Group Tasks, Activities, Dynamics, and Interactions in Collaborative Robotics Projects with Elementary and Middle School Children

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Abstract

Robotics provide the opportunity for students to bring their individual interests, perspectives and areas of expertise together in order to work collaboratively on real-world science, technology, engineering and mathematics (STEM) problems. This paper examines the nature of collaboration that manifests in groups of elementary and middle school students attending a summer robotics camp. The research study provides a preliminary look at the tasks, activities, dynamics and interactions of the students that occur during the collaborative work time of the camps. Findings detail the role of discussions and hands-on robot building as important predictors of on-task behavior during collaborative work time.

Keywords: robotics, collaboration, group dynamics, engineering education

Background

In order to increase student engagement in science, technology, engineering and mathematics (STEM) fields, it is imperative that children increase their time working with concrete STEM tasks in collaborative groups, similar to the way engineers and scientists work in real-world settings. Robotics is often used to provide STEM experiences for children in a manner that is concrete, authentic, accessible and motivating (Cannon, et al., 2007; Mukai, Watanabe, & Jun, 2005; Verner, Waks, & Kolberg, 1997). In addition to providing a tangible and observable platform (the robots) to learn about STEM concepts, children also learn how to work in collaborative groups. Real engineering problems are often complex and involve a diverse team in terms of expertise. As an engineering activity, robotics is interdisciplinary and easily lends itself to collaboration. Robotics has the potential to bring together people from various disciplines and fields to work on a single project (e.g., De Vault, 1998; Kitts & Quinn, 2004). The many and diverse aspects of robotics address a wide variety of interests and capabilities. Computer-savvy team members can focus on the programming aspects of robotics. Those who enjoy kinesthetic and hands-on experiences can construct the components of the robots and the team members who are more interested in the structure and materials can focus on engineering the design of the robot. True collaboration is recursive. It involves team members whose abilities and skills complement each other as well as build on each other in order to realize a shared goal or solve a shared problem. Though such collaboration is ideal, what actually happens when children attempt to solve an engineering challenge collaboratively? How well do they actually work together? What group roles and individual task preferences emerge? This study is a preliminary examination of the nature of collaboration when children are working together on collaborative robotics projects by observing their engagement with the different aspects of robotics.

Review of Literature

Collaborative Learning

Collaboration is important to the learning process because it brings together multiple perspectives, ideas and abilities. The complexity of engineering problems often requires many different sets of skills and knowledge, which can best be addressed collaboratively. Such collaboration results in a broader and deeper understanding of the problem space. Learners become aware of how their own strengths (as well as their own weaknesses) and interests complement those of their group members, and devise ways in which everyone's strengths and expertise can be capitalized upon to reach a richer solution than that of a solo learner. Within a social constructivist framework, learning is viewed as a social process and meanings are made through interactions with people and artifacts that are situated within an authentic environment (Palincsar, 1998). As a knowledge building tool, collaboration elicits discussion and peer interaction which helps to identify areas of growth, while also providing opportunities for learners to support each other through information sharing and problem solving (Sullivan, 2011). Therefore, true collaboration requires active participation and dialogue among the group members.

The social environment necessary for collaboration provides a network of support, which can result in positive affect towards robotics, motivated learning and a higher sense of self-efficacy. Students engaging in collaborative activities may have a higher sense of self-efficacy with respect to the content area they are studying, particularly in the fields of science, math, engineering and technology (Bowen, 2000). Stump's (2011) study of collaborative learning in engineering courses reported that students felt they learned more content by working collaboratively because they could discuss, question, work and learn together with their peers. Despite the positive reports found surrounding collaborative learning, drawbacks are found when collaboration is unsuccessful.

