Discourse of Middle School Girls in Collaborative Microelectronics Lessons

Vanessa Blas, University of Illinois at Urbana - Champaign
Joshua E. Katz, University of Illinois at Urbana - Champaign

Joshua E. Katz is a Ph.D. student in the Department of Curriculum and Instruction, DELTA program, at UIUC, where his research centers on collaborative learning in engineering education and other STEM disciplines. He obtained his B.S. in Technology and Engineering Education in 2019 and his M.S. in STEM Education and Leadership in 2021 from Illinois State University. Additionally, he holds a professional educator license for secondary education in Technology and Engineering Education in Illinois.

Dr. Molly H Goldstein, University of Illinois at Urbana - Champaign

Dr. Molly H. Goldstein is a Teaching Assistant Professor and Product Design Lab Director in Industrial and Enterprise Systems Engineering at the Grainger College at the University of Illinois. She is also courtesy faculty in Mechanical Science and Engineering, Curriculum & Instruction (College of Education) and Industrial Design (School of Fine and Applied Arts). Dr. Goldstein's research focuses on student designers through the study of their design actions and thinking.

Prof. Tamara J Moore, Purdue University at West Lafayette (PWL) (COE)

Tamara J. Moore, Ph.D., is a Professor of Engineering Education and University Faculty Scholar at Purdue University, as well as the Executive Co-Director of the INSPIRE Research Institute for Precollege Engineering. Dr. Moore's research is focused on the integration of STEM concepts in K-12 and postsecondary classrooms in order to help students make connections among the STEM disciplines and achieve deep understanding. Her work investigates engineering design-based STEM integration, computational thinking, and integration of high-level content in K-14 spaces. She is creating and testing innovative, interdisciplinary curricular approaches that engage students in developing models of real-world problems and their solutions.

Dr. Greg J Strimel, Purdue University at West Lafayette (PPI)

Greg J. Strimel, Ph.D., is an assistant professor of Technology Leadership and Innovation and coordinator of the Design & Innovation Minor at Purdue University. Dr. Strimel conducts research on design pedagogy, cognition, and assessment as well as the pre

Team Discourse of Middle School Girls in Collaborative Microelectronics Lessons (Fundamental)

Abstract

Engineering and technical activities are crucial aspects of education curriculum and standards. Substantial efforts have been made to increase the number of women in STEM careers and majors; however, they remain underrepresented. Even at the middle school level, literature shows that girls are not actively being exposed to and participating in engineering contexts compared to their male counterparts. Researchers have suggested collaborative learning might lead to increased interest and participation in STEM. Yet, the literature points to the need for understanding how minoritized students interact with and experience collaborative group work settings. This study aims to explore how middle school girls in STEM engage with their peers during microelectronics group activities and how these interactions influence their learning experiences and collaborative skills through the research question: What are the discourse patterns present in girl-only groups during a pre-college microelectronics activity?

Researchers collected approximately eight hours of data over 5-unit lessons in a middle school engineering and technology classroom. The students participated in creating an electronic expansion pack for the Sphero BOLT using a micro:bit and sensors. This analysis focused on video recordings of two pairs of girls in this classroom. Using the Team Interaction Observation Protocol outlined in [1], we employed a qualitative discourse analysis approach to analyze videos. This conceptual framework specifies six types of discourse actions: task-oriented, response-oriented, learning-oriented, support-oriented, challenge-oriented, and disruptive, and was used to categorize students' interactions.

Results suggest that girls who engage in collaborative group work during the microelectronics lessons are most engaged with task-oriented, learning-oriented, and disruptive discourse. Girls were able to engage in collaborative exchanges fluidly and can build on each other's ideas efficiently, creating an environment of support and mutual engagement, and understanding. Although the girls engage in off-task conversations, they demonstrate the ability to refocus and complete their tasks efficiently. By asking clarifying task questions, girls exemplify their engagement towards the task as they fill gaps in their learning and task responsibilities. Future work will compare the discourse of girl groups and boy groups working on the same microelectronic activity.

