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LEARNING WITH LEGO EV3 ROBOTICS FOR STUDENTS WITH ASD AND EMOTIONAL DIFFICULTIES IN A MIDDLE SCHOOL IN ILION, GREECE: A PILOT STUDY

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Abstract:
This study investigates the effectiveness of collaborative learning using LEGO EV3 robotics in a mixed abilities public middle school classroom in Ilion, Greece, consisting of typically developing students along with two students diagnosed with autism spectrum disorder (ASD) and social and emotional difficulties. This study uses a collaborative learning approach in which students work together in groups to complete tasks, with an emphasis on developing social and cognitive skills. The methodology includes an introductory two-week period in which students work on group assignments, followed by an eight-week period in which students build and program a LEGO EV3 robot. Data was collected through observation and interviews with students. The results show that the use of cooperative learning and LEGO EV3 robotics was effective in improving social and cognitive skills in students with ASD and social-emotional difficulties, as well as in the whole class. The class also created strong bonds through teamwork, and this helped all the children to improve their performance. The findings have implications for educators looking for innovative ways to engage students with diverse learning needs in the classroom.

Keywords: inclusive education, community building, collaborative learning, STEM

1. Introduction

Autism Spectrum Disorder (ASD) is a complex developmental disability that affects many aspects, such as social interaction, behavior and communication. Students with ASD may face challenges in the classroom, such as difficulty with communication, social skills, and sensory processing. Additionally, students with social-emotional difficulties

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may also experience challenges in the classroom, such as difficulty with self-regulation, attention, and social interactions (Raver & Knitzer, 2002).

Collaborative learning has been identified as an effective approach to address the needs of students with ASD and social-emotional difficulties in the classroom (Hume et al., 2009). Collaborative learning environments promote social interaction, communication, and problem-solving skills, which are essential for students with ASD and social-emotional difficulties (Bellini & Akullian, 2007).

LEGO EV3 robotics has also been used as a tool for teaching and learning, particularly for students with ASD (Bers et al., 2014). LEGO EV3 robotics can provide a hands-on and interactive learning experience that can be engaging and motivating for students with ASD and social-emotional difficulties.

Previous research has shown that using LEGO EV3 robotics in educational settings can have positive effects on students' social skills, problem-solving abilities, motivation, and interest in science and technology. Furthermore, studies have demonstrated the potential of LEGO EV3 robotics to improve communication, collaboration, and the overall educational experience for children with ASD.

2. A review of existing research on collaborative learning environments for students with ASD and social-emotional difficulties

Collaborative learning is a teaching method that encourages students to work together in groups to complete tasks and solve problems. This method has been widely used in the classroom to improve academic performance and social skills among students with autism spectrum disorder (ASD) and social-emotional difficulties. Several studies have investigated the effectiveness of collaborative learning for students with ASD and social-emotional difficulties.

One study examined the use of peer-mediated intervention to improve the social skills of children with ASD in inclusive classrooms (Kasari et al., 2012). The study found that children who received the intervention showed significant improvement in social engagement and initiations, as well as increased social responsiveness.

Another study found that cooperative learning approaches can be effective in promoting social interaction and collaboration among children with autism spectrum disorder (ASD) in both mainstream and special class settings (Grey et al., 2007). The study observed that structured group work and opportunities for shared decision-making within cooperative learning activities facilitated positive social interactions and improved social skills among the participating children with ASD. This inclusive approach fostered a sense of belonging and increased their engagement in learning activities, highlighting its potential for supporting the educational development of children with ASD in diverse classroom settings (Grey et al., 2007).

Another study (Dugan et al., 1995) investigated the use of cooperative learning to improve the academic performance of students with emotional and behavioral disorders.

The study found that students who participated in cooperative learning groups had significantly higher academic achievement scores than those who did not.

Moreover, a study (Moreno-Ger et al., 2008) explored the use of collaborative learning with technology-enhanced environments to improve the academic performance of students with ASD. The study found that the use of technology-enhanced collaborative learning environments significantly improved the academic performance of students with ASD.

In summary, collaborative learning is an effective teaching method for improving the academic performance and social skills of students with ASD and social-emotional difficulties. The use of technology-enhanced collaborative learning environments has also been shown to be particularly effective. These studies suggest that collaborative learning can be an important tool for promoting inclusion and improving outcomes for students with ASD and emotional difficulties in mixed middle school classrooms.

3. Overview of previous research on using LEGO EV3 robotics as a tool for teaching and learning, particularly for students with ASD and social-emotional difficulties

Research has shown that robotics can be an effective tool for teaching and learning for students with ASD and social-emotional difficulties. According to a critical review (Koller & Stoddart, 2021), incorporating approaches that promote social inclusion, such as utilizing LEGO EV3 robotics in a group setting, has shown positive outcomes in enhancing social skills and problem-solving abilities, and fostering interest in science and technology among children with disabilities, including those with autism spectrum disorder (ASD).

