5-2019

The Impacts of Teaching Specific Engineering Group Processes to Cooperative Learning Groups in a Middle School STEM Classroom

Mollly Gareis
St. Catherine University

The Impacts of Teaching Specific Engineering Group Processes to Cooperative Learning Groups in a Middle School STEM Classroom

Submitted on May 6, 2019

in fulfillment of final requirements for the MAED degree

Molly Gareis

St. Catherine University

St. Paul, Minnesota

Advisor Natasha Yates Date April 25, 2019

Abstract

This action research investigation studied the impacts that teaching specific group processes to cooperative learning groups had on students' success in a middle school STEM classroom. The participants of this study were fifth grade students enrolled in a STEM course. During the five weeks of this study, students were explicitly taught how to create accountability and interdependence in their cooperative learning groups by learning about specific group roles and communication strategies. Data was collected through weekly self-reflections, videos, teacher observations, daily exit slips, and pre- and post-assessments. The results of this study indicated that students were more engaged in their tasks, gained better understanding of certain portions of the engineering design process, and created positive interdependence within their groups. Because of these conclusions, the researcher suggests the following courses of action: utilizing pre- and post-assessments to help determine students' content understanding, specifically teaching group roles and interdependence strategies, allowing for student reflection, and monitoring learning groups for accountability and interdependence.

Keywords: cooperative learning groups, group processes, engineering design process, interdependence, accountability, engagement

The world today is entirely connected. New technologies have made communication with the rest of the globe commonplace, and new careers are being created daily that require this global communication. In fact, nearly all 21st century careers require communication, collaboration, and teamwork. Because of this progression in the professional sector of society, educators need to help their students develop new "21st century" skills.

Teaching pedagogies, curricula, and courses themselves have changed to help teach students the 21st century skills that will be required of them once they enter the workforce. A focus on critical thinking, collaboration, creativity, and communication has been emphasized along with the incorporation of science, technology, engineering, and mathematics (STEM) in many school systems. This focus has encouraged teachers to adapt to a new style of teaching in which students work more closely with one another in teams, utilize more communication skills, and are given more accountability for their learning.

While creating classrooms where students collaborate and communicate is essential to developing 21st century skills and a deeper understanding of content, teachers do not always explicitly teach students how to successfully collaborate and communicate with one another. If students do not understand how to work cooperatively, effectively communicate, or be a productive team member, then learning groups are not serving the purpose for which they were intended, and students are not developing the desired skills. With direct instruction on collaboration and communication, students can gain the tools they need to be successful in groups and teams thus, increasing their understanding of 21st century skills.

As courses in STEM become increasingly popular in school districts, there is a greater need for students to understand how to work collaboratively. This skill is essential to be successful throughout students' academic careers and beyond. However, there is much debate over how cooperative learning groups should operate within a classroom, resulting in a need to evaluate how groups are formed and their roles in student learning. Particularly, how students create interdependence and accountability within groups needs to be addressed. With that in mind, the research questions guiding this study are as follows:

1. In what ways, if at all, does teaching group processes to 5th grade cooperative learning groups affect their opinions of group work?
2. In what ways, if at all, does teaching group processes to 5th grade cooperative learning groups affect their engagement when working in groups?
3. In what ways, if at all, does teaching group processes to 5th grade cooperative learning groups affect their overall understanding of the engineering design process (EDP)?

Theoretical Framework

Two theories provide the framework for this action research: social interdependence theory and 21st century skills. Social interdependence theory has changed over time. Originally developed by Morton Deutsch (1949), the theory states that the success of a group is dependent on the way its members work together towards a common goal. Within the group's interactions, there are often both positive and negative interdependence. Positive interdependence results when the actions of individual group members benefit the group, resulting in the achievement of the group's common goal. Negative interdependence results when the actions of individuals prevent or limit the success of the whole group (Deutsch, 1949; Johnson & Johnson, 2009). Ultimately, the accomplishments of a group depend on the interactions between each member, and the group's level of success is dictated by how those members interact (Johnson & Johnson, 2009).

The social interdependence theory creates the framework for cooperative learning groups. This theory states that an "intrinsic state of tension in group members motivates movement toward the accomplishment of the desired common goals" (Johnson, Johnson, & Smith, 2007, p. 29), Johnson, et al. (2007) address the idea that student groups are more motivated to reach their goals when each member is reliant upon the other. When individual goals are impacted by the actions of others, students are more willing to do their share of the group work and fulfill their role (Johnson, et al., 2007, p. 29). To ensure that groups are effective and attain this social interdependence, it is essential for educators to understand cooperative learning and its benefits, review prior methods used in creating groups, and teach the group processes that make cooperative learning successful.

Twenty-first century skills also influenced this action research project. 21st century skills do not center on content, but instead focus on teaching students the life and career skills that will prepare them to participate in a global society. These skills are commonly referred to as the 4C's and include critical thinking, communication, collaboration, and creativity (P21, 2019). Teaching these concepts promotes literacy in civic, financial, health, and environmental issues and helps to create global awareness (P21, 2019).

Social interdependence theory suggests that students who have specific roles and understand the importance of accountability to one another in cooperative learning groups will see more success because they are working towards a common goal (Johnson & Johnson, 2009). STEM students in this study were observed to determine whether learning about social interdependence causes them to be more successful in their learning and comprehension of the engineering design process. The 21st century skills of critical thinking, communication, collaboration, and creativity were also observed throughout this research. To be successful in cooperative learning groups, STEM students need to be able to communicate and collaborate in a positive way and to establish the interdependence necessary to succeed as a group.

Review of Literature

Cooperative learning groups are critical components of a successful classroom. While many teachers use student groups for instructional purposes, not all groups are beneficial to student learning (Johnson & Johnson, 1999). For instance, in pseudo-learning groups students do not want to be working together, and competition develops within the team (Johnson & Johnson, 1999; Johnson & Johnson, 2000). Traditional learning groups are ones in which students accept that they must work together but do not necessarily see themselves as a cohesive unit. When working in these types of groups, certain students may take control of every task while others may become uninvolved completely. Higher achieving students often cannot reach their full potential in groups with this dynamic (Johnson & Johnson, 1999). According to extensive research by Johnson & Johnson (1999), cooperative learning groups differ from traditional learning groups in that the students are working collectively towards the same goal with the understanding that their role in the group will impact the success of others. In this formation, students work hard to discuss content with one another and ensure that each member understands the material. These cooperative groups result in higher performance and achievement for all students (Johnson & Johnson, 1999).

While cooperative learning is described in many ways, an agreed-upon definition is students working together towards a shared goal. In this style of learning, each member understands their role in meeting that goal (Johnson & Johnson, 2000; Johnson, et al., 2007; Palincsar & Herrenkohl, 2002; Fong, 2010; Felder & Brent, 2016). While students are working together to achieve a goal, there are also five key characteristics that need to be present for a cooperative learning group to be successful. First, positive interdependence, in which students are collaborating and relying on one another, is crucial (Johnson, et al., 2007; Johnson & Johnson, 1999; Felder & Brent, 2016). While this interdependence is critical, it is also necessary for individual students to be held accountable within the group. The instructor can do this via the assessment and grading of the group (Finelli, Bergom, & Mesa, 2011). Additional factors in maintaining a healthy cooperative learning group include: allowing for productive group discussion and information processing to occur, building and teaching strong social skills to each group member, and allowing the opportunity for positive face-to-face interactions to occur (Finelli, et al., 2011).