Introduction

Girls are underrepresented in science, technology, engineering, and mathematics (STEM). Women are awarded 20% of engineering degrees; this number has remained constant and low since the early 2000s [2]. To help close the gender gap in engineering, girls' exposure to engineering at the middle school level must be increased. Exposure to STEM careers at the middle school level is beneficial in determining their career paths [3]. The relationship between early STEM career aspirations highlights the need for establishing collaborative skills, which can prepare students for problem-solving group work within engineering. Group work is a fundamental aspect of engineering education; it helps students develop critical thinking skills through collaboration, problem-solving, and communication. "Engaging in collaborative groups provides cognitive benefits and deepens conceptual understanding given opportunities to explain, question, justify, and negotiate, with benefits for learning and achievement outcomes" [4]. These activities enhance student engagement and interest to pursue STEM, helping students envision themselves in STEM careers and increase their self-efficacy [5]. Successful projects depend on the interest and enthusiasm of team members and on effective team building [6]. Understanding how minoritized students participate in groups reveals team dynamics, interactions, and any challenges that minoritized students face in collaborative group activities.

We lean on a conceptual framework to categorize types of discourse actions withing collaborate group settings, the Team Interaction Observation Protocol [1] developed by Purzer. Identifying which discourse actions are most occurring during the participation of girls as they work in a microelectronic activity, can help both educators and researchers improve minoritized students' abilities, confidence, and sense of belonging within STEM, in turn pursuing careers. This focus is necessary not only for achieving equity but is also essential for increasing and diversifying the U.S. STEM workforce and producing technological innovation that serve and benefit all communities [7]. Creating inclusive educational practices is critical for improving the retention and success of minoritized students, ultimately will contribute to a more diverse and innovative STEM workforce.

Theory

Work by Vygotsky provides insight relevant to this research that examines the way one learns. His theory plays into the concept that learning is a social process, and knowledge is constructed through interactions with others [8]. [8] uses the term "zone of proximal development" which refers to the difference between what a learner can do without help; with guidance of knowledgeable peers or adults. This suggests that students should be somewhere in the middle of the zone not to be frustrated or bored with the lesson activity [9]. Learning is most effective in the middle of this zone. Discourse and argumentative interactions between students and their

peers occur within the zone of proximal development (ZPD), thus enhancing the learning process [1].

Discourse actions of task-oriented and challenge-oriented relate to a higher self-efficacy through more confidence in one's capabilities. Minoritized students may have lower self-efficacy, thus engaging less in these actions, which in turn restricts their access to support and learning opportunities within their ZPD, impacting their academic growth and confidence. The discourse actions of support-oriented and response-oriented may relate to one's sense of belonging as they involve feelings of being valued and supported, thus feel accepted within their team while also engaging in meaningful conversation can make students feel included and that their contributions are important to the groups' progress. By using Purzer's Team Interaction Observation Protocol framework [1], it provides a structured approach to examine the nature of student interactions during collaborative tasks.

Collaborative Learning and Inclusivity

Existing literature brings insight into the importance of collaborative and engaging group activities that help students be effective team members and prepare them to solve real-world problems in STEM fields. Other prior studies have examined collaborative learning benefits [10-12] collaboration in regards to gender [13-16] and how marginalized groups learn [17], [18].

Studies reveal challenges in ensuring equitable participation within group dynamics. For instance, students with the abilities but lack the scientific knowledge to plan or strategize are excluded from decision-making processes and are given passive roles, such as writing what to draw on posters or reading while the rest of the team makes the decisions [19]. Tasks that make connections between science and everyday life are needed to "make science more understandable and more interesting, especially to students traditionally ignored in science education (low-achieving students, girls, and minorities)" [19]. Classroom behavior can also provide insight into the way social class can affect students' interaction strategies and outcomes. Calarco spent time in classrooms observing and documenting interactions between students and teachers and conducted interviews with parents and students [17], [18]. Calarco found that middle-class children proactively seek help, gaining more teacher attention and assistance [17], while working-class children are encouraged to solve problems independently, leading to a developing a sense of constraint with authoritative figures [18]. These studies reflect on the challenges that can hinder student participation in their learning environments.

Gender is a significant factor when discussing group work. The effects of gender diversity on teams depend on the context, but including women in team collaboration and performances generally has improved intelligence, social sensitivity, and conversation equity [20]. Increasing women's participation in STEM fields can foster better processes and team productivity.

Inclusivity in collaborative learning environments would encourage students to participate, this creates equitable learning opportunities in which especially minoritized students are able to engage and construct knowledge. Mercier and team explicitly calls for additional research investigating collaborative learning with DEI frameworks [12]. By studying girl groups in engineering, researchers gain insight into how girls communicate and work to problem-solve while identifying disparities that can help educators create more inclusive classroom settings.