A study highlights the significant role of robotics in special education, shedding light on its potential benefits for students with disabilities and special educational needs. The findings underscore how educational robotics can effectively enhance various aspects of their development, including social skills, cognitive abilities, and functional capabilities. The study emphasizes the importance of carefully designing robotics programs tailored to meet the specific needs of individual students, considering the diverse range of abilities and characteristics among this population (Syriopoulou & Gkiolnta, 2021).

A study comparing two LEGO Robotics-based interventions for social skills training with children with ASD. The research findings highlighted the effectiveness of LEGO Robotics in promoting social skills development among children with ASD (Albo-Canals et al., 2013). The hands-on nature of LEGO activities, combined with the interactive and engaging aspects of robotics, provided a meaningful and motivating platform for children with ASD to practice and enhance their social interactions. Similarly, a pilot study on robot programming for a child with ASD (Gkiolnta et al., 2023), demonstrated the potential of robotics as a tool for promoting engagement and learning outcomes for individuals on the autism spectrum. These studies collectively emphasize

the positive impact of LEGO-based interventions and robot programming in supporting the social and educational needs of children with ASD.

Furthermore, robotics has been found to be a valuable tool for teaching mathematics to students with ASD and social-emotional difficulties. In a recent study (Kalaitzidou et al., 2023), it was discovered that the integration of LEGO EV3 robots in STEAM (Science, Technology, Engineering, Arts, and Mathematics) education proved beneficial for students with emotional difficulties. The utilization of these robots not only facilitated a better understanding of mathematical concepts but also significantly enhanced their motivation to learn, emphasizing the positive impact of robotics on the educational experiences of students with emotional challenges (Kalaitzidou et al., 2023). Overall, previous research suggests that robotics, particularly the use of LEGO EV3 robotics, can be an effective tool for teaching and learning for students with ASD and social-emotional difficulties, improving their social skills, problem-solving ability, and academic performance.

4. Purpose - Objectives - Research questions

The purpose of this paper is to explore the use of collaboration in a mixed middle school class, comprising one student with Autism Spectrum Disorder (ASD) and one student with social-emotional difficulties, utilizing LEGO EV3 robotics. The primary objectives of this study are to investigate the effectiveness of collaborative learning in enhancing the academic performance and social skills of students with ASD and social-emotional difficulties, as well as to examine how collaborative learning can foster a sense of bonding among all students in the class and facilitate the improvement of their social skills.

This project encompasses multiple objectives, including:

- To evaluate the effectiveness of collaborative learning in promoting the social and task engagement of students with ASD and social-emotional difficulties, thereby enhancing their overall educational experience.
- To assess the impact of collaborative learning on team bonding and positive social interaction among all students in the class, with a particular focus on fostering a sense of unity and cohesion.
- To facilitate the improvement of social skills and interactions for all students in the class, promoting positive peer relationships and creating an inclusive and supportive learning environment.
- To enhance the task engagement and social skills for both students with ASD and social-emotional difficulties, recognizing their unique challenges and addressing their specific needs within the collaborative learning framework, thereby promoting inclusivity within the classroom.

5. Methodological Framework

5.1 Participants and Sampling

The study took place in a mainstream public-school setting in Ilion, an urban neighborhood in Athens, Greece and involved 11 8th-grade students. The sessions occurred once a week during school hours and were held at the school's IT classroom. Each session had a duration of 45 minutes.

One of the students has been diagnosed by the Greek Central Health Council with ASD. He appears to have difficulty with social interactions, communicating appropriately and shows some signs of repetitive behavior when he is under stress. He has been assigned "parallel support" teachers during math and Greek classes. The student is mannerly but timid and avoids talking in the classroom, as he and his mother express worries that his classmates might make fun of him due to the student's atypical speech patterns.

The second student has been diagnosed by the same Institution with dysorthography and social and emotional difficulties. According to his diagnosis, the student *"...shows reduced interest towards his environment and people of his age since he does not mention any friends nor expresses a desire to enter friendly relations*".

During school staff meetings, teachers initially reported that both students showed minimal to no interest in actively or passively participating in social interactions within the classroom. Additionally, both students were observed to passively engage in tasks and displayed a lack of initiative in academic engagement.

The other participants, including the ASD-diagnosed student's twin brother, were typically developing adolescents. All the participating students were familiar with each other since they were classmates for two consecutive years.

6. Procedures and Timeline

The grouping of the students changed for each session and each group consisted of students of different genders and academic abilities thus giving them the opportunity to socialize with all their peers throughout the study.

The materials for the study included LEGO EV3 robotics kits, computers with programming software, geometry workbooks, measuring instruments and household materials.

At the beginning of each session, the rules of the classroom were read aloud to the participants. The rules included listening to each other, encouraging one another, avoiding shouting, or cursing, and being polite (Benton et al., 2012). Next, the members of each group were announced and received their assignment sheets with the instructions for the session project and the role assignment for each member of the group.