When cooperative learning groups include the above characteristics, there are many benefits for students. Finelli, et al. (2011) reported that students had increased levels of retention and were able to access higher order thinking skills when they were a part of a cooperative learning group (Johnson, et al., 2007). Students also learn more material overall and develop skills such as accountability, giving feedback, and supporting the learning of others. (Johnson, et al., 2007; Johnson & Johnson, 2000; Felder & Brent, 2016). When students are in a productive, cooperative learning group, they are actively engaged in learning, and the amount of disruptive behavior decreases (Johnson & Johnson, 1999). Benefits of cooperative learning move beyond the classroom and into the social lives of students. Students who work in cooperative learning groups see an improvement in their social skills, report higher levels of social support from their peers, and demonstrate higher levels of self-esteem (Johnson, et al., 2007).

Because of its many benefits, educators have used many strategies to create cooperative learning groups and incorporate this style of teaching into their classrooms. This is especially true in STEM classrooms, where cooperative learning and collaboration are important skills

(Cheng, Lam, & Chan, 2008). Some specific strategies used in past practices to create cooperative learning groups include grouping by gender and ability (Dasgupta, Scircle, & Hunsinger, 2015; Schnitka & Schnitka, 2016).

Gender-based grouping in STEM fields has had mixed results in the literature. According to Dasgupta, et al. (2015), female students in engineering were positively impacted by groups that were composed of more females than males. The female learning experience was more positive when male students made up the minority of the group than when males were the majority. Female students felt that they were more challenged and less threatened in female-dominant groups (Dasgupta, et al., 2015).

Despite the above findings, a study of middle school students in an engineering course by Schnitka and Schnitka (2016) showed how gender-norms are present in cooperative learning groups composed of different ratios of male and female students. When the group was composed of all male students, hierarchies based on capabilities emerged. In the mixed-gender groups, students delegated tasks to one another based on each member’s skillset. In blended groups, both genders were able to change their mode of interaction based on how other members of the group responded. However, girls tended to change their mode of interaction more than their male counterparts (Schnitka & Schnitka, 2016). In mixed-gender groups, girls seemed to change their style of interaction to be less collaborative and more independent, indicating that girls tend to overcompensate to gain power (Schnitka & Schnitka, 2016). Overall, for all students to make gains in a cooperative learning setting, groups should be of mixed genders, thus supporting the concept of using a mixed-gender structure when creating learning groups (Schnitka & Schnitka, 2016).

Educators have also created cooperative learning groups based on students' abilities and cognitive skills. Just as the literature provides conflicting viewpoints related to gender-based groups in STEM, there is also a discrepancy in the literature regarding the use of ability-based groups. According to Cheng, et al. (2008), in groups with a mixture of abilities, low achieving students receive help from high achieving students, and in return, those high performing students can elaborate on the content. However, other studies contradict this idea (e.g. Robinson, 1990; Hooper & Hannafin, 1988). As ability level changes, the benefits of mixed-ability grouping changes as well. High achieving students do not benefit as much from heterogeneous groups as much as low achieving students (Hooper & Hannafin, 1988). Low achieving students perform best when in mixed-ability groups and middle-achieving students perform best in groups with students of similar abilities (Cheng, et al., 2008).

Because of these discrepancies and gaps in the literature, it is difficult to determine whether creating groups based on ability or gender benefits all students. Claims can be made for both mixed and similar groupings, with benefits and pitfalls for each (Barkley, Cross, & Cross, 2014). A change in focus needs to be made to determine a strategy for creating cooperative learning groups that benefit all types of students. Instead of focusing on what students make up cooperative learning groups, educators need to focus on how cooperative learning groups function. Before they create groups, teachers must ensure all students understand that using specific processes within their groups will make their learning more successful. "We cannot just put children into groups and expect them to work well together" (Blatchford, Kutnick, Baines, & Galton, 2003, p. 164). Students must be taught social and communication skills prior to engaging in group work (Blatchford, et. al., 2003; Felder & Brent, 2016). For example, teaching students how to become interdependent and how to create an environment where students respect one another's perspectives positively affects academic performance (Fong, 2010). Communication skills, like learning how to build ideas on one another's ideas, are another vital factor in successful cooperative learning groups because the ability to communicate encourages collaboration among students (Rudnitsky, Barclay, & Binger, 2017). Teaching students to ask questions, understand and accept new perspectives, and provide evidence for their thinking are skills that will improve group experiences (Rudnitsky, et al., 2017).

In addition to teaching social and communication skills, educating students on how to take on different roles in their learning groups is critical for success (Cheng, et al., 2008). For example, teachers can define tasks that eliminate the unequal distribution of work within groups and require the participation of all students. Leadership can be rotated throughout the group to allow students to take on different responsibilities, resulting in better cooperation and higher achievement (Finelli, et al., 2011; Felder & Brent, 2016; Barkley, et al., 2014). The idea that students are being held accountable for their work and for completing their tasks for the success of the group needs to be taught to ensure students understand their importance (Finelli, et al., 2011).

Cooperative learning groups are those in which students work together towards a common goal. This type of learning is critical in STEM, as collaboration, critical thinking, and creativity develop through cooperative learning. Cooperative learning groups benefit students positively when developed properly. Grouping strategies that have been discussed in the literature include basing groups on ability and gender. However, there are inconsistent findings related to the success of both kinds of learning groups. Results of various studies have demonstrated that only certain students benefit from these types of cooperative learning groups. Explicitly teaching students the processes of creating interdependence, delegating tasks through group roles, and holding one another accountable can create cooperative learning groups that are helpful to all students. These strategies will be the focus of the action research presented in this paper.

Methodology

The population for this action research study was fifth grade students attending a middle school in a small, Midwestern city in the United States (N = 122). The sample was approximately 40 fifth graders, comprised of 20 males and 20 females, enrolled in a STEM class during the second trimester of the year. STEM is a required class that meets every other day for the duration of a trimester and the sample is representative of the 5th grade population.

The *Teacher Observation Chart* was used to record observations regarding on-task behavior, positive anecdotes, and behavioral redirections to record accountability and interdependence in groups (Appendix A). The charts were used daily to monitor each cooperative learning group throughout the lesson. The *Flipgrid Video Reflection* was used each week to gather data on group understanding of the engineering design process and collaboration (Appendix B). In these videos, students answered prompts regarding their use of the design process as well as positive and negative things that happened throughout the week. The *Critical Thinking Rubric* was used to analyze the videos. Each week, students also completed a self-reflection (Appendix C). This *Weekly Self-Reflection* was an online questionnaire referencing student opinions of group work and collaboration and its importance in learning (Appendix D). These reflections were scored using a Likert scale (strongly agree, agree, disagree, strongly disagree). Daily *Student Exit Tickets* asking students to reflect on their cooperative learning group, how engaged each member was, and any questions they may have that day regarding STEM were collected (Appendix E). Finally, an *Engineering Pre- and Post-Assessment* in the form of an online quiz was given to assess student understanding of the engineering design process (Appendix F). These short answer questions asked students to explain the design process, work through examples of using the method, and explain why it is essential in engineering.

