia & Zhong, 2018; Cheng et al., 2013). This study saw no significant differences in achievement in the LoA, which considers all challenges and skills within the assessment. Previous studies primarily dealt with upper elementary students. This study now adds to the literature and consensus that gender does not seem to be a factor in achievement with younger children as well. It was observed, however that the types of gender groupings appear to affect the types of interactions.

Of the groups observed, the all-female groups primarily demonstrated promotive interactions. The all-male groups also primarily demonstrated group processing and promotive interaction types. The mixed groups appeared to show primarily positive interdependence and group processing-type interactions. In general, homogenous gender grouping created higher levels of interaction and more promotive interactions during the initial observations. The heterogeneous gender groups produced lower interaction levels compared to the same-gender and more group processing. From a practitioner's standpoint, intentional gender grouping could be an effective strategy if the goal is to produce specific types of interaction. If robotics teachers or instructors want to increase promotive interactions amongst students in the classroom, homogenous gender groupings could be effective. If practitioners want to create positive interdependence or group processing types of interactions, heterogeneous groupings could be a more effective grouping system.

Additionally, this study again solidifies that even at the youngest ages, gender does not impact achievement within STEM education. The gender disparities within the STEM fields are not occurring because of a lack of ability, as demonstrated in this study. Even at young ages, both genders can achieve equally in ER activities. Gender did not have an impact on the overall achievement.

Table 5.8 Recommendations for Creating Interaction Types

Desired Interaction Type	Group Structure	Recommendations
Promotive Interactions	Homogenous gender groupings.	*If ER instructors would like to facilitate more promotive interactions and higher levels of interactions in the classroom, homogeneous gender groupings could prove to be an effective group structure.*
Group Processing Positive Interdependence	Heterogenous gender groupings.	*If ER instructors would like to try and facilitate more group processing or positive interdependence types of interactions in the classroom, heterogenous groupings could be a more effective group structuring strategy.*

Limitations

One limitation of this study was that the amount of time with the students put some constraints on the assessment. The achievement could only be measured through one assessment. While the assessment was valid, it would have been more beneficial to do multiple assessments to get a more comprehensive data set of the student's full abilities. It is possible that certain groups could not have been performing to their full potential because of other factors.

This research was also limited to just one type of robotics technology. Students used tangible coding blocks from the Matatalab kits. This set does not require any physical assembly, and its programming process is straightforward. While this design is purposeful for the use of young children, the mechanics of the technology itself can limit the opportunities students have to work together. It is possible that other robotics kits may be more suitable for observing the interactions, but this was the only type of set available at the research site and in the learning context.

Another limitation might be that the interactions seen in these classrooms were specific to the context of Thai society. Some of the interactions seen amongst students were directly related to Thai language and cultural context. While the interaction types can be seen in classrooms around the world some of the specific interactions noted in this study will most likely manifest differently in other countries and contexts.

Future Research

The findings have the potential for new opportunities in future research. It has demonstrated that the types of interactions can affect achievement in robotics in young children. Future research into facilitating these types of interactions regardless of the group structure would help expand ER instructional strategies. Researchers could determine which teaching strategies will produce the different types of student interactions within both homogenous and heterogenous gender groups. A powerful, comprehensive approach could be created if instructors know how to produce specific interactions and which interactions are effective for different types of robotics challenges.

Future research should examine different age groups to see how interaction types affect older students. Knowing how the different interaction types can impact the various age groups and levels can help inform instructional practices further to produce maximum achievement at the different stages of ER learning. Creating effective pedagogies and instruction for students will continue to be essential to ER education. Student interactions are an important part of group achievement.

Conclusion

This study has contributed to the field of ER in a few different ways. First, it has provided a framework for observing young children's interactions in ER robotics activities. The adapted CLOP was based on prior research and effectively documented the interactions occurring within the elementary ER classroom. The study has observed, identified, and defined how the different interaction types manifest within ER activities. This framework and these observations will be helpful in future research.