A. Weeks 1-2

In the first two weeks, the participating students were introduced to the concept of working in groups and engaging in collaborative tasks. One of the tasks involved the use of GeoGebra, a dynamic mathematics software. Additionally, to foster teamwork and problem-solving skills, the groups had to compete in "The marshmallow Challenge" (Daoudy & Verstraeten, 2013), a contest to build a tower using household materials such as spaghetti. Each group was timed, and the tower that reached the highest point won. The challenge is considered a team bonding activity (Neyem et al., 2014). These activities aimed to promote collaboration, communication, and critical thinking among the students.

B. Week 3-4

During these two weeks, the participants focused on the construction of the LEGO EV3 robot. They were divided into groups and began by opening the robot kit. To ensure effective assembly, the students watched instructional videos that provided guidance on building the robot. They also documented and organized the different parts of the robot. The students worked in their groups to complete the construction of their assigned robot components. Within each group, the students had specific roles assigned to them – architect, supplier, and builder (Nanou et al., 2021). As the groups progressed, the entire class collaborated to integrate all the parts and finalize the construction of the robot.

C. Week 5

During this week, the groups completed the construction of the LEGO EV3 robot, installed the software on the computers and familiarized themselves with the software interface and functionality.

D. Weeks 6-7

The students watched a tutorial on how to use basic commands to move the robot and had the opportunity to program the robot to perform specific tasks and solve challenges.

E. Week 8

The students were divided into groups, and each group designed a geometric shape on a piece of cardboard. They tried out their initial codes to move the robots on the cardboard shapes. They experimented with different commands and programming sequences to achieve the desired movements.

F. Week 9-10

The students watched videos demonstrating robot movement. They learned more advanced programming techniques and commands to create more complex behaviors for the robot and reviewed the codes they had written. They attempted to identify and correct any errors or issues in their programs and completed the robot's movement on the geometric shapes.

The following week, in a whole-class discussion, the students reflected on their experiences and achievements.

Throughout all the weeks, the team members had clear roles and assigned tasks, as well as written and oral instructions to guide them.

7. Data Collection and Analysis

Data was collected through direct observation of the students' behavior and interactions during group work and robotics activities.

Interviews were also conducted with the students to gather their feedback on the collaborative learning experience.

In the interviews, the data was analyzed using discourse analysis, a method that focuses on understanding language use and social interactions. The interview data was transcribed, organized, and analyzed to identify meaningful units and themes related to the effectiveness of collaborative learning, academic performance, and social skills of students.

For the observations, a content analysis approach was employed. This method involved systematically analyzing observational data to identify and categorize meaningful units, patterns, and themes. The observations specifically focused on two different students: one student diagnosed with ASD and the other student diagnosed with social-emotional difficulties. The data collected during the observations was transcribed or summarized, and key details and behaviors related to social engagement (social initiations or social responses), and task engagement (active or passive) were identified and categorized. Social initiations were defined as vocal, or motor behaviors addressed to a peer with the intention to elicit a positive response. Social responses were defined as vocal, or motor behaviors given in response to an initiation. (Grey et al., 2007). Active task engagement behaviors included writing, task involvement, reading aloud, talking about task, and answering related questions. Passive task engagement was defined as listening or observation of a lesson but without an apparent student reply (Grey et al., 2007).

By examining these specific aspects, the analysis aimed to gain insights into the dynamics of collaborative learning, social skills development, and class bonding for each of these individual students. The data collected during the observations was transcribed or summarized, and key details and behaviors related to social engagement (social initiations, social responses), and task engagement (active or passive) were measured for each of these students.

The methodology section of the research paper outlined the rigorous procedures followed to ensure credibility and transparency in the study. An independent researcher with expertise in the field was involved in the project to enhance the reliability of the findings. The researcher's qualifications and experience were detailed, highlighting their knowledge and understanding of collaborative learning approaches, autism spectrum disorder (ASD), and social and emotional difficulties. Ethical considerations were

carefully addressed, including obtaining informed consent from all participants and following ethical guidelines for research involving human subjects, including confidentiality and the protection of personal information.

The research design employed a mixed-methods approach, combining direct observation and interviews to collect comprehensive data. Data collection procedures were clearly described, outlining the protocols followed during the ten-week study period. The analysis techniques utilized were also specified, ensuring the systematic examination of the collected data. By adhering to these rigorous methodologies, the study aimed to provide accurate and reliable insights into the effectiveness of collaborative learning using LEGO EV3 robotics in the classroom.

8. Data analysis and presentation of results

8.1 Analysis of data collected through observation

A. Week 1

The student with ASD engaged in social responses but was passive in social initiations. He was talking with another student, and he was actively engaged in the task, trying to participate despite displaying some discomfort (staying behind his brother and stating that he didn't want to participate).