A specific procedure was used to conduct this action research using the data collection instruments described. Students were assigned a random ID number (to ensure anonymity) and a cooperative learning group number. Students took an engineering pre-assessment related to the engineering design process. This pre-assessment assessed student understanding of content before group interventions were implemented. Students then filled out a weekly self-reflection. This provided data about student opinions on group work. Students filled out this reflection weekly so that changes in mindset and opinions related to group work could be documented. Specific group processes were then taught using videos and a Google Document presentation. Students learned about the roles they would have during the project, how to keep each other accountable, and how to create interdependence in their learning groups. Once group roles had been assigned, students learned about and used the engineering design process using a Project Lead the Way robotics curriculum. Specifically, students designed and created a toy using VEX kit materials following a given set of criteria and constraints. As students worked in groups, the teacher observed student engagement and recorded this data on a teacher observation chart. Approximately five minutes were spent observing every cooperative learning group each day. At the end of each class period, students filled out the student exit slip. At the end of each week, groups created a Flipgrid video reflection related to group processes and collaboration skills. The teacher analyzed these videos using a critical thinking rubric. At the end of the unit, students took an engineering post-assessment (identical to the pre-assessment) to determine students' growth in content knowledge related to the engineering design process.

Analysis of Data

The student weekly self-reflection generated both qualitative and quantitative data. The quantitative data included responses to eight Likert scale statements. Students responded to each statement on a scale of 1 (strongly disagree) to 4 (strongly agree). This was completed once a week over a five week period. The answers were broken down into weeks and then sorted numerically. The amount of responses in each category on the scale were counted and then converted into a percentage to account for any student absences each week. Percentages for each of the eight questions over five weeks were then compared to help determine if student opinions regarding group work changed over time.

The weekly self-reflection included two open-ended, short answer questions which generated qualitative data. These questions asked for students' opinions regarding the best and most difficult parts of working in a group. Answers from each week were coded into common themes and tracked over the five weeks. The number of responses from each theme was tallied to compare how student opinions of group work changed over five weeks.

At the end of each class period, students filled out a daily exit ticket. The two main questions analyzed were:

1. What was one thing that I contributed to my group that showed my individual engagement in the task today?
2. Was everyone engaged in today's group activity? If yes, give an example. If not, what can be done to make it better?

Answers to these questions were coded and placed into the following categories: positive interdependence examples, negative interdependence examples, positive engagement examples, and negative engagement examples. The same type of coding system used for the weekly self-reflection was used to categorize the exit ticket data. Additionally, this same coding process was used to code the observations made by the researcher on the teacher observation chart. These categories were then compared across multiple data collection tools to determine any emerging patterns over the course of the data collection period.

A weekly Flipgrid video reflection was created by each group to discuss the following topics: how the group used the engineering design process, what went well that week, and what were some struggles. As the researcher watched the videos, the engineering design process responses were evaluated using a critical thinking rubric that ranked understanding on a scale of 1-4 for each step of the design process. The scores were then averaged into a weekly average. Rubric scores for each group were compared to determine how critical thinking scores may have changed over time.

Students took the same assessment two times (pre- and post-implementation of teaching group processes). The assessment was based on the engineering design process. Student answers were coded, and common themes and concepts were identified for each question in both the engineering pre- and post-assessments to determine whether changes in understanding occurred throughout the intervention period. The frequency of answers fitting into these themes before and after the teaching and implementation of group processes were calculated to determine whether working in cooperative learning groups impacted the ability of students to learn the engineering design process.

Findings

The purpose of this study was to investigate the impacts that teaching specific group processes had on students' engagement and academic achievement while working in cooperative learning groups in a 5th grade STEM classroom. The action research generated both qualitative and quantitative data using student self-reflections, exit tickets, Flipgrid videos, and teacher observations that was used to assess student engagement and learning.

Opinions of Group Work

The first research question addressed by this study was: *in what ways, if at all, does teaching group processes to 5th grade cooperative learning groups affect their opinions of group work?* To answer this question, the students' responses to a weekly self-reflection form and their responses to two opinion-based questions on the pre- and post-assessment were analyzed. From the pre-assessment to the post-assessment, a larger percentage of students ranked their ability to use the engineering design process at a higher confidence level on the post-assessment than on the pre-assessment (Figure 1). However, there was also a higher percentage of students (9.09%) that had very low confidence in their ability to use the process on the post-assessment when compared to the pre-assessment (Figure 1). Before any intervention or assignment took place, students valued the engineering design process (Figure 2). This percentage dropped through the time frame in which this study was conducted. In the pre-assessment, a majority of students ranked the value of the engineering design process as high, with no students giving it a minimal ranking (Figure 2). In the post-assessment, the opinions of students were more spread out, with a higher percentage indicating they did not value the engineering design process (Figure 2).

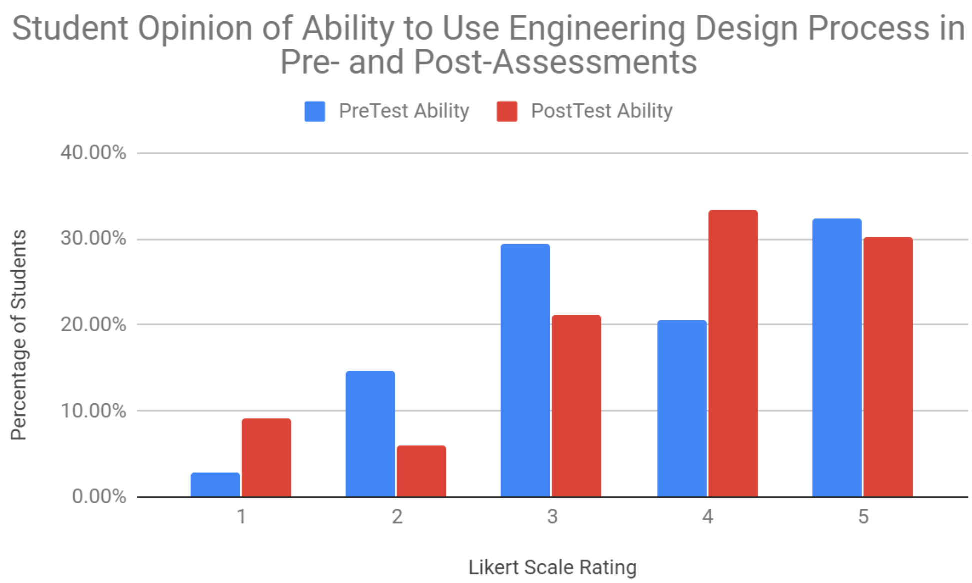

Figure 1. Students' opinions of their ability to use the engineering design process in a group in a pre- and post-assessment.