When collaboration is problematic, learning experiences revert to situations that resemble individual work because of the inability of group members to take turns effectively (Barron, 2003). In these cases, the cognitive advantage of having multiple people with different expertise is diminished. For instance, students who have difficulty collaborating with others indicated they did not learn as much nor had the positive experiences as those classmates that did collaborate successfully (Haller, Galagher, Weldon, & Felder, 2000). Thus, collaboration goes beyond putting students in a group environment. If the quality of collaboration is correlated to learning outcomes, then groups must also learn how to work together effectively towards a shared goal. Often, groups form naturally because of a shared interest. Group members may voluntarily collaborate because they have past experiences working well together (e.g. former group members, friends, etc.). Unfortunately, it is not always possible for such ideal groupings to occur, or group members find changes in dynamics from past experiences because of different combinations of people, roles and tasks. Collaboration goes beyond simple cooperation where group members do their assigned tasks and work well together, such as in the Jigsaw method (Johnson & Hyde, 2003). Collaboration is about the integration and synthesis of every group member's ideas and expertise. Large engineering projects must consider a wide range of perspectives, be it theoretical, environmental, financial or legal, to find an optimal solution. In order for collaboration to exist, groups must have established procedures for interactions.

Group Dynamics

Groups must have a purpose for existence and a structure for how activities are conducted and coordinated (Savin, 1988; Shaw, 1976; Thelen, 1949). Thelen (1949) proposes that in order for a group of people to accomplish a goal, they need to have the ability to complete the tasks and have the socialization skills necessary for them to coordinate their efforts. Thelen suggests that group members need to be able to coordinate and complement each other instead of obstructing themselves from accomplishing the goal. An ideal group would have members working on parts in which they have the most strength and experience. An example of this would be the Jigsaw method where each group member has separate individualized tasks to work on before bringing it back to the whole group (Johnson & Hyde, 2003). All members must be active participants who support each other in order for the group to succeed.

When assigning roles, group members must be aware of each other's strengths (in order to take advantage of them) and weaknesses (so others can offer support and guidance). Knowing an individual's ability also influences the roles he or she may take on in the group, thus affecting the responsibilities and tasks assigned. There is a process of negotiation among the group in which roles are determined (Johnson & Hyde, 2003). Since this approach requires group members to have individualized tasks, individual accountability to the group becomes important (Savin, 1988; Shaw, 1976). That is, success relies on the group's ability to work together to complete the task. Thus, all group members must be held individually responsible for their assigned tasks so that they can adequately contribute to the group goal. In collaborative robotics projects, group members work together in constructing a robot. As described above, group members may be assigned the roles of builder, programmer or tester. Each group member has his or her own role and tasks. There are procedures and rules that guide how group members work together. For example, the tester's tasks cannot be done until the builder is finished constructing the robot and the programmer is finished programming. This dependence on other group members creates a sense of accountability for each individual. The final robot cannot be completed unless all group members have completed their tasks successfully, on schedule, and in full collaboration with each other.

The sense of individual accountability within the group establishes a key component of the fundamental knowledge structure for collaboration (Johnson & Hyde, 2003). The group members can support and motivate each other, building a sense of team pride and camaraderie. This group pride may motivate the group to protect each other and become competitive with other groups who share a common challenge like a robot build-off. The group pride functions as a motivational tool. As robotics projects and courses are used as learning and motivational tools in social contexts, it becomes necessary to explore the types of group dynamics and interactions that emerge from collaborative robotics projects.

Research Questions

This study seeks to understand the nature of collaboration in collaborative robotics projects. The research questions are:

1. What group tasks, activities, dynamics and interactions occur during collaborative robotics projects?
2. What group tasks, activities, dynamics and interactions predict on-task behavior in collaborative robotics projects?