The student with social-emotional difficulties did not present with any prosocial behaviors. However, he was actively engaged in the task, making an effort to participate.

B. Week 2

The student diagnosed with ASD engaged in social responses but was passive in social initiations. He actively engaged in the task. He was answering his team's questions and he was holding parts for constructing the tower.

The student diagnosed with social-emotional difficulties engaged in social initiations and responses, talking to two different students, laughing with team members and responding to members of other teams. He actively and passively engaged in the task by asking for directions, cutting ropes and applying the tape.

C. Week 3

The student diagnosed with ASD did not engage in social initiations or responses. He followed his brother's lead, watched from the back, did not touch anything, but passively engaged in the task by observing other students' work.

The student diagnosed with social-emotional difficulties showed active social engagement, social initiations, and social responses. However, he was passive in task engagement, not actively participating in the task. He engaged in conversations with other students, responded actively, and laughed at jokes.

D. Week 4

The student diagnosed with ASD was not socially engaged. He was actively engaged in the task, asking questions regarding the pieces of the robot, looking for them and responding to other students' questions. Additionally, the student was passively engaged in the task, observing other team members' work.

The student diagnosed with social-emotional difficulties was engaged in social initiations and responses, talking to other teams' members, making jokes and laughing. The student was passively engaged in the task by observing other students' work but did not actively participate.

E. Week 5

The student diagnosed with ASD engaged in social initiations by talking to the student with social-emotional difficulties. He also engaged in social responses by laughing at other students' jokes. The student was engaged in the task both actively by looking for robot parts and answering questions and passively by listening and observing.

The student diagnosed with social-emotional difficulties did not engage in social initiations but was active in social responses by answering comments from members of other teams. He engaged in the task both actively and passively by using the computer to complete the task and observing other team members' work.

F. Week 6

The student diagnosed with ASD was passive in social engagement. He was consistently awkward, stayed behind his brother, and did not participate in the task. He was passively watching the video and his team members' work.

The student diagnosed with emotional difficulties showed active social engagement, social initiations, social responses, and task engagement. He engaged in conversations with group members while actively working.

G. Week 7

The student diagnosed with ASD was actively engaged in social initiations and social responses. He was actively talking and interacting with another student. He was also active in task engagement as he made significant efforts to program the robot.

The student diagnosed with social-emotional difficulties was active in social initiations and social responses as they played, made jokes, and laughed with another student who joined them during the project. However, he was passive in task engagement as he only played with the student and did not actively participate in the task.

H. Week 8

The student diagnosed with ASD was not active in social initiations but did engage in social responses as he was replying to his team members. He was engaged in the task

both actively by putting an effort into drawing a square and answering questions related to the task and passively by observing other team members' work.

The student diagnosed with social-emotional difficulties was active in social engagement, social initiations, and social responses. He actively engaged with his team, made jokes, and talked. Additionally, he was actively and passively engaged in the task by writing the code for the robot, listening and observing.

I. Week 9

The student diagnosed with ASD was passive in social engagement, as he only interacted with his brother. However, he was actively and passively engaged in the task by watching a video on how to program the robot and trying to replicate the steps.

The student diagnosed with social-emotional difficulties did not present social engagement. However, he was engaged in the task by actively writing code for the robot and passively watching the video.

J. Week 10

The student diagnosed with ASD did not engage in social initiations or responses. However, he was engaged in the task both passively by observing the other team members' work and actively: He answered questions about the code, replied to another team member, and re-adjusted the robot's position on the square.

The student diagnosed with social-emotional difficulties was active in social initiations and social responses as he had a full conversation with a member of his team. He was also active in task engagement, actively writing code for the robot and passively observing other team members' work.

K. Final Week

In a whole-class discussion where students reflected on their experiences and achievements, both students appeared awkward and initially reluctant to participate. However, they eventually answered questions when prompted.

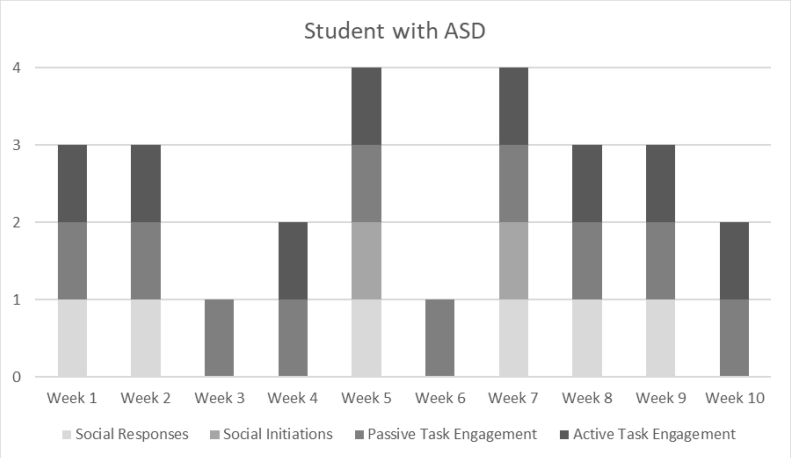

Figure 1: Weekly observations regarding the presence of social and task engagement of the student with ASD