Team Discourse

Previous studies have examined discourse in engineering students at the college level [21-23], [4]), however there is limited research at the pre-college level. [24] conducted a literature review on communicative literacies in K-12 Engineering Education, highlighting the challenges and opportunities in integrating engineering and communicative literacy research. Their analysis determined notable gaps in existing literature, particularly the limited exploration of engineering-specific discourse in early elementary grades and high school contexts. It is crucial to analyze and understand how students navigate discussions at the middle school level and use verbal discourse to make meaningful contributions during group work and construct their individual knowledge. Studies need to analyze verbal data while working in teams to understand the challenges students face in team settings [4]. Most studies rely on survey data that reveals how students collaborate; few studies "examine verbal data in engineering student teams" [4]. This gap is significant for underrepresented and minoritized students. With this, there is also a need for insights into their communication and participation styles.

In [25]'s paper, they wrote about the importance of oral communication among engineers. Public speaking, meetings, and other communication mediums with technical and non-technical personnel audiences are present in many fields. Within engineering education, these skills are crucial for developing and advancing a career. Because of this, the authors state that engineering education should focus on informal communication (i.e., public speaking) and team-based experiences. Communication is at the heart of lesson proficiency and professional expansion.

[26] studied dialogue patterns in peer collaboration. From their research, during a collaborative problem-solving task, groups that are constructive and interact in dialogue promote deeper comprehension and learning outcomes. These outcomes depend on the active participation and engagement of all participants. Similarly, [27] wrote about the structure of discourse in peer collaboration and its impact on learning outcomes. The authors focused on how argumentation plays a role within the collaborative learning environment by supporting the statements with evidence, rebuttals, and counterarguments. Ideas and reasonings can be connected and linked to improved learning outcomes. In this study, they observed fifth graders working on electrical circuits in groups. They found that groups who had more complex argumentation formed better skill development within critical thinking and knowledge construction.

As middle school is a crucial time for career exploration, verbal discourse analysis for girls will help educators understand student learning outcomes, social dynamics, and STEM interests.

Research Question

This research aims to analyze the interactions and determine if there are any patterns in how minoritized students in engineering, specifically girls, work with others in group work and determine if there are any challenges that these students face. The team asks the following research question:

> *What are the discourse patterns present in girl-only groups during a pre-college microelectronics activity?*

Methods

Study Design

This study analyzed recorded videos that were part of a larger data collection effort with SCALE K-12, which focuses on implementing microelectronic lessons in schools and for students in the K-12 academic range in various schools in Indiana, Illinois, and Michigan. The curricular unit that was analyzed for this study was Let the Good Ideas Roll, where students were tasked to create an electronic extension pack for the Sphero BOLT using a micro:bit and sensors. The curricular unit consists of ten lessons, in which the team only analyzed five lessons to focus on key discourse segments in collaborative settings in which students/participants are actively working on a task. This resulted in a total of 490 minutes of discourse analyzed. As this project works to implement a microelectronic curriculum into grades of K-12 in various schools in Indiana, two target groups were recorded in each classroom. These groups were chosen by the teacher, in which they are not necessarily overachieving students but rather students who would not be off topic all the time or have behavioral issues and would have interesting communication. Cameras and microphones were set up to capture student collaboration during this project. These groups were recorded in the months of November and December of 2023. The Team Interaction Observation Protocol (TIOP) by Purzer has 35 codes, the research team assessed and categorized the discourse actions of three cases: two pairs of girls and a larger group of six. The team counted the number of times the discourse action was performed to quantify the occurrence.

Research Site

The analyzed classroom videos were recorded at a middle school in the Midwest United States. The participants are middle school students aged 11-14. An Engineering and Technology teacher facilitates the selected classroom.

Participants

The participants are middle school students aged 11-14 years old. This study used a non-probability sampling approach where middle school students were chosen by convenience sampling. The sample to study is middle school students near a large midwestern university in the United States. The size sample are the recruited participants that received consent and assent from both parents and students as they are under 18 to participate in the study. This study focuses on a total of six girl participants.

Data Analysis

The data analysis techniques applied to the gathered video data is a discourse analysis that focuses on language and conversation in the video amongst the girls who are recorded in pairs of two. This gives us context to their interactions, reasoning behind their tone, and ability to see some power dynamics and overall interests while the girls work in collaborative group work. This qualitative video data analysis provides overall insight to the verbal interactions amongst the middle schoolers as they engage in a microelectronics activity with a partner. In this study, the classroom is set up for group work to be in pairs and this makes it easier to track the student interactions (by who and to whom) and to determine the highest quantified discourse action and by which pair.