Methods

Setting

This study was conducted at a summer robotics camp at a large university in Texas in 2011. The camp offered one-week camp sessions in robotics throughout the summer. Children were divided up by grade level: 3rd-5th (elementary) and 6th-8th (middle school). Camp instructors utilized a combination of direct instruction and learner-centered activities. The LEGO Mindstorms NXT Robotics Kit was used during the camp. Instructors spent the first part of the morning teaching children how to build, incorporate sensors, and program a robot. Instructors would then assign the children to groups for independent practice on the day's lesson. Each group would work together to apply the new knowledge to the building, programming, and testing of its own collaboratively constructed robot. Daily projects included getting the robots to move a certain distance before turning, following lines using light sensors, and activating motors when touch sensors were triggered. At the end of the day, each group would test their robots on an obstacle course, in a battle, or in another comparable challenge against the robots of the other groups.

Sample

Eighteen groups were observed over two full camp sessions (26 females and 44 males). Camp sessions were each five full days, and groups were composed of different children each session. There were 15 elementary groups and three middle school groups. Most groups had four students while there were three groups of three and one group of five. Instructors reassigned groups in the middle of the week at least once for each camp session. Therefore, some of the data may include multiple observations of the same children. Group changes were done in order to allow the children to engage with different members of the camp. Group roles were also reassigned throughout the camp to allow every group member an equal chance to work on a different aspect of robotics.

Instruments

Researchers completed a Group Observation Form (GOF) while observing the participants working within their groups. The GOF was designed by the researchers to capture information related to children's observable behaviors and different types of interactions that occur in collaboration while they worked on the robotics projects. The GOF categories were:

- On-task behavior – A child is measured on his/her on-task, off-task, and over-tasked behaviors. On-task behavior is described as a child working on the assigned robotics project. Off-task behavior is described as a child not doing anything related to the assigned project. Over-tasked behavior is described as a child doing more than his/her share of the work. An example of over-tasked behavior a child taking over for another child in addition to having his/her own work to do. These three options were mutually exclusive.
- Current task – These are the individual tasks in robotics: building the robot, programming the robot, testing the robot in the competition arena, debugging the robot, observing any robotics-related activities in the classroom, designing and planning that is directly related to the robot, and discussing or talking about any topic. These are also referred to as phases in robotics (building, programming, testing).
- Hands-on – The child is touching a robot or its parts, the computer, or nothing. A robot's parts may include parts of the competition venue such as obstacles and items the robot must grab.

- Grouping – This describes any sub-grouping that occurs within the group. This includes whole group, small group (such as a pair-work) and solo/independent work. These three options were mutually exclusive.
- Exclusion – A child may be excluded by his/her group, may choose to exclude himself/herself or may not be excluded at all. These three options were mutually exclusive.
- Interaction – Interaction denoted any communication or other interactions between a child and others. Others may include his/her own group, other children outside the group, or an instructor.

Prior to this study, the researchers conducted classroom observations of other children at this camp for approximately three weeks. The researchers frequently observed that the group dynamics and interactions seemed to have an effect on the students' projects and robots. The items of the GOF represent a countable range of behaviors and types of interactions gleaned from the collective observations throughout the study. Categories 1, 2, and 3 represent the robotics tasks (phases of robotics) and activities while Categories 4, 5, and 6 represent the group dynamics and interactions.

Procedures

In teams of two, researchers observed each participant for 10 minutes as s/he worked collaboratively within his/her group. Observational data was collected on the GOF. Two researchers were used in order to ensure that data collected on the GOF was reliable. Inter-rater reliability was calculated using the collected data from the GOF. Momentary Time Sampling (MTS) was used to structure the observations. The 10-minute period was divided up into one-minute intervals with the first 15 seconds being designated for observation and the remaining 45 seconds for recording the data the GOF and making miscellaneous annotations. Any occurrence of the items on the GOF during the first 15 seconds was recorded. The 10-minute interval was a continuous block of time. The researchers had no control over classroom operations. If the class had to break for lunch or a field trip in the middle of a participant's observation, the 10 minute observation was invalidated and a new 10 minute observation was initiated upon the return of the participant. At the onset of data collection, it was difficult for the researchers to get a 40-minute continuous block of time (or 50 for groups of 5) throughout the week because of periodic breaks, change in scheduled meal times and regroupings. There were occasions in which observations of a group had to be discontinued because instructors would regroup all participants in the middle of an observation. The data associated with these partial observations was rendered unusable for the purposes of analysis and were discarded. Eventually, the researchers found the optimal time to observe continuously without interruption.