The research presented has also revealed some valuable information for ER instructional practices. It was found that the type of interactions that occur within a group can affect the achievement of robotics activities. Moreover, the effect of the interaction type can vary depending on the type of ER skills and challenges being practiced. Instructors should consider focusing on facilitating promotive interactions as a primary interaction type when teaching simpler robotics skills that require basic generalization. Instructors should consider facilitating more group processing interactions during their activities if the goal is to teach more advanced algorithmic thinking challenges.

The research also found that group structure in terms of gender does not affect the overall level of achievement for young children in ER activities. However, observations revealed that the group structure did seem to affect the types of interactions among the students. Using homogenous gender groupings may be more effective when trying to create higher levels of interaction and promotive interaction types. The use of heterogeneous gender grouping might be more effective when promoting and facilitating positive interdependence and group processing types of interactions. Future research can build off this study by finding effective strategies for facilitating different types of group interactions regardless of group structure within the classroom.

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APPENDIX A

Cooperative Learning Observation Protocol Form

Cooperative Learning Observation Protocol Form

Class/Level		Date	
Observer		Instructor	
Group Structure (Male/Female/Mixed)		Level of Achievement Score	
Instructional Context.			
Group #/Name		Number of Students in Group	

Activity Log

Interaction Type Frequency		**Notes**
Group Processing		
Promotive Interaction		
Positive Interdependence		
Group Categorization		

APPENDIX B

Parent Permission Form

INFORMED CONSENT

Study Title: The Effect of Group Interactions and Group Structure on Achievement in Elementary School Robotics

Principal Investigator: Jonathan Yogi

Co-Principal Investigator/Faculty Adviser: Dr. Baek

Dear Parent/Guardian:

My name is Jonathan Yogi and I am the STEM teacher and coordinator here at Denla Primary School. What you may not know about me is that I am also a doctoral candidate at Boise State University, in America. I am asking for your permission to include your child in my research. This consent form will give you the information you will need to understand why this study is being done and why your child is being invited to participate. It will also describe what your child will need to do to participate as well as any known risks, inconveniences or discomforts that your child may have while participating. I encourage you to ask questions at any time. If you decide to allow your child to participate, you will be asked to sign this form and it will be a record of your agreement to participate. You will be given a copy of this form to keep.

PURPOSE AND BACKGROUND

As you know, DLPS strives to be one of the best STEM schools in the country. As a part of this students have a weekly robotics class. Normally, Mr. Vega and I co-teach these classes. As a part of my dissertation, I would like to take notes on the way that your child interacts with their classmates during our robotics activities and ask them to take a survey at the end of each class. This will help to develop our teaching practices and contribute to the field of educational robotics. This study will be conducted over two class sessions.

PROCEDURES

This study will include an observation of your child's normal classroom activities. They will not be asked to do anything that they would not normally do in robotics class. Your child has the choice to opt-out of the survey as well. If you choose not to allow your child to participate, they will remain in their classroom, but none of their interactions will be recorded, nor will they be asked to participate in the survey. No matter what decision you may come to, this will have no effect on your child's grade.

This study will take place over the course of 2 class periods starting from January 24th to February 4th, 2022. In each class, I will be an observer in the class while Mr. Vega teaches. I will take notes on your child's interactions with the other students in their robotics groups. No audio or video recordings will be made during this time. At the end of the class, students will participate in a short written survey.

RISKS/DISCOMFORTS

There is minimal risk to this study. Students will not have any experiences that are different from their regularly scheduled classes. They will only be asked to voluntarily take part in a survey.

EXTENT OF CONFIDENTIALITY

Reasonable efforts will be made to keep the personal information in your research record private and confidential. Any identifiable information obtained in connection with this study will remain confidential and will be disclosed only with your permission or as required by law. The members of the research team and the Boise State University Office of Research Compliance (ORC) may access the data. The ORC monitors research studies to protect the rights and welfare of research participants.