The focus of this study is primarily on lesson videos in which significant team discourse occurred. This resulted in watching classroom recordings from Lessons 5-10, totaling to 490 minutes watched. Microsoft Excel and Word were used to track the specific timestamps and intervals in which a specific discourse move is occurring. As the videos had issues with the level of sounds, the researchers implemented the use of Adobe Audition and Premiere to change the level of the audio to make the girls' dialogue more apparent. Purzer's conceptual framework was then used as a basis to categorize discourse actions from the pairs of girls.

Conceptual Framework

Team Interaction Observation Protocol (TIOP)

The research team used the Team Interaction Observation Protocol (TIOP) [1] coding scheme as a conceptual framework to categorize discourse occurrences, and with this, quantify the incidences in which each type of discourse action occurs in the pairs that are working together. The TIOP

categorizes group work interactions into six types: task-oriented, response-oriented, learning-oriented, support-oriented, challenge-oriented, and disruptive.

1. Task-oriented Discourse: “Clarifying tasks, focusing team discussions, giving directions, etc.” ([1], p. 662)
2. Response-oriented Discourse: “Sharing new ideas, answering questions, elaborating on ideas, etc.” ([1], p. 662)
3. Learning-oriented Discourse: “Asking questions and reflecting on learning and challenges” ([1], p. 662).
4. Support-oriented Discourse: “Agreements, praise and defending a peer” ([1], p. 663).
5. Challenge-oriented Discourse: “Disagreements, defending one’s own point, and interruption” ([1], p. 663).
6. Disruptive Discourse: “Staring or participating in off-task conversations and sharing incorrect or unrelated information” ([1], p. 663).

The TIOP Coding Scheme (Appendix A) is broken down with a code for each discourse move, description, and examples of utterances in each of the six types of discourse actions, which sets up this study to follow for analysis. Figure 1 illustrates the planning and implementation of the study to answer the research question.

Coding Procedures

Each discourse instance was coded in Microsoft Excel in line with the Purzer’s conceptual framework. With the videos transcribed, each instance was coded in a main document indicating the presence of a discourse code. This procedure was implemented for each of the five lessons that were transcribed.

Interrater Reliability

A researcher coded the data (100%) and another researcher from the College of Education coded for inter-reliability. The second researcher coded 30% of videos; double coding for one lesson. The researcher, who coded 100%, trained and explained the Purzer framework to the second researcher for clarification and interpretation. Any discrepancies were discussed and challenged to apply the agreed-upon codes for each section. During the initial meeting of comparing the codes between the two researchers, any changes were on a specific case basis. A follow up meeting between the two researchers, confirmed the agreement upon the existing codes. After the discussions with the second researcher, the reliability test of Cohen’s Kappa Coefficient and Cronbach Alpha was used to calculate the agreement between the two coders in SPSS. All domains had a Cohen’s Kappa greater than 0.64. The Cronbach Alpha measurement was .802 indicating a very reliable agreement between both coders [28]. All collected artifacts within the study were

within the tolerance of substantial or near perfect agreement, conveying that the 100% coding is reliable.