In order to conduct observations in a non-intrusive manner, without disrupting the natural flow of activity and group interactions, the researchers observed the participants from the perimeter of the classroom space. The researchers observed the participants from a distance such that they were not obtrusive to the natural interactions between children, but close enough that they could see the behaviors and hear verbal exchanges. Total observation time for the 18 groups amounted to 13.3 hours.

Reliability

One-third of the data collected from the total GOFs were used to calculate the k (kappa), which measures inter-rater reliability and agreement (Cohen, 1960; Harrop, Foulkes, & Daniels, 1989). In this study, k was calculated between the two observers' for each time sample and item on the GOF for each child. Suen and Lee (1985) recommended the use of k instead of a percentage agreement index because agreement indexes are less reliable because of a lack of taking "chance agreement" between raters into account. With k = .80, it can be concluded that there is statistically significant inter-rater reliability in their observations (Landis & Koch, 1977). Though there were two observers for each child, only scores from one of the rater pairs were used for analysis. The first and fourth authors' observations were used. They did not conduct their observations together, but all 18 groups were observed by either the first or fourth author.

Results

The first research question explored types of group tasks, activities, dynamics and interactions that occur during robotics projects. In order to answer this question, a summary of all the tasks, activities, dynamics, and interactions observed (Table 1) is provided as a context for the group work. These are the items found in the categories indicated on the GOF. Each item on the GOF was compiled for each participant as a percentage of occurrences during the 10-minute observation period. Only complete observations that constituted the entire 10-minute period were included in the final analysis. Field notes taken by the researchers during observations were used to support the results.

Variable	Mean	Median	SD
	On-Task Behavior		
On-task	82.0	100.0	26.3
Off-task	17.0	0.0	26.0
Over-task	0.9	0.0	7.2
	Current Tasks		
Building	19.1	50.0	31.4
Programming	7.1	0.0	14.4
Testing	6.7	0.0	14.4
Debugging	2.6	0.0	8.5
Observing	44.1	50.0	30.7
Planning	3.6	0.0	13.7
Discussing	38.7	40.0	2.67
	Hands-on Activity		
Hands on robot	40.7	40.0	35.1
Hands on computer	16.7	10.0	25.8
Hands on nothing	43.9	45.0	34.2
	Grouping		
Whole group	54.1	60.0	34.6
Small group/Pairs	30.7	20.0	32.3
Independent/Individual	13.6	0.0	21.8
	Exclusion		
Excluded by group	1.1	0.0	7.3
Excluded self	10.4	0.0	24.9
Not Excluded	87.1	100.0	26.8
	Interaction Targets		
Within group	86.0	100.0	26.2
With others	9.4	0.0	22.8
With instructors	4.4	0.0	7.9

N = 70 children, 18 groups

Table 1. Frequency of Tasks and Activities (as a % of times in the 10-minute observation)

The children were mainly on-task (M=82) while working on the robotics projects and occasionally off-task (M=17). Very seldom were children observed going above and beyond their own tasks (M=0.9). The tasks that the children were mostly involved in during the robotics projects were observing activities and events within and outside their groups (M=44.1), discussing ideas with their group members (M=38.7), and building the robot (M=19.1). Programming, testing, and planning were the least observed tasks. Examples of on-task behaviors, as observed by researchers, include children who were building the robot, gathering parts to assemble the robot, programming the robot through use of the computer, testing the robot on the challenge course, discussing the current task with group members, and observing tasks being done by other group members or other groups.