Your name or your child's name will not be used in any written reports or publications which result from this research. Data will be kept for three years (per federal regulations) after the study is complete and then destroyed.

BENEFITS

There will be no direct benefit to your child from participating in this study. However, the information gained from this research may help education professionals better understand how students engage with each other in robotics-based activities.

PAYMENT

There will be no payment to you or your child as a result of your child taking part in this study.

QUESTIONS

If you have any questions or concerns you should contact Mr. Yogi first or his advisor Dr. Baek at youngkyunbaek@boisestate.edu.

If you have questions about your rights as a research participant, you may contact the Boise State University Institutional Review Board (IRB), which is concerned with the protection of volunteers in research projects. You may reach the board office between 8:00 AM and 5:00 PM, Monday through Friday, by calling (208) 426-5401 or by writing: Institutional Review Board, Office of Research Compliance, Boise State University, 1910 University Dr., Boise, ID 83725-1138.

DOCUMENTATION OF CONSENT

I have read this form and decided that my child will participate in the project described above. Its general purposes, the particulars of involvement, and possible risks have been explained to my satisfaction. I will discuss this research study with my child and explain the procedures that will take place. I understand I can withdraw my child at any time.

____

____

Printed Name of Child

__________________________ ____________________________________

Printed Name of Parent/Guardian	**Signature** of Parent/Guardian	Date

Signature of Person Obtaining Consent ___________________

Jonathan Kimei Yogi

APPENDIX C

Head of School Permission Form

Denla Primary School
Nakhon In Frontage Rd
Nonthaburi, Thailand 11130
02 459 5656

September 15th, 2021

Dear Jonathan Yogi,

Based on my review of your proposed research, I give permission for you to conduct the study entitled *The Effect of Group Interactions and Group Structure on Achievement in Elementary School Robotics Classes* within Denla Primary School. I authorize you to observe, document, distribute student questionnaires, and interact with students and teachers in robotics classes as part of this study. Individuals' participation will be voluntary and at their own discretion.

We understand that our organization's responsibilities include: educational robotics technologies, a room for robotics classes, and a robotics teacher. We reserve the right to withdraw from the study at any time if our circumstances change.

The research will include observing classroom robotics activities, student questionnaires, and interaction with students and teachers. This authorization covers the time period of January 1st, 2022 to May 31st, 2022.

I confirm that I am authorized to approve research in this setting.

I understand that the data collected will remain entirely confidential and may not be provided to anyone outside of the research team without permission from the Boise State University IRB.

Sincerely,

____

Dr. Matthey Fahey
Head of School
Denla Primary School
matthew.fa@denlaschool.ac.th

APPENDIX D

Deputy Head of School Permission Form

Denla Primary School
Nakhon In Frontage Rd
Nonthaburi, Thailand 11130
02 459 5656

September 15th, 2021

Dear Jonathan Yogi,

Based on my review of your proposed research study entitled *The Effect of Group Interactions and Group Structure on Achievement in Elementary School Robotics Classes* at Denla Primary School, you are permitted to observe, document, distribute surveys, and interact with students and teachers in the Grade 1 robotics classes in accordance with the provisions and guidelines of the Nonthaburi Provincial Education Authority. During this time you must adhere to the following parameters:

1) Individuals' participation will be voluntary and at their own discretion.
2) Parental permission slips must be distributed, signed, and collected before the start of the study.
3) Students must understand that they are participating in the study.

The research may include observation of classroom robotics activities, surveys, and interaction with students and teachers. This authorization covers the time period of January 1st, 2022 to May 31st, 2022.

I confirm that I am authorized to approve research in this setting.

I understand that the data collected will remain entirely confidential and may not be provided to anyone outside of the research team without permission from the Boise State University IRB.

Sincerely,

____

Thanakrit Supsin
Deputy Head-Operations
Denla Primary School