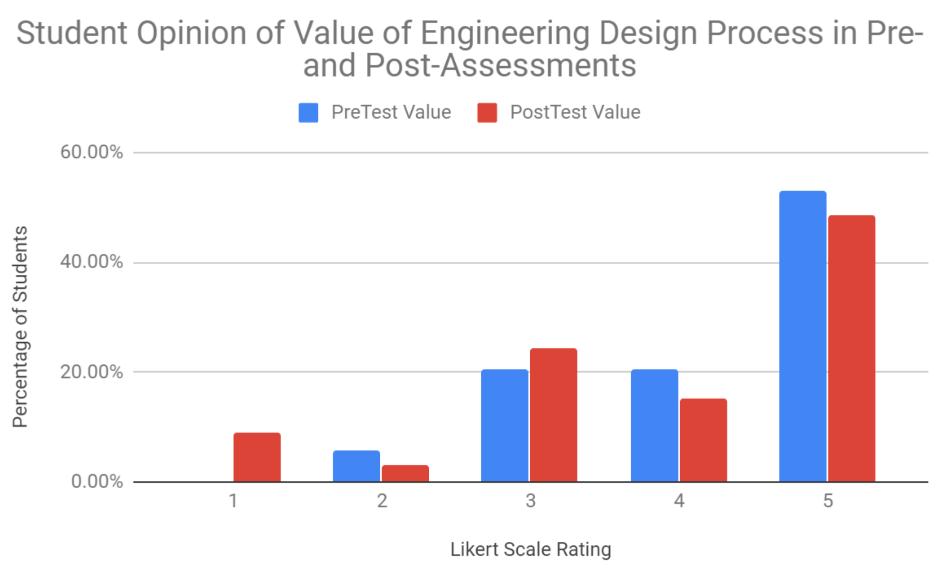

Figure 2. Students' opinions of the value of the engineering design process in a group in a pre- and post-assessment.

Data collected from the weekly self-reflection form suggested that over time, students' opinions of how group work helped them understand and engage with the content changed.

Opinions of certain statements improved, while others did not change at all or worsened. During week 1 of the study, 6.45% of students felt that working in a group does not help them better understand the content studied. By the end of the study, only 3.45% held this opinion (Figure 3). There was an increase in the percentage of students that agreed they were more engaged in their learning increased from week 1 to week 5 (Figure 4). Figure 7 demonstrates that during week 1, many students agreed that group roles allowed cooperative learning groups to function better. While this percentage decreased in week 2, by the conclusion of the study all of students felt that cooperative learning groups are improved when group roles are used (Figure 5). Students' opinions of accountability within groups showed a very similar trend, with a change from some students disagreeing that group members need to hold each other accountable in week 2 to no students disagreeing in week 5 (Figure 6).

Students' opinions of group work changed over the course of this study. Figure 7 showed that in week 1, 80.65% of students felt they received better grades when working in a group compared to working independently. This percentage decreased in week 5. In week 1, 35.71% of students felt that discussing content with a group impacted their understanding positively. This percentage slightly increased in week 5 (Figure 8). Students' opinions about how learning group skills would improve their experience in cooperative learning groups did not change (Figure 9). This same consistency in opinion is shown in Figure 10. Students did not agree that they work better by themselves when compared to working in a group and agreed that they enjoy working with others. This opinion did not change by the end of the study.

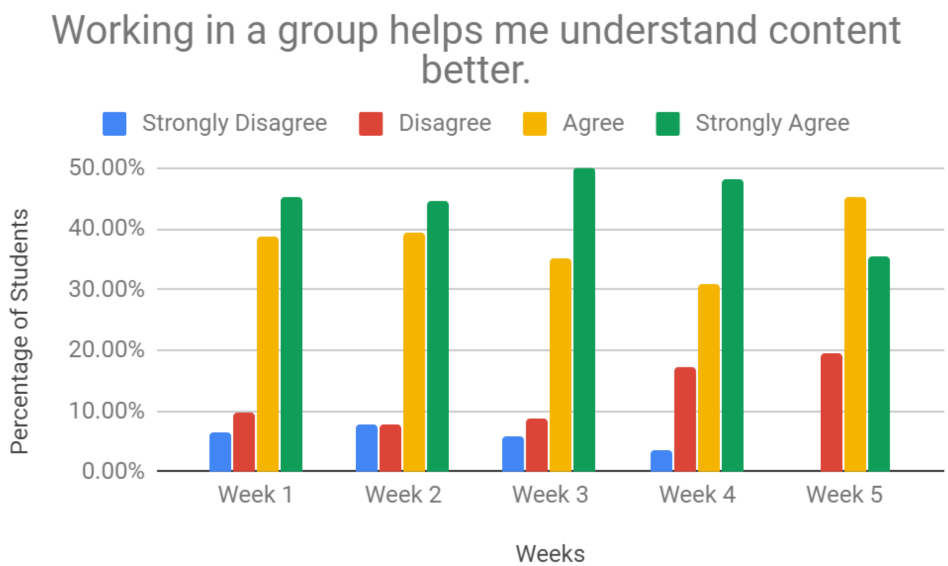

Figure 3. Students' opinions of how group works helps in understanding of content over five weeks.

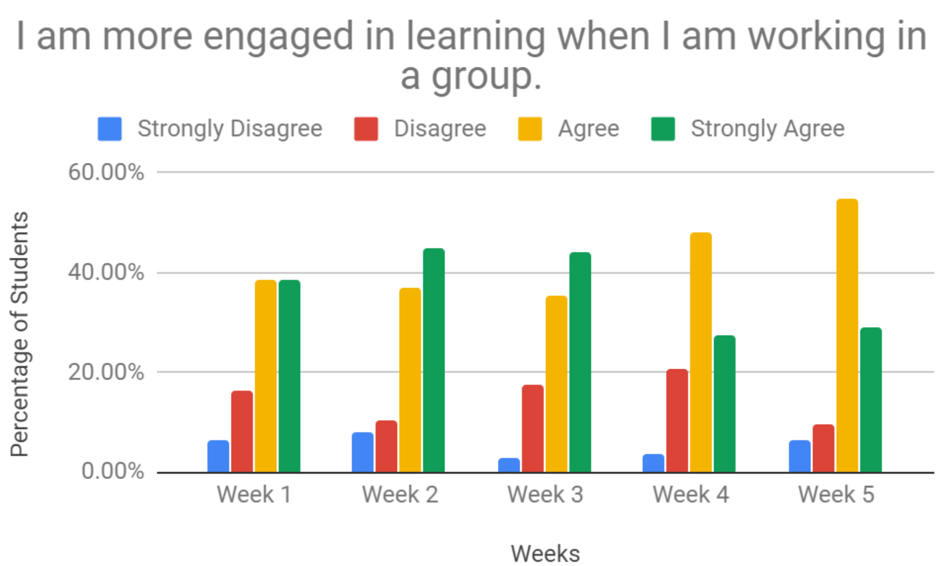

Figure 4. Students' opinions of engagement levels when working in a cooperative learning group.