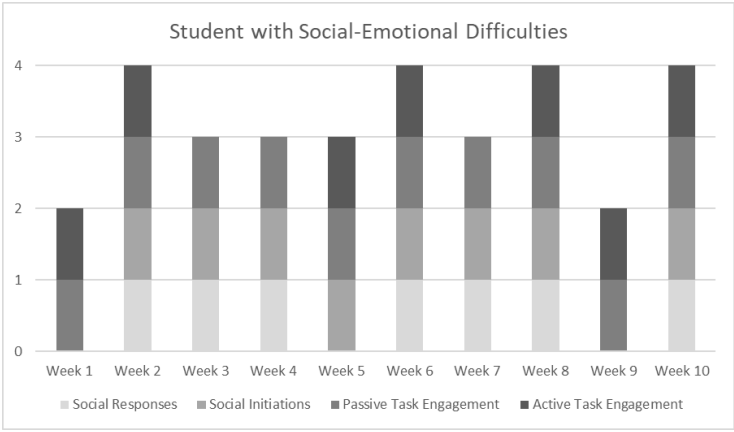

Figure 2: Weekly observations regarding the presence of social and task engagement of the student with social-emotional difficulties

8.2 Analysis of data collected through interviews

The discourse analysis of responses to the question "What was the most enjoyable thing about working in teams?" revealed recurring themes and strategies regarding the positive aspects of group work. Participants expressed satisfaction and highlighted various factors that contributed to their enjoyment.

Collaboration and teamwork were frequently mentioned (A3, A5, A6, A7, A9). Participants appreciated working together as a team, valuing mutual support and assistance (A5) and the sense of camaraderie that emerged (A6). Some also mentioned the benefit of sharing the workload (A6).

Achievement and witnessing successful outcomes were also mentioned (A2). Participants found joy in seeing their collective efforts come to fruition and emphasized the importance of shared goals (A2).

Learning and personal development emerged as positive aspects (A4). Participants recognized the opportunity to acquire knowledge, learn from others, and expand their skills through collaboration (A4).

Building relationships and social interactions were cited as enjoyable elements (A8, A10). Participants appreciated connecting with their peers, forming new friendships, and gaining insights into their classmates' characters (A8). Social dynamics and connections within the group contributed to a positive atmosphere (A10).

Participants also emphasized the support and assistance received from group members (A5, A7). They valued their peers' willingness to help overcome challenges (A5) and recognized the importance of mutual support in fostering collaboration, trust, and teamwork (A7).

In response to Q2 "What was the biggest challenge you faced?", the participants' responses (A1-A10) shed light on the diverse range of obstacles encountered and their perceptions of these challenges.

The challenges mentioned by participants encompassed various aspects of the project. These included programming difficulties, such as grappling with the complexity

of programming (A1) and struggling to understand and implement programming instructions (A2). Achieving specific robot movements, such as maneuvering the robot on a predetermined path, emerged as a significant challenge (A3).

Time pressure and the desire to complete the project quickly were identified as challenges (A4), leading to the need for effective time management within the given timeframe. The pressure to meet project objectives also contributed to feelings of anxiety and stress (A5).

Participants expressed concerns about the value and relevance of their ideas, fearing their contributions might not be deemed useful or that their team's performance would be compromised (A6). Additionally, collaborating with uncooperative team members posed a challenge (A10), requiring effective communication and conflict resolution skills.

Technical challenges related to programming, such as programming the robot to execute a specific turn (A7), sourcing necessary components for the robot (A8), and installing required software (A9), demanded problem-solving abilities and resourcefulness.

In the discourse analysis of responses to Q3 "Did you feel comfortable expressing your ideas and opinions within the team?", participants shared their experiences and attitudes towards expressing themselves in the team. The analysis (A1-A10) reveals varying comfort levels and willingness to share thoughts in a group setting. Some participants had limited participation due to a lack of ideas (A1), while others felt discomfort and fear (A2). Concerns about idea usefulness and potential annoyance hindered expression (A6). However, some participants felt very comfortable sharing ideas (A7, A3, A4, A5, A8, A9), attributing it to team cooperation (A3) and a supportive environment. They emphasized the value of freely expressing thoughts without shame (A4) and the presence of familiarity, respect, and friendship within the team (A5, A8). Expressing ideas within a team was seen as fostering better outcomes (A9) and collaborative success.