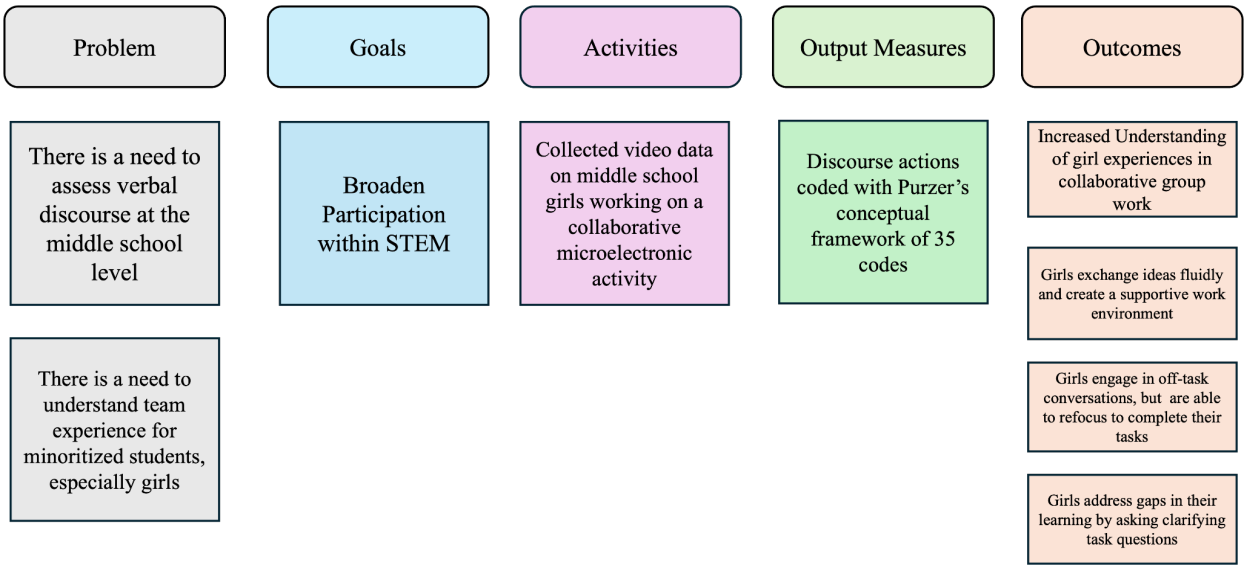

Figure 1. Study logic model

Results

Case 1: First Team

The two girls in this pair demonstrated great comradery as they completed their task. This comradery was demonstrated through their off-topic conversations, sarcastic comments, and jokes as they worked. Although often off-task, these two girls were able to complete their tasks as they asked the teacher various clarifying questions to complete their activity. Throughout their off-task conversations, they would also include the teacher, demonstrating that they were comfortable with their teacher, and engaged in playful interactions demonstrating a relaxing dynamic with their teacher. Girl #1 exhibited more authority during collaborative work, frequently taking the initiative to start the tasks and directing her partner to complete certain tasks. This pair also had some disagreements and debates which demonstrates that they were actively engaging with the material even if off-topic.

Table 1 : Quantified Discourse Interactions for the First Team (Case 1)

Discourse Code	PER	TAQ	ANS	COM	CHA	IGN	DEF	DIS	AGR	CLQ	DIR	OFFP	OFF
Number of Times Occurred	1	1	1	1	1	3	3	3	5	6	6	7	9

Discourse Examples

G1: Okay so we take turns, okay? And the thing makes noise .. find the light on.. yea.. yup I have two, you need to make your ideas now, okay it's your turn to make the ideas for two..

G2: I was going to say that

G1: Jesus..

G2: It's the same thing!

G1: So if I do these two, you do those

G2: Or you can just.. down here

G1: ... and make my way up

G1: no, probably no

G2: because you're not using google!

G1: I am you .. you see me

laughs

G1: we argue like a married couple

G2: laughs

G1: because we are.

writes

mimics opening ring box

Will you marry me Chloe?

*G2: no *while typing in laptop**

G1: OK

Both laugh

Case 2: Second Team

This set of partners exhibited more independence, working on the task separately. These girls appeared quieter and less engaged in conversation. This limited engagement is seen throughout the lessons, as Girl #1 in this team demonstrated greater interest and was more engaged with the hands-on activities. Girl #2 in this group was often more distracted and off-task, and it was seen drawing and checking into the activity every once in a while. As a result, this team asked fewer questions to the teacher, and only Girl #1 would ask clarifying questions to the teacher if needed. In the same way, Girl #1 would display more authority, have more control over the task materials, and direct her partner.

Table 2 : Quantified Discourse Interactions for the Second Team (Case 2)

Discourse Code	IGN	AGR	CLQ	INFQ	DIR
Number of Times Occurred	1	1	1	2	5

Discourse Examples

G1: I want it to play music ... okay what music? I can make it play something... okay stop! Hannah, what are you doing? I'm going to make you stop. Please stop please stop please stop…

G2: we can do something like,
G1: Yea replace
G2: Like an ID you know?
G1: We can replace that with a sensor and like a __
G2: So like a lot of them… (?)

G1: So take all these wires, and it's stuck of course this one's stuck

G1: No! That's fine just leave it, now make it stop you need to download it. But I think it should still work, here hold this.