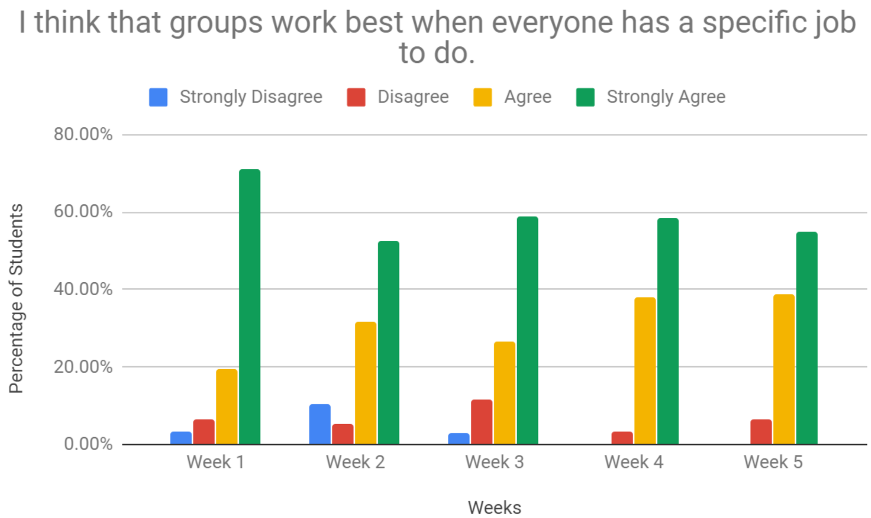

Figure 5. Students' opinions of how cooperative learning groups function when members are given specific roles.

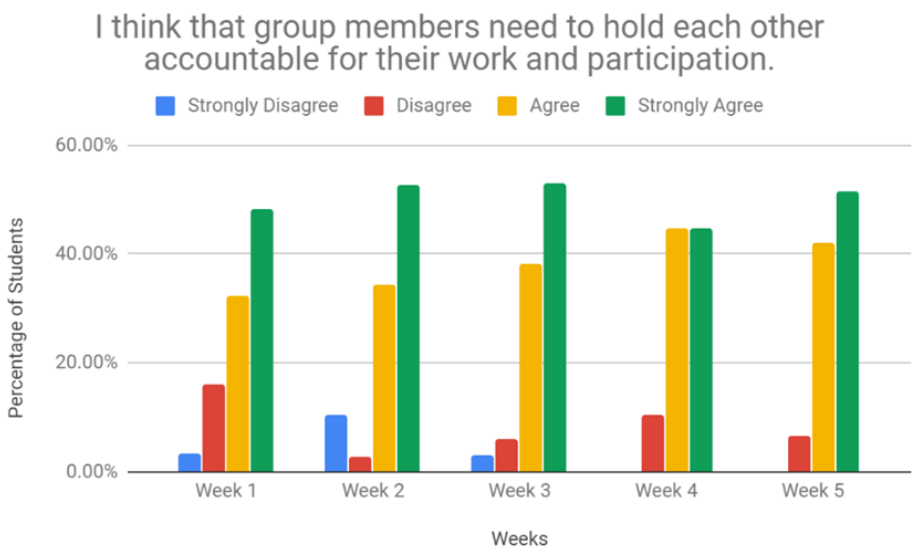

Figure 6. Students' opinions of the importance of holding group members accountable for their roles and participation.

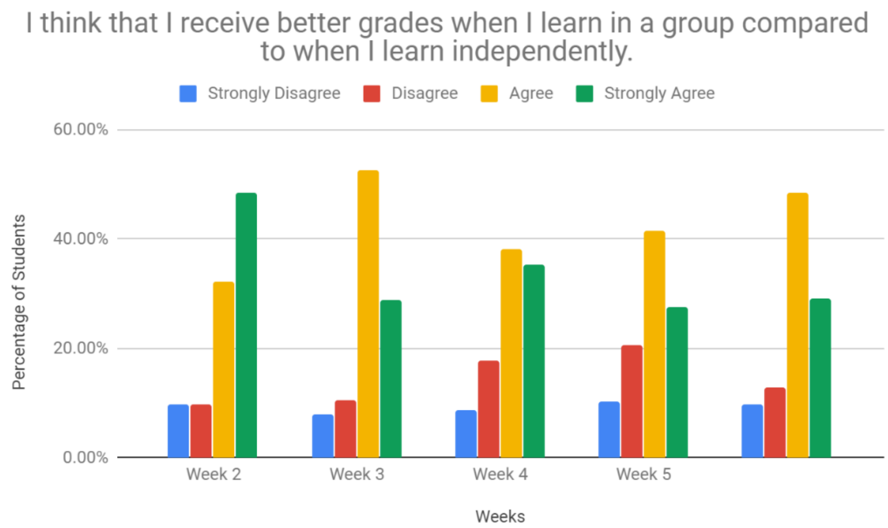

Figure 7. Students' opinions of how group work impacts grades when compared to working independently.

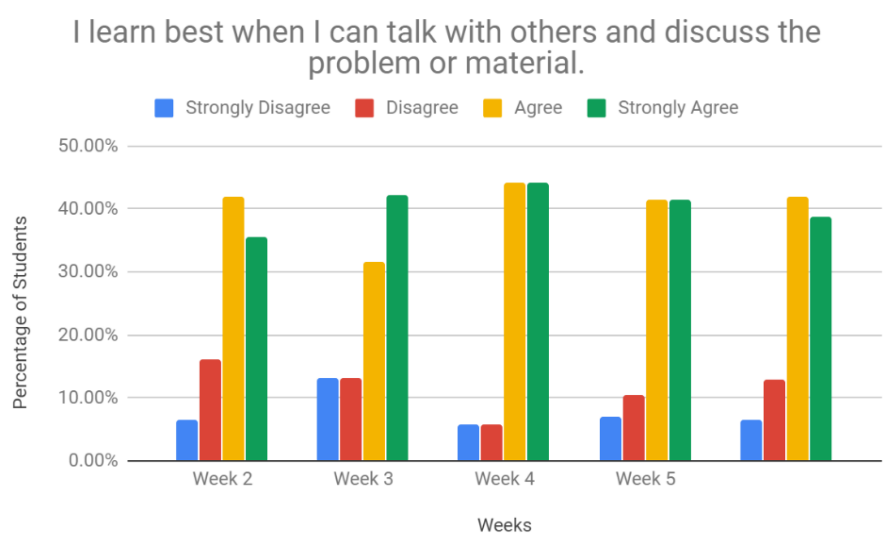

Figure 8. Students' opinions of group discussion in problem solving tasks.