Based on the responses of the participants to question 4, which addresses the effectiveness of teamwork in learning, we once again observe a variety of answers. Some participants stated that teamwork did not help them learn more effectively, possibly due to interruptions and noise (A1, A2, A4). Conversely, other participants mentioned that teamwork was very helpful and assisted them in learning things they wouldn't have learned on their own (A3, A6, A7). Additionally, some participants prefer collaborating with their classmates and believe that teamwork yields better results and contributions from all members (A5, A9, A10). According to their perspective, teamwork entails a pleasant and easier process as they are not alone and can listen to multiple opinions and better comprehend the subject matter (A8). Lastly, certain participants emphasize that teamwork helped them get to know their peers better, uncovering their weaknesses and strengths (A10).

Based on the responses of the participants to question 5, which pertains to how they feel they contributed to the team, we can observe a range of answers. Some

participants mentioned that they contributed by writing the instructions (A1), collaborating with their sibling on the square design (A2), providing ideas and suggesting various actions (A3), and utilizing their sociability (A4). Others mentioned that they made efforts to help the team in any way, whether practical or psychological, by encouraging and persuading their teammates not to give up (A5). Participants also expressed that they felt their contributions were valuable when they motivated others or received positive feedback for their ideas (A6). Additionally, some participants mentioned that they contributed by bringing new ideas to the team and providing encouragement (A7), offering psychological support (A8), expressing their opinions and ideas (A9), and taking on the responsibilities assigned to them (A9).

However, it's worth noting that one participant did not provide a response to this question (A10).

Based on the responses to question 6, which asks whether participants felt they improved their social skills while working in teams, we can observe a variety of answers. Some participants indicated that they did not feel they improved their social skills to a great extent (A1, A2). One participant mentioned that they were already sociable, so they did not feel a significant change (A3). On the other hand, several participants expressed that they felt they had fulfilled their social skills while working in teams. They mentioned reasons such as collaborating with others (A4), believing that their social skills improved significantly and that they became more sociable and open to their classmates (A5), and acknowledging that it depended on the individual they worked with (A6). Additionally, participants mentioned that they felt they fulfilled their social skills by working with all the children in the team (A7), engaging in discussions with their teammates (A8), not being afraid to express their opinions and collaborate with other children (A9), and learning about their strengths (A10).

Based on the responses to question 7, which asks what participants learned about programming and robotics, we can observe a range of answers. Some participants indicated that they did not learn anything new (A1). Others mentioned specific skills they acquired, such as using the robot to make turns and follow a shape (A2), understanding the importance of concentration and attention (A3), and recognizing the difficulty involved in programming and robotics (A4).

Several participants expressed that they learned a lot about programming and robotics. They mentioned valuable and interesting things they learned, such as assembling a robot and creating various things (A5), understanding that programming involves giving commands and selecting the correct ports (A6), learning about collaboration in a team, and constructing and programming robots (A7), discovering the existence of many intriguing things to learn (A8), realizing that programming and robotics require a lot of thinking and are based on mathematics (A9), and acquiring knowledge through activities like construction, assembly, and movement programming of the robot, as well as watching various videos (A10).

Based on the responses to question 8, which asks whether the project helped participants develop their critical thinking skills and problem-solving abilities, we can observe the following patterns.

Some participants indicated that the project did not significantly contribute to the development of their critical thinking and problem-solving skills. They mentioned that they were simply following instructions without actively thinking about them (A1) or stated that the project did not help them in this aspect at all (A2).

On the other hand, several participants expressed that the project had a positive impact on their critical thinking and problem-solving abilities. They mentioned that they started analyzing things and generating ideas and solutions to problems (A3). Some participants also emphasized that they learned new things through the project, which contributed to their personal growth (A4). Others noted that the project required hard work and effort, and it helped them develop problem-solving skills not only within the project but also in their daily lives (A5). Participants highlighted the importance of collaboration and considering others' opinions in developing their critical thinking skills (A6).

Additionally, participants mentioned that the project taught them the value of perseverance, patience, and effort in achieving their goals (A7). Some participants simply confirmed that the project helped them develop their critical thinking skills and problem-solving abilities without providing specific details (A8).

Based on the responses to question 9 regarding participants' experience collaborating with their team members, several patterns emerged.

Some participants expressed a positive collaboration experience, either with a simple "yes" response (A1) or by specifically mentioning successful collaborations with certain individuals (e.g., their brother and Lefteris) (A2).

A few participants believed they collaborated effectively with their team members (A3), although they initially faced challenges and arguments with specific individuals (A4). However, they recognized the value of teamwork and the importance of building better relationships (A5).

One participant acknowledged themselves as the problem in every team they worked with (A6), while another honestly admitted to not collaborating well with all team members (A7).

Some participants highlighted positive collaboration experiences with friends, allowing for freedom of expression (A8). Others mentioned mostly good collaboration but difficulties with a few team members (A9). One participant acknowledged the challenges of collaborating due to different personalities and opinions but recognized moments of perfect teamwork (A10).

Overall, the responses indicate a mix of positive and negative experiences in collaboration within the teams. While some participants enjoyed smooth collaboration, others faced challenges or conflicts in effectively collaborating with all team members.