For the hands-on activity, the children were observed with their hands on a robot for building and testing (M=40.7) and hands on a computer for programming (M=16.7). The children were frequently observed with their hands on nothing (M=43.9). That is, they were not physically touching the robot or the computer. Again, this may have been a result of children having to share the robot and computer within their group as well as roles each child assumed. Those children that did not have a current task assignment ended up observing or discussing the task with others most times.

Next, the nature of the group dynamics and interactions that surrounded the tasks and activities are discussed. In terms of grouping, the children mostly spent their time physically in their whole groups (M=54.1). Children sometimes worked in smaller groups or pairs (M=30.7) and independently (M=13.6) when they needed to work on separate tasks concurrently. Such small group and independent tasks include searching for parts around the classroom, observing other groups, testing the robot, or building an attachment or appendage to be integrated into the larger robot. Each child mostly interacted with his/her group members (M=86). The children would interact with others outside their group (M=9.4), usually to gain assistance. The children rarely interacted with instructors (M=4.4) since most groups worked independently only asking instructors for help in the most dire situations. Few explicit exclusionary behaviors were displayed in which a student either excluded others or excluded him/herself. There was no exclusion (M=87.1) most of the time. There were four cases in which a child was excluded by group (M=1.1). In terms of gender, two of those children were part of the gender majority while two were the only one of their gender in their respective groups. There were 19 children that excluded themselves from the group (M=10.4) during the observation. A common example of self-exclusion was when children left their groups for the purposes of observing other groups' work. This occurred when the child was waiting for his/her turn to do a task.

The second research question examined how group tasks, activities, dynamics and interactions predict on-task behavior in the collaborative robotics activities. On-task behavior is an indicator of engagement. When students have the freedom to choose on which task to focus, they are more engaged in dynamic learning activities. As students are able to better manipulate their own on-task behaviors, they become engaged in learning objectives at higher levels (Laurillard, 1987). Therefore, on-task behavior can be used as a dependent variable to examine the effects of individual children's tasks, activities, interactions and dynamics on on-task behavior with respect to a robotics activity. A stepwise multiple regression found four predictors for on-task behavior ($R2 = .516$, $F(4, 65) = 11.513$, $p < .001$): observing ($B = .538$, $p < .001$), building ($B=.521$, $p < .001$), testing ($B = .473$, $p = .006$), and hands on computer ($B = .244$, $p = .008$). Table 2 shows the final model of the stepwise regression with the included variables. Observing and building was discussed earlier as two of the more frequent tasks observed by the researchers. Despite a low percentage of occurrences, testing was a significant factor in the regression model, which could be explained by the fact that testing the robot on the course is clearly an on-task activity. Since the overall outcome of the project is constructing a robot that functions correctly, the robot must be thoroughly tested in order for it to be successful.

Variable	B	Std Err.	Beta	t	Sig.
CONSTANT	4.102	.664		6.178	.000**
Observing	.538	.094	.628	5.698	.000**
Building	.521	.093	.623	5.598	.000**
Testing	.473	.179	.259	2.643	.010*
Hands on computer	.244	.099	.239	2.455	.017*

	Sum of Squares	df	Mean Square	F	Sig.
Regression	197.886	4	49.472	11.513	.000**
Residual	279.314	65	4.297	-	-
Total	477.200	69	-	-	-

*p<.05, **p<.001

Table 2. Stepwise Regression Results

Discussion

Identifying Common Tasks/Activities and Group Dynamics/Interactions

Children were mostly on-task while working on their collaborative robotics projects. There may be some underlying explanation of what facilitates their on-task behavior, such as intrinsic interest in robotics or the extrinsic motivation to win the competition. The data showed that the children were mostly engaged in observing, discussing, and building over programming, debugging, testing, and planning. The least observed tasks are vital activities in engineering design (planning and testing) and computing (programming and debugging). If an instructor knows that students are less likely to engage in programming tasks, for example, then she may be better able to direct students towards these activities by closer monitoring, more explanation, changing groups/roles, or emphasize the importance of those tasks in STEM.