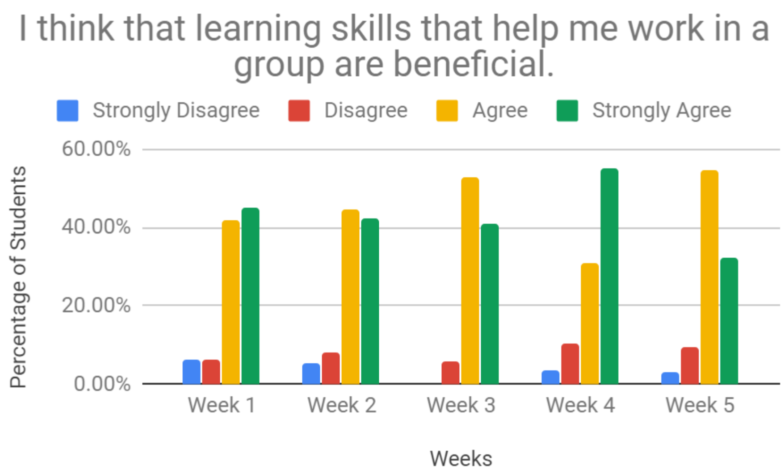

Figure 9. Students' opinions of how learning group processes are helpful when working in a cooperative learning group.

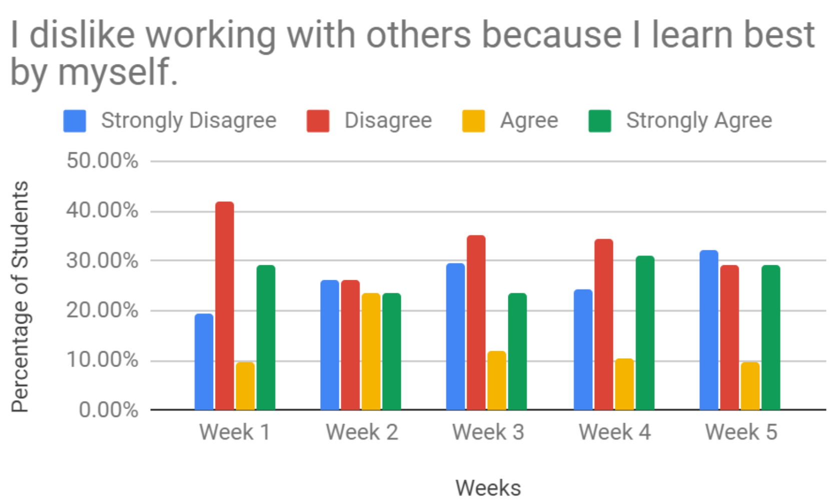

Figure 10. Students' opinions of working in cooperative learning groups compared to working independently.

Student Engagement

The second research question of the study was: *in what ways, if at all, does teaching group processes to 5th grade cooperative learning groups affect their engagement when working in groups?* To answer this question, students completed a daily exit slip that provided evidence of both their group's engagement and their personal engagement during the task. In addition, the researcher filled out a teacher observation form during each class period. Observations about on-task behavior, examples of engagement, and any redirection needs were made.

Common responses or themes from the responses and observations found on the exit slips and teacher observation charts that demonstrated negative interdependence and engagement could be broken down into common phrases. Many students reported that their partners did not do their job or help with the task. In addition, students stated that certain partners took over the task, were distracted, messing around, or not staying on task. Other common observations made by both students and teacher were group members tinkering with irrelevant VEX kit pieces or leaving the group. Some groups were also observed arguing over which roles each student held. These categories indicate that certain behaviors were common throughout all cooperative learning groups and that students were not utilizing the group processes taught to them prior to the learning activity.

Overall, in both the student exit tickets and teacher observation charts, there were more responses addressing positive engagement and interdependence in groups. Students reported 196 times that their groups were working together positively (Table 1). They also reported group members doing their job. Students wrote “everybody had a job” and “we all did what we were supposed to do.” Teacher observations demonstrated students communicating in a productive way that led to all students being engaged in the task. For example, one student was observed saying “Do you want to try?”, ensuring that her group member was involved in the project. Another student stated, “I need you to tell me your idea.” Many observations included students designating other students to specific tasks when they noticed the group was not functioning at its highest level. There were also many examples of students working cohesively together to complete the assigned task. One student reported “that one of our group is trying to help us understand." Another student wrote "we all did an equal amount of building" while yet another stated "we all get to combine almost all our ideas." Statements like these were common throughout the exit slips.

Table 1

Common themes taken from pre- and post-assessments regarding the engineering design process (EDP).

Common Themes	Pre-Assessment	Post-Assessment
EDP as series of steps used to create something	47.06%	54.55%
Ask: what problem am I solving	20.59%	30.30%
Explain: explain, plan, process, and design	85.29%	75.76%
Models necessary to EDP to show what changes need to be made	50.00%	42.42%
Evaluate: test model to see what improvements need to be made	55.88%	54.55%
Explaining results is important so consumers understand product	35.29%	42.42%
Application of EDP to new situation	32.35%	36.36%
Diversity in engineering is important because different perspectives can be offered	50.00%	42.42%

Table 2 compares student responses on daily exit slips to teacher observations of students regarding engagement and interdependence. Overall, both the researcher and the students reported making more observations and responses about positive interdependence and engagement than negative interdependence and engagement. While there were 30 responses of negative engagement and/or interdependence from students and 71 observations made by the researcher, it is clear the positive interactions were more frequent (Table 2). The data indicates that students had positive interactions with their peers when working in their cooperative learning groups and that they felt each member was contributing. The teacher made similar observations.

Table 2

Number of student exit slip responses and teacher observations of negative and positive interdependence and engagement.

# Negative Interdependence and Engagement Examples (Exit Slips)	# Positive Interdependence and Engagement Examples (Exit Slips)	# Negative Interdependence and Engagement Examples (Teacher Chart)	# Positive Interdependence and Engagement Examples (Teacher Chart)
30	196	71	133

Understanding of the Engineering Design Process

The final research question in this study was: *in what ways, if at all, does teaching group processes to 5th grade cooperative learning groups affect their overall understanding of the engineering design process?* To answer this research question, pre- and post-assessment and Flipgrid video responses were analyzed. Overall, as students worked more in their group and progressed throughout their project, group understanding of the engineering design process increased (Figure 11). Most groups began at a 1 because the prompts for the first week did not ask about the engineering design process. One group began with a 0 because they did not submit a video to be analyzed. In the following weeks, prompts were more specific and averages increased, with most groups' understanding of the engineering design process ranging from a 2-3 (Figure 11). In week 3, some groups experienced a decline in their understanding, while others continued to show growth. In the final week of the study, all groups reported higher average than in week 2 (Figure 11).