Based on the responses to question 10, participants shared various suggestions for changes if they were to do the project again. Some expressed satisfaction with the project

and wouldn't change anything (A1, A2, A10). Others mentioned the importance of avoiding rushing and taking more time (A3), modifying team formation (A4, A7), prioritizing collaboration (A9), allocating more time or diving deeper into certain aspects (A5), adjusting the team structure (A6), or having a larger robot (A8). These suggestions encompass aspects such as time management, team dynamics, collaboration, individual preferences, and project-specific elements. Incorporating these insights can enhance future iterations of the project and improve participants' overall experience.

In conclusion, the analysis of responses to the questions highlights the multifaceted nature of working in teams and the diverse experiences encountered by participants. The findings underscore the positive aspects of group work, including collaboration, achievement, learning, social connections, and support, which align with the idea that working in teams can be enjoyable (Tsay & Brady, 2010; Li & Lam, 2013). The analysis also reveals the challenges faced by participants, such as programming difficulties, time constraints, and dealing with team dynamics. Furthermore, the analysis identifies variations in comfort levels when expressing ideas within the team, influenced by factors like cooperation, respect, familiarity, and belief in the benefits of sharing ideas.

This aligns with the notion of cooperative learning and the importance of communication pedagogy (Tsay & Brady, 2010; Li & Lam, 2013). Opinions on the effectiveness of teamwork for learning vary among participants, with some recognizing its value in enhancing learning outcomes and promoting social interaction, while others face challenges. These findings correspond to the case study of cooperative learning and its impact on student performance (Tsay & Brady, 2010). The contributions made by participants to the team encompass a wide range of activities, demonstrating their active involvement and commitment to the team's success. The varying experiences in social skill development, learning in programming and robotics, and the perceived benefits for critical thinking and problem-solving skills align with other research (Kilty & Burrows, 2022). Additionally, the analysis reveals diverse experiences in collaboration within teams, reflecting the complexities of team dynamics and interpersonal relationships. This resonates with the concept of cooperative learning and its influence on collaborative interactions (Li & Lam, 2013). The suggestions for improvements provided by participants, such as refining team structures and fostering better collaboration, align with the exploration of effective teams in other research (Kilty & Burrows, 2022). Overall, the analysis of responses to the questions aligns with the other research, highlighting the positive aspects and challenges of working in teams and emphasizing the importance of personal and interpersonal development within the context of cooperative learning and effective teams in informal settings.

9. Discussion / Analysis

Throughout the observation period, both the student diagnosed with ASD and the student diagnosed with social-emotional difficulties demonstrated unique patterns of engagement in social interactions and task participation. The student diagnosed with

ASD consistently displayed active social responses but tended to be passive in social initiations. However, he actively engaged in the assigned tasks, making efforts to participate despite feeling awkward at times. His involvement varied from actively answering team questions, holding parts for construction, and searching for robot components, to watching instructional videos for programming. This aligns with research findings that highlight the active social responses and task engagement displayed by individuals with autism (Bellini & Akullian, 2007; Bers et al., 2014).

On the other hand, the student diagnosed with social-emotional difficulties exhibited active social responses and social initiations. He actively participated in conversations, laughed with team members, asked for directions, and actively worked on tasks. However, his level of task engagement varied, with instances of active involvement in writing code, while also being passive at times, primarily engaging in playful interactions with team members. This pattern of engagement resonates with research on social-emotional difficulties and cooperative learning, emphasizing the importance of active social interactions and collaborative efforts (Grey et al., 2007; Dugan et al., 1995).

Overall, both students demonstrated their willingness to engage in social interactions and task-related activities, despite facing challenges. While the student diagnosed with ASD relied on social responses and task engagement to contribute, the student diagnosed with social-emotional difficulties actively engaged in social interactions but had fluctuating levels of task engagement. This highlights the individual differences in engagement and social skill development within a team setting (Kasari et al., 2012; Neyem et al., 2014). The fluctuation of social initiations and active task engagement observed may have been related to team reassignments.

As mentioned before, at the beginning of the school year, teachers reported that the student diagnosed with ASD and the student diagnosed with social-emotional difficulties exhibited limited social engagement and some passive engagement in the classroom. However, following the completion of the project, teachers observed and reported significant improvements in the everyday social interactions of both students, with a notable focus on the student diagnosed with social-emotional difficulties. Teachers noted that the student began actively trying to communicate not only with peers but also with teachers in the classroom. This positive change highlighted the student's newfound willingness to engage in meaningful conversations and interact with others.

In conclusion, the discourse analysis of the responses to the various questions provide valuable insights into participants' experiences with teamwork, challenges faced, comfort levels in expressing ideas, the effectiveness of teamwork in learning, contributions to the team, improvement of social skills, learning outcomes in programming and robotics, development of critical thinking and problem-solving abilities, and collaboration within the team. Participants' experiences align with previous research on the benefits of teamwork, including collaboration, achievement, learning, social connections, and support (Raver & Knitzer, 2002; Tsay & Brady, 2010).