G1:no, so you know, turn the volume on, on your computer

Case 3: A larger group of girls

From the girls analyzed, their interactions included task-oriented discourse actions, which were the most common. Task-oriented discourse focused on "Clarifying tasks, focusing team discussions, giving directions"([1], p. 662). There was an emphasis on clarifying tasks to ensure the group stayed on track and concentrated on completing the task. These discourse actions helped with organization and in effective teamwork. Response-oriented discourse was also displayed through discourse actions of sharing ideas, answering questions, and elaborating on ideas. This demonstrates that the girls were actively engaging, exchanging ideas, and building on each other. This created an environment of engaged discussion, and this helped get everyone on the same page and understanding as a team. Support-oriented discourse was also shown, these interactions occurred as all members felt comfortable sharing their ideas and were in a positive and playful team environment. This group, although oftentimes engaging in off-topic conversations, were able to essentially stay on track and concentrate back to the task, and there was one girl who stood out the most that did this. There was minimal argumentation, mostly focusing on agreement and idea refinement and clarity over confrontational conversations. While the first videos analyzed include the girls working in partners, the girls appear to engage in more direct task-oriented discourse, assigning their partner to complete certain directions. This was shown in this larger group setting as well, but it changed to a question asking "Who is going to ___", in seeking volunteers to complete the task. The girls' discourse actions demonstrate that they actively participated through sharing ideas, making suggestions to the ideas, and encouragement through completing sentences. This demonstrates overall productive collaboration and encouragement.

Table 3: Quantified Discourse Interactions for the Larger Team (Case 3)

Discourse Code	TAS	TAQ	INFQ	SYN	SUP	DEF	CHA	MIS	EXP	AGR	DIS	NEG	IGN
Number of Times Occurred	1	1	1	1	1	1	1	1	2	2	2	2	2

Table 3 Continued: Quantified Discourse Interactions for the Larger Team (Case 3)

Discourse Code	VOL	INPQ	DIR	COM	ANS	FOC	CLQ	IDE	OFF	OFFP
Number of Times Occurred	3	3	4	4	5	6	6	7	7	7

Discourse Examples

G1 from Group 2: okay we have to combine our ideas! Which way do we want to choose?
Different group girl: we should choose a top two and then decide
G1 from Group 2: this is not a top two but like
G1 from Group 1: Ours
G1 from Group 2: what's yours? oh okay. It is like really complex directions
Different group girl: that's a lot of work
(?): shut up!
Different group girl: they chose it and we have to code all of that.

G1 from group 2: We only need one, right? Will someone search up the, how much money it costs?
G2 from group 1 : I will
G1 from group 2: Yay, thank you!
(?): chloe you are the goat

G1: well BG ladies, lets compare ideas while I put on mascara
RB: you're making the best of list , whoever wants to write, write it
G1 : ill write it! I call dibs on writing. Okay ladies! Lets go with Hannahs group first and then well do yours and then well do ___

(?): Sharon follow-up (??)
G1 from group 2: why are you asking me?
?: because you are the one whose paper where we are writing things down
G1 from group 2: no, I was trying to think of more items that we need like accessories

G1 from Group 2: okay I know the two best ones that we have well that I think are the best ones
G1 from group 1: no read them all!
The rest of the group : we don't have time for that

G1 from group 1: well y'all spend most of that time thinking! G1 from team 2: okay so our two best ones are one team hides their bolt and has a light on it and then like they'll come back and the person that hides it the team stays there and the first person to find it wins

Discussion

The findings of the discourse analysis of the collaborative unit of "Let the Good Ideas Roll", gives insight into the communication styles and collaborative dynamics of the engagement of how girls learn during a novel microelectronics activity. The conceptual framework of Team Interaction Observation Protocol (TIOP) that was used to categorize the discourse action, highlights that girls work successfully collaboratively by creating a positive group environment while supporting one another. **Girls tend to engage most with task-oriented, learning-oriented, and disruptive discourse.** In our study, we observed the girls clarifying and assigning tasks to encourage the group to maintain focus and building on each other's ideas to engage in effective discussions. They blended social and task-based discourse to sustain engagement in the activity while fostering a comfortable and supportive environment.

Girls are able to engage in collaborative exchanges fluidly and are able to build on each other's ideas easily, creating an environment of support and mutual engagement and understanding. This fluidity might be attributed to possible friendships and a desire to prioritize good relationships amongst themselves sustaining positive group dynamics. Students develop different problem-solving skills to manage conflict when interacting with their peers during collaborative learning. Other research has indicated that girls are more skilled at suggesting positive resolutions when conflict arises through negotiations, thus exhibiting greater social competence [14]. This social competence means that girls navigate collaborative group work with a focus not just on understanding but through positive conflict resolution, thus maintaining a supportive environment for everyone. Students in collaborative and interactive settings perform and learn significantly better than students who work in individual conditions when learning engineering concepts, especially those in learner-learner interactions such as turn-taking and constructive contributions [29]. Literature supports the finding that collaborative learning fosters an overall highly effective learning environment in STEM fields.