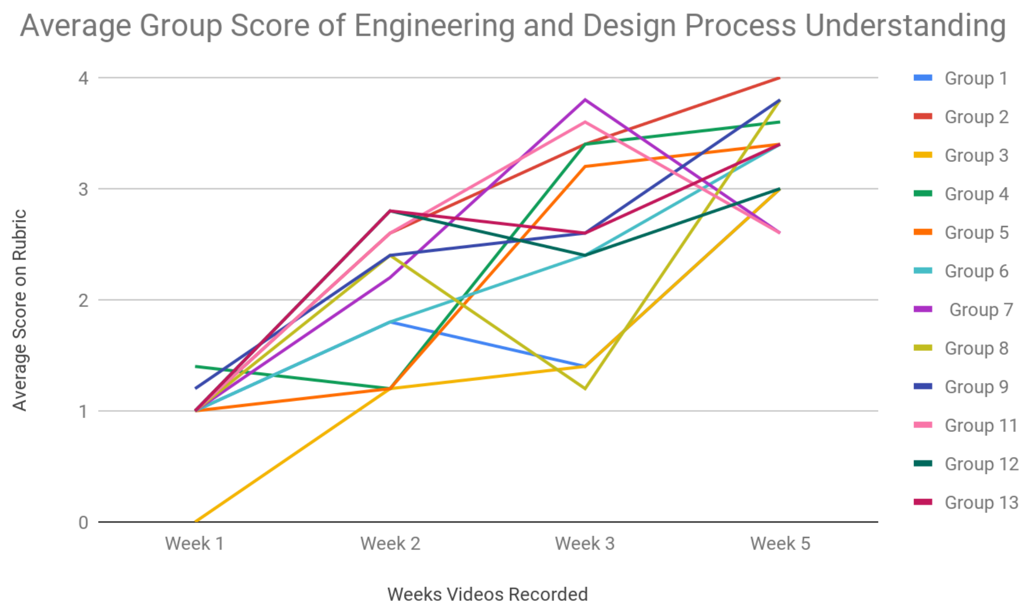

Figure 11. Average score of comprehension of engineering design process using critical thinking rubric to analyze Flipgrid videos.

Table 2 represents increases and decreases in students' understanding of the engineering design process on the pre- and post-assessment. The data shows that there was an increase in students responding correctly to the question related to the ask portion of the design process on the post-test. A higher percentage of students also seemed to better understand the importance of explaining results in the design process after working in their groups. There was an increase in the number of students that understood how to apply the engineering design process to a new situation on the post-assessment. While there were increases, there were also some decreases in students' understanding of the engineering design process. A decreased number of students suggested that diversity in engineering can result in varying perspectives and that a model is important to demonstrate changes needed in a design.

Action Plan

The purpose of this study was to understand how teaching specific group processes to students impacted their success in a middle school STEM classroom. Creating opportunities for interdependence and accountability is necessary for student success within groups, as it allows students to work together towards a common goal (Johnson, et al., 2007). Students must be directly taught methods to help this happen. If the intended purpose of the study was met, students would use these group processes (i.e. using group roles and holding one another accountable) resulting in higher levels of engagement, improved levels of interdependence, deeper understanding of the engineering design process, and more positive attitudes about group work. This study demonstrated that it is necessary to explicitly teach students how to effectively work in cooperative learning groups and that positive outcomes result from this intervention.

Various conclusions can be made from this study for categories related to opinions of group work, student engagement, and understanding the engineering design process. Conclusions for each of those categories were as follows:

Opinions of Group Work

- Students felt their ability to use the engineering design process improved after working in cooperative learning groups and learning specific group processes.
- Overall, more students valued the engineering design process than those who did not after the intervention took place.
- When students worked in cooperative learning groups, their opinions of group work improved in areas related to engagement, having group roles. and group accountability.
- Students' opinions regarding the benefits of group work on grades were negatively impacted after working in cooperative learning groups.

Student Engagement:

- Students who have been taught effective group processes were able to remain engaged with their cooperative learning groups.
- Teaching students specific group roles and processes resulted in better communication within groups and made students more aware of how their group was functioning. Students had a better understanding of how to create interdependence, resulting in higher levels of engagement.

Understanding the Engineering Design Process:

- Teaching students how to work in cooperative learning groups resulted in deeper understanding of content.
- Students' understanding of certain aspects of the engineering design process, such as its purpose and application, improved after the intervention. However, other aspects (i.e., modeling), resulted in less comprehension after the intervention.

The data gathered from this study can impact the way educators approach group work and establish cooperative learning groups. This data can be used in many ways to help improve outcomes in different classrooms. One recommendation is that teachers provide a content pre-assessment before having students work in cooperative learning groups, and a post-assessment after. This allows for a clear depiction of each students' understanding of content. Because some group members may dominate over others, this is a way to ensure that all students are learning and which areas of content may need additional attention.

Another recommendation is that teachers provide students direct instruction on specific group processes before they establish cooperative learning groups. There are two processes that result in better student engagement and positive interdependence: 1) teaching specific group roles, and 2) teaching students how to hold one another accountable. In doing this, students work towards a common goal within their learning group and each student has a clearly defined role that will help contribute to this objective. These roles could include: recorder, materials coordinator, manager, and technology coordinator. Students will be more engaged in the task knowing they have a specific job they need to fulfill. Students will also gain the skills to be able to communicate productively, problem solve with their group in a more effective way, and understand their role's importance to the group. All of this leads to higher levels of engagement from students. However, without being taught clear criteria for each role and what positive communication looks like, positive outcomes may be more limited.

Students should be provided time to reflect on their learning. Allowing students time to process their understanding of content and reflect upon where they are within learning targets is a productive practice. In this study, students better understood their abilities and growth and how they could improve their understanding of content.

A final recommendation is to continually monitor cooperative learning groups for examples of positive and negative interdependence and engagement. In this study, the groups that demonstrated the best teamwork were the ones that identified each group member as being on task, doing their job, and equally contributing. By observing group dynamics, the teacher can redirect students early and reteach processes that enable them to improve. This will lead to a deeper understanding of content for group members at the conclusion of the project.

Overall this study demonstrated that teaching specific group processes had positive results on student comprehension, engagement, and interdependence within groups. Students showed greater confidence in their ability to use the engineering design process and gained important 21st century skills. In our interconnected world in where technology makes collaboration and communication essential, understanding how to work productively in groups will give students the competencies they need to be successful beyond their educational career.

References

Barkley, E., Cross, P., & Cross, P. (2014). *Collaborative learning techniques: A handbook for college faculty*. Retrieved from https://ebookcentral-proquest-com.pearl.stkate.edu/lib/ stkate -ebooks/reader.action?docID=1745058

Blatchford, P., Kutnick, P., Baines, E., & Galton, M. (2003). Toward a social pedagogy of classroom group work. *International Journal of Educational Research*, *39*(1-2), 153-172. https://doi.org/10.1016/S0883-0355(03)00078-8

Cheng, R., Lam, S., & Chan, J. (2008). When high achievers and low achievers work in the same group: The roles of group heterogeneity and processes in project-based learning. *British Journal of Educational Psychology*, *78*, 205-221. DOI: 10.1348/000709907X218160.

Dasgupta, N., Scircle, M., & Hunsinger, M. (2015). Female peers in small work groups enhance women's motivation, verbal participation, and career aspirations in engineering. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(16), 4988-4993. Retrieved from www.pnas.org/cgi/doi/10.1073/pnas.1422822112.