Challenges encountered by participants ranged from technical difficulties to time pressure, anxiety, concerns about idea validity, and collaborating with uncooperative team members. These challenges required problem-solving skills, effective time management, and overcoming personal and interpersonal obstacles. This resonates with previous research on the complexities of teamwork and the need for adaptive strategies to address challenges (Moreno-Ger et al., 2008; Albo-Canals et al., 2013).

Comfort levels in expressing ideas and opinions varied among participants, influenced by factors such as cooperation, mutual respect, familiarity, and belief in the benefits of expressing ideas. This aligns with research emphasizing the importance of a supportive and collaborative environment for fostering comfort and participation (Li & Lam, 2013; Kilty & Burrows, 2022).

The effectiveness of teamwork in learning was perceived differently by participants, with some highlighting reservations and challenges, while others found teamwork highly valuable for knowledge acquisition and fostering better understanding through diverse perspectives and collaborative efforts. This reflects the varied experiences and perceptions of participants, as documented in previous studies (Hume et al., 2009; Kalaitzidou et al., 2023).

Participants demonstrated active involvement and made various contributions to the team, reflecting their willingness to contribute to the team's success. These contributions included providing instructions, collaborating with others, offering ideas, motivating and supporting teammates, expressing opinions, and taking on responsibilities. This aligns with research highlighting the importance of active engagement and contributions within a team context (Benton et al., 2012; Daoudy & Verstraeten, 2013).

Regarding social skills, participants had diverse experiences, with some reporting enhanced sociability, openness, and better collaboration, while others felt they did not experience significant improvement. This reflects the individual differences in social skill development within a team setting, as highlighted in previous research (Syriopoulou & Gkiolnta, 2021; Kasari et al., 2012).

Participants had varied learning experiences in programming and robotics, with some not reporting any new learning and others acquiring specific skills and knowledge related to robot assembly, programming, collaboration, and problem-solving. This underscores the interdisciplinary nature of these fields and the importance of hands-on activities for learning (Kasari et al., 2012; Bers et al., 2014).

The project had varying impacts on participants' critical thinking and problem-solving abilities, with some not perceiving significant development, while others mentioned outcomes such as analyzing, generating ideas, perseverance, collaboration, and considering different perspectives. The project also taught participants the value of perseverance, patience, and effort in achieving their goals, aligning with previous research on the development of critical thinking and problem-solving skills through project-based learning (Dugan et al., 1995; Moreno-Ger et al., 2008).

Collaboration within the team was perceived positively by some participants, while others experienced challenges, conflicts, and instances of ineffective collaboration. The importance of getting to know and understand each other better was recognized as beneficial for effective teamwork, emphasizing the significance of team dynamics and interpersonal relationships (Benton et al., 2012; Daoudy & Verstraeten, 2013).

In summary, the observations and analysis shed light on the unique patterns of engagement, challenges faced, learning outcomes, and social skill development of the student with ASD and the student with social-emotional difficulties within a team context. The findings align with existing research on teamwork, social-emotional difficulties, and autism spectrum disorder, providing valuable insights for educators, researchers, and practitioners in the field of inclusive education and collaborative learning.

10. Conclusion

The observation period emphasized the willingness of both students to engage in social interactions and task-related activities, despite the challenges they faced. These findings underscore the importance of providing appropriate support and accommodations to facilitate their active participation in collaborative learning experiences. By recognizing and addressing their individual strengths and challenges, educators and practitioners can effectively support the learning journey of students diagnosed with ASD and social-emotional difficulties, fostering their overall growth and development within a team context.

The discourse analysis of the responses provides a comprehensive understanding of participants' experiences with teamwork, challenges faced, contributions made, and the impact on their learning, social skills, critical thinking, and problem-solving abilities. The findings underscore the significance of collaboration, support, and a positive team environment in achieving successful outcomes and personal development within group settings.

The findings suggest that providing a supportive and inclusive learning environment can enhance the engagement of students with autism and social-emotional difficulties. Tailoring instructional strategies to accommodate individual needs and promoting peer interactions can further foster their social and task participation. By recognizing their unique strengths and challenges, educators can effectively support their learning journey and facilitate their overall growth and development.

11. Limitations

The study has a few limitations that should be considered.

Firstly, the sample size was relatively small, which may limit the generalizability of the findings to other populations. Additionally, the study was conducted over a relatively short period of time, preventing the assessment of the long-term effects of the

collaborative learning experience. It is worth noting that the student diagnosed with ASD and his twin brother participated in the same team to ensure the autistic student's comfort and willingness to engage in the activities. Despite these limitations, the study provides valuable insights into the immediate impact of collaborative learning for students diagnosed with ASD and emotional difficulties.

Conflict of Interest Statement
The authors declare no conflicts of interest.

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