Children were also usually physically located within their entire group with few exceptions and interacting within their group. Children were rarely observed willfully excluding a single member, and individuals were not often observed excluding themselves from the group, which implied that most children were willing to be part of the group.

Part of the robotics process was to wait for one's turn with the robot and/or computer. Rather than waiting, the children could have been doing off-task activities such as talking with others, playing around with the computer or leftover parts, etc. Instead, most children waited patiently and observed the others. Sullivan (2011) also reported this process of observation occurring in group robotics projects. Sullivan's findings suggested that the observations were influential on decision-making. In this study, the children observed activities for the purposes of gathering information and returning those results back to the group for further problem solving. This was an example of simple cooperation in which students worked well together did the necessary tasks so they would succeed in their projects, but only as far as making their contributions when needed. Collaboration would require children to work together even when it is on a task that is not part of their main responsibility. It was not until the testing phase in which more discussions from all group members took place, that is, in true collaboration rather than cooperation.

Discussion plays a large role in collaborative projects as the main method of communication. The children engaged in discussions with others on topics relating to outcomes of test runs, ideas for improving the robot, and strategies for winning the competition, and non-related subjects. This was mostly done during the testing sessions in which groups would take their robots onto the course and do a trial run. The tester—or the "driver" of the robot—would report back the results to the rest of the team so they could devise the next steps for the robot and/or its program. Children would occasionally observe other groups' robots and programs to collect information. The results from these "reconnaissance missions" would inform their own robot designs and programs.

Building is an important part of robotics since robots require a physical structure. Since there were no significant correlations between building and any group interactions and dynamics, it could be suggested that building was not part of the collaborative process. The children were interested in building and spent more time with their hands on the robot rather than the computer. A study on using robotics in the K-12 system in conjunction with the university setting had similar results in that the children were far more interested in the building of the robot than the programming involved in the robotics curriculum (Soares, Riveiro, Lopes, Leao, & Santos, 2011). Programming the robot seems to be a secondary task to building. Again, this may have to do with an emphasis on the physical nature of robotics or the fact that the children are more interested in building the robots rather than programming it. Soares et al. (2011) reported that after engaging in a robotics camp, the children identified building as the task they liked most and programming ranked last when asked which part of the overall camp they enjoyed most.

In terms of group dynamics and interactions, the children generally worked as groups to complete the tasks. Robotics concepts are a new and interesting topics to many students which prompted students to communicate with more purpose than in regular activities (Karna-Lin, Pihlainen-Bednarik, Sutinen, & Virnes, 2006). Despite having random groupings, students were rarely exclusionary toward each other, which may have facilitated the collaborative processes. So it could be that the competition aspect could be a form of team building. Johnson and Hyde (2003) also found that competition could be a factor in collaborative tasks when one of their subjects purposefully withheld materials during a task so that they could be the first ones to finish the project. Group members mostly stayed in their groups, interacted with each other, and at least attempted to include all participants within the group. In summary, there was a strong sense of team among the group members, because of the common goals of finishing the robots and winning the competition. And, though they worked well together, collaboration occurred mainly in the testing stage when the robots would do trial runs.