Moreover, our findings support other studies that have reported on the neurological benefits of female-female collaboration, namely that these dynamics tend to foster fluid idea exchanges and mutual engagement and understanding. Gender composition affects group creative processes. Female-female dyads showed higher interpersonal brain synchronization (IBS) increments in their right posterior parietal cortex, meaning that when females work together in creativity tasks, they tend to comprehend their partners' ideas and use them to generate novel ideas thus interact more frequently [16]. This suggests that girls in collaborative settings develop mutual engagement, empathy, and have a good learning process through seamless idea exchanges through

conversations. This also demonstrates that interactive learning is more productive than solo constructive learning because by having partners respond to each other's ideas, posing challenges, and considering their partners' perspectives, the teams create solutions and ideas that neither student could come up with by themselves [29]. The girl dyads build upon each other's ideas, which means that contributions to the task are individual yet collaborative.

Although the girls do engage in off-task conversations, they demonstrate the ability to refocus and complete their tasks efficiently. Girls work together and to sustain this positive group dynamic, they can share responsibilities to complete tasks accordingly. Girl #1 from the second pair engages in these off-task conversations but seems to be the one who is able to regroup and bring the rest of the team to focus. Off-task discourse can be seen as distractions when completing tasks. Engaging in excessive off-topic discussions is seen as a failure-mode for team discourse, as it restricts learning focus and teaching opportunities for students involved [23]. Off-task conversations occur through the nature of discourse and are even helpful in online learning environments. Chen in a study of online group learning environments, stated "Social conversation is not an off-task activity. On task and off-task talks not only co-occur but also interweave to accomplish effective discussion and negotiation" [30]. Off-task discourse is essential to maintain progressive focus and in working collaboratively. Off-task interactions promote engagement and can bring a new focus and engagement to the task. In this study, although girls did demonstrate off-task discourse many times, they would essentially refocus on the task while building a positive learning environment.

Off-task discourse can work to build a sense of belonging and understanding in group work. Off-topic conversations have been linked to build stronger relationships, including between tutors and students [31]. This highlights that a sense of connection and support can be created with off-task conversations. Task-focused and casual conversations go hand-in-hand to help groups work together. In fact, other research has concluded that groups that are "task-focused and mediated for the entire session might be a less effective study group" [32]. Sawyer, in a study of undergraduate study groups, argues that casual conversation that is not task-focused cannot be dismissed as "off task" because these are the conversations that help discussions flow, be balanced, and create an atmosphere where all group members are comfortable and build trust. Overall, these small breaks lead to more productive collaboration, as demonstrated in this research study by the girls successfully working together.

By asking clarifying task questions, girls demonstrate their engagement towards the task as they fill gaps in their learning and their task responsibilities. When students ask clarifying task questions, they are able to assess what they currently know and are able to ask what they need to move forward. This is a concept that aligns with Evidence-based reasoning. Evidence-based decision making (EBR) are practices used in engineering learning environments. Instances of EBR are demonstrated when students use EBR to address confusion or uncertainty about a design idea

or decision [33]. In our research study, we also found that when girls express confusion or uncertainty, their partner or group member responds instantly to share their understanding to ensure that there is alignment between them.

In the same way, work distribution might depend on task demands and the levels in which students understand the task they need to complete. When students engage in a novel activity, having a clear understanding of what needs to be done or investigated is useful to effectively assign roles and responsibilities to successfully complete the task. This was demonstrated in Case 3, with someone implicitly assigning a task, by asking "who is going to …". This call for volunteers demonstrates that girls are able to bring their group partners to individually contribute. With clarifying questions, girls are able to work together responsibly and coordinate responsibilities to distribute task roles. In exploring different types of verbal episodes of: questions, conflict and reasoning, [4], found that students primarily engaged in question episodes, followed by reasoning episodes and rarely participated in conflict episodes. Our findings are similar, as the girls generate questions to address their knowledge deficit and to coordinate social action to clarify roles and expectations to coordinate tasks. According to [34], there are four major mechanisms that generate questions in conversations, including knowledge-deficit questions, common ground questions, social-action questions, and conversation-control questions. In this research study, we found that girls are asking the two out of the four types of questions of knowledge-deficit and social-action questions, which helps to ensure members are participating and filling their individual knowledge gaps.