Deutsch, M. (1949). A theory of co-operation and competition. *Human Relations*, *2*(2), 129–152. https://doi.org/10.1177/001872674900200204

Felder, R.M., & Brent, R. (2016). Teaching and learning STEM: A practical guide. Retrieved from https://ebookcentral-proquest-com.pearl.stkate.edu/lib/stkate-ebooks/reader. action?docID= 4406048

Finelli, C., Bergom, I., & Mesa, V. (2011). Student teams in the engineering classroom and beyond: setting up students for success. University of Michigan, *CRLT Occasional Papers*, *29.*

Fong, P. (2010). Building teams that learn: Study of learning effects in engineering student teams. *Journal of Professional Issues in Engineering Education and Practice, 136*(3), 121-127. DOI: 10.1061/(ASCE)EI.1943-5541.0000017.

Hooper, S., & Hannafin, M.J. (1988). Cooperative CBI: The effects of heterogeneous versus homogeneous grouping on the learning of progressively complex concepts. *Journal of Educational Computing Research, 4*, 413-424.

Johnson, D., & Johnson, R. (1999). Making cooperative learning work. *Theory Into Practice, 38*(2), 67-73. Retrieved from http://www.jstor.org.pearl.stkate.edu/stable/1477225

Johnson, D., & Johnson, R. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher, 38*(5), 365-379. DOI: 10.3102/0013189X09339057

Johnson, R., & Johnson, D. (2000). How can we put cooperative learning into practice? *The Science Teacher, 67*(1), 39.

Johnson, D., Johnson, R., & Smith, K. (2007). The state of cooperative learning in postsecondary and professional settings. *Educational Psychology Review, 19*(15), 15-29. DOI: 10.1007/s10648-006-9038-8.

P21. (2019). Frameworks & Resources. Retrieved February 21, 2019, from http://www.battelleforkids.org/networks/p21/frameworks-resources

Palincsar, A., & Herrenkohl, L. (2002). Designing collaborative learning contexts. *Theory Into Practice, 41*(1), 26-32. Retrieved from: https://www.jstor.org/stable/1477534.

Schnitka, J., & Schnitka, C. (2016). “Can I drop it at this time?” Gender and collaborative group dynamics in an engineering design-based afterschool program. *Journal of Pre-College*

Engineering Education Research, 6(2). Retrieved from https://doi.org/10.7771/2157-9288.1120.

Robinson, A. (1990). Cooperation and exploitation? The argument against cooperative learning for talented students. *Journal for the Education of the Gifted, 14*, 9-27.

Rudnitsky, A., Barclay, C., & Binger, L. (2017). What students need to know about good talk: Be BRAVE. *Middle School Journal, 48*(3). Retrieved from https://search-proquest-com.pearl.stkate.edu/education/docview/1923045313/abstract/60F211AAAAD841D3PQ/5?accountid=26879.

Appendix A

Teacher Observation Chart

Date:

Time Observed and Group Number	**Assigned Student ID Number**	**Observations** • Examples of interdependence, understanding, and engagement • Off-task behaviors • Positive anecdotes • Redirected group back to using group processes and outcomes of that redirection

Appendix B

Flipgrid Video Reflection

Prompts:

1. Describe what you did with your VEX kit/robot this week and how you used the design process.

2. What were some accomplishments you made as a team this week?

3. What were some struggles you had as a team this week?

Appendix C

Critical Thinking Rubric

Problem: Ask	Student consistently identifies and seeks information to understand the problem.	Student often identifies and seeks information to understand the problem.	Student sometimes identifies and seeks information to understand the problem.	Student rarely identifies and seeks information to understand the problem.
Brainstorm Solutions or Strategies: Imagine	Student consistently brainstorms solutions or strategies to solve a problem.	Student often brainstorms solutions or strategies to solve a problem.	Student sometimes brainstorms solutions or strategies to solve a problem.	Student rarely brainstorms solutions or strategies to solve a problem.
Develop and Select a Plan	Student consistently selects a problem solving strategy and develops a plan to use it.	Student often selects a problem solving strategy and develops a plan to use it.	Student sometimes selects a problem solving strategy and develops a plan to use it.	Student rarely selects a problem solving strategy and develops a plan to use it.
Implement a Plan: Create	Student consistently uses a selected plan.	Student often uses a selected plan.	Student sometimes uses a selected plan.	Student rarely uses a selected plan.
Evaluate and Improve a Plan	Student consistently reflects in order to improve the plan.	Student often reflects in order to improve the plan.	Student sometimes reflects in order to improve the plan.	Student rarely reflects in order to improve the plan.

Taken from:

Tatanka Elementary School

http://www.bhmschools.org/sites/default/files/downloads/tatankas_4_cs_rubric-_grades_3-5.pdf

Appendix D

Weekly Self-Reflection

Students will complete this reflection weekly. Answer each question with as much detail as possible. It is important that you are honest in your answers in order for me to determine how successful cooperative learning groups are. Your grade will not be impacted by these answers so be as specific as possible. Thank you! * Required

1. Working in a group helps me understand the content better. *

1 2 3 4

Strongly Disagree Strongly Agree

2. I am more engaged in learning when I am working in a group. *

1 2 3 4

Strongly Disagree Strongly Agree

3. I learn best when I can talk with others and discuss the problem or material. *

1 2 3 4

Strongly Disagree Strongly Agree

4. I think that I receive better grades when I learn in a group compared to when I learn independently. *

1 2 3 4

Strongly Disagree Strongly Agree

5. I think that learning skills that will help me do group work is helpful. *

1 2 3 4

Strongly Disagree Strongly Agree

6. I dislike working with others because I learn best by myself. *

1 2 3 4

Strongly Disagree Strongly Agree

7. I think that groups work best when everyone has a specific job to do. *

1 2 3 4

Strongly Disagree Strongly Agree

8. I think that group members need to hold each other accountable for their work and participation. *

1 2 3 4

Strongly Disagree Strongly Agree

9. Describe the best parts about working in a group. *

10. Describe the hardest parts about working in a group. *

Appendix E

Student Exit Tickets

Group Processes Exit Slip: Fill this out each day before you leave class.

Group Number: ______________________________ Assigned ID # ___________________

Date:	**One thing that I contributed to my group and showed my individual engagement in the task today that I feel good about is...**	**Was everyone engaged in today's group activity? If yes, give an example. If not, what can be done to make it better?**	**One question I have about STEM today is...**

Appendix F

Engineering Pre- and Post-Assessment

Students will complete this assessment before and after learning about the engineering design process in their Project Lead the Way modules on robotics and automation. Data will used to help conclude the impact of cooperative learning groups on student engagement and understanding. * Required

1. What is the engineering and design process? *

2. What occurs in the "ask" portion of the design process? *

3. What do engineers do in the "explain" phase of the design process? *

4. In what ways are models necessary to engineering? *

5. What does it mean to evaluate a model? How does this contribute to the final product being made? *

6. Why is it important to explain the results of an engineering project? *

7. An engineer is designing a new type of cell phone. Explain the process she might go through to create this new phone. *

8. Why do engineering teams get better results when teams are made of people from different backgrounds and different areas of engineering? *

9. On a scale of 1 to 5, how valuable do you feel that the engineering and design process is to an engineer who is completing a project? *

1	2	3	4	5
Not valuable				Very valuable

10. On a scale of 1 to 5, rate your ability to use the engineering design process with a group in class. *

1 2 3 4 5

Not able to use the process Very able to use the process.