Predictors of On-Task Behavior

If students were on-task, they were working on their robotics projects. Part of the purpose of this study was to discover what aspects of the collaborative robotics projects kept children engaged. Four significant factors were found to predict on-task behavior: observing, building, testing, and hands-on computer. Observing and building were two of the more frequent tasks in which the students were involved. As discussed above, observing was not just a passive task; observing was also part of the collaborative process. Observing was a task done while waiting for one's turn. Observing also enabled students to participate in collaborative problem solving as students returned to their groups with their observations of either their robot testing or other groups' efforts. Building was an expected predictor for on-task behavior. Students rarely built parts that had nothing to do with the robot. Interestingly, discussing the tasks with others was the second most occurring task, yet it was not a significant predictor. This may indicate that off-topic discussions and conversations were related indirectly to the robotics project. Though it had a low rate of occurrence compared to other tasks and activities, testing the robot was still a significant predictor of on-task behavior. With the overall objective of trying to win the competition, students must make sure the robot works correctly and effectively on the course; and only thorough testing can assure a competitive robot. Testing allowed students to see if their efforts in both the building and programming were correct and effective. This testing, building, programming sequence is more complicated than it first appears (Sullivan, 2011). Hands-on computer is a significant predictor of on-task behavior despite having a low rate of occurrence. This finding may be explained by a low occurrence of programming, which meant that students were usually only on the computer if they were programming. Conversely, having hands-on robotics was not a significant predictor. This may be surprising in that robotics is often a physical activity, yet physical interaction was not always on task.

Limitations

Only 18 groups were observed during this study, and most of those observations were of the elementary students. Another limitation of this study is the groupings changed at least once in the middle of the week by the instructor. The researchers did not anticipate such group changes until observations commenced. Furthermore, the researchers were not able to track the children as they moved to other groups since they did not acquire any identifying information from each child. Since the researchers were guests of the camp, they did not have any say on how the instructors structured their camps. However, a change in groups allowed researchers to observe new dynamics and interactions during the allotted daily observation times. If a student was observed more than once, it was within a new set of circumstances: the student was working with a new group of peers and a new set of activities.

It would be interesting to see how students contribute to or change the group dynamics and interactions given individual personalities, knowledge and skill sets. An upcoming study will take a more in-depth look at how each child works in groups during robotics activities and tasks. In this study, the researchers will be able to follow each child as they work on collaborative robotics activities even if they change groups as well as interview them to ask about their beliefs and reflections on collaboration in robotics activities. The researchers will use the GOF items as a basis for observing interactions and interviewing children. Future studies may include a more controlled setting in which the groupings are static for the entire camp session, yet still allow for naturally occurring group dynamics and non-intrusive observations.

Conclusions

By observing the most frequent tasks, activities, group dynamics and interactions, we can begin to understand the nature of collaboration when the objective is to design and construct a robot. As a learning experience, collaborative robotics projects are engaging for students, and solicit questions regarding the nature of collaboration. There is the distinction between cooperation and collaboration whereas the latter is about working well together and collaboration usually generates a synthesis of ideas. Were students merely peacefully cooperating with each other or was there actual collaboration that resulted in a synthesis of ideas? Where cooperation will allow children to reach a goal, collaboration will help them to become creative thinkers and problem solvers who understand their own strengths and how to respect the strengths of others. Teachers must understand difference between assigning cooperative group projects and facilitating collaborative group projects.

The implications from these findings not only make a case for using collaborative robotics projects to motivate children to take an interest and learn with STEM fields, but they also inform educators about the types of tasks, activities, dynamics, and interactions that occur when children are collaborating in robotics projects. These findings may also guide how educators design their collaborative robotics projects with respect to social, cognitive, and affective outcomes. STEM educators may be particularly interested in using these findings in order to facilitate collaboration and increase time on STEM tasks for children. Educators may take note of which tasks students were more engaged in and which tasks students were less engaged in, in order to mitigate these "outlying" tasks when presenting an engineering challenge to students. While there are easily identifiable implications for STEM educators, the findings can inform all fields of education. This study shows how using robotics can help introduce a collaborative component into education where children are not used to working together. It also introduces the importance of collaboration in the learning process for children. This need for collaboration will not only be of interest to teachers of all subject areas and designers of curricula, but also to those who may design classrooms and schools to better facilitate group work and collaborative activities.

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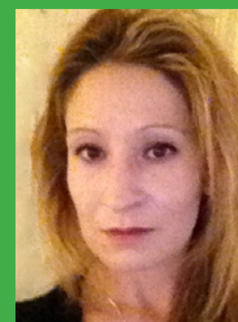

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