Although collaborative learning has multiple benefits, its success and effectiveness largely depends on dialogue patterns [26]. In this research study, Case 1 and 2 highlight differences in communication dynamics, Case 1 shows more collaboration and discourse than that of Case 2. Studies suggest that "the more collaborative partner (the speaker) learns more than the less constructive partner (the listener) and it is more likely that the more constructive the speaker is the more they learn" ([26], pg. 260). This was demonstrated in Case 2, where the pair had limited discourse. In this pair, Girl #1 exhibited the most interest in the activity and occasionally tried to involve her partner into the activity. However Girl #2 in this case demonstrated little to no interest in the activity. This case demonstrates that there are cases in which students do not benefit from collaborative learning when one student takes the majority of the workload of the activity, forming an imbalance in participation and task completion.

Limitations and Future Work

There are no predefined general assumptions for discourse analysis, as it examines naturally occurring conversations during a genuine discussion. However, since discourse is inherently subjective, this leads for this study to follow a constructivist perspective to ensure transparency for readers to understand that the research methods and analysis are aligned with constructivist

principles. This informs the team's choices as researchers, acknowledging the influence on the interpretation of the data, especially during the categorization of the discourse actions into the 35 different codes of the TIOP. Part of the discourse analysis involved an approach to line-by-line analysis of occasions where the girls would talk amongst each other. Given that the data available is a large data set of long videos, from ten units, only five units are analyzed to focus on key segments of discourse in collaborative settings in which they are actively working on a task. This also leads into the transcription of the audio from the video, which was done by playing the video and converting speech from the girls into text, however, there was some difficulty with the audio quality which is misinterpretation. The implication of this approach is that the findings of this study may not be generalizable to other middle schools especially if they are not similar in terms of social conditions or population in the classroom, and these are conversations that cannot explain larger social structures in larger populations. Another limitation to this research study is the small sample size, there were two target teams consisting of two girl-girl participants each and in Case 3 that formed the larger group the total sample is six girl participants. This limits the generalizability of our findings, these results may not fully represent the populations of girls when in similar settings. With a small sample size, although it limits the generalizability, this provides insights to smaller group interactions and discourse patterns of the participants which can still give insight into future studies with larger girl groups.

Future work that can build upon this study would be able to compare different analyses into how girls and boys collaborate in groups during the same activity. This is significant because it can help with providing deeper insight into collaborations amongst working with the same gender and their discourse to complete tasks with the same gender. Future work can also implement this same microelectronics activity at the high school level to analyze discourse differences and group dynamic influences at different age groups. This helps in bridging the gap of discourse analysis at the precollege level.

Implications and Conclusions

This study offers insights to teachers on girl-girl collaborations and the discourse styles that best helped them to learn and communicate throughout a novel task. This study resulted in positive outcomes for girl-girl grouping. As girls are a minority within engineering, this study can encourage teachers to place girls together during a novel group task to maintain a positive learning environment and essentially maintain girls' interest in STEM to pursue careers. By understanding how girl-girl groups learn and work in collaborative group tasks, teachers can develop skills needed to teach students to work in diverse teams, not just with the same gender team.

Collaborative learning is complex, with tasks, tools, and teachers impacting student functioning and task goal achievement [12]. At the middle school level, teachers should focus on preparing students for diverse collaborative group work activities. However, as helping students work on

diverse teams takes a lot of work [35] it is necessary for real-world collaborations. For example, structuring and working in teams is critical for successful design-based activities to function due to the incorporation of multiple perspectives [36]. By placing girls in a diverse group setting, this can help girls to develop different skills. Our study demonstrates that girls tend to collaborate through positive interactions and sharing of ideas. To build on different skills, teachers can incorporate more structured work in which girls are able to practice questioning and argumentation. "Teachers can place students in groups where members have diverging viewpoints" [27]. This can help challenge girls to justify their thinking and ideas, which furthers their reasoning and engagement. Students should not remain passive while learning complex and content-dense materials, to get students more actively involved instructors need to structure cooperative interaction into their classes such as having students teach course material to one another to deepen their understanding while getting to know their classmates and building a sense of community [37]. Smith and team highlights that cooperative learning helps students with constructing their knowledge but also with their social aspects and building community which is important during collaborative group tasks.

This study holds significance for educational outcomes, during the implementation of curriculum writing and in improving teacher instructional practices. Teachers should be examining group discourse to determine how students engage and if the discourse is productive for students to successfully complete their assigned tasks. As previously mentioned, off-task conversations are deemed as negative and as distractions, and with this study, teachers can see that disruptive discourse occurs a lot during group work. However, this serves to better improve group dynamics and continue to progress on the task. This can help teachers better make the use of "off-task" conversations to encourage students to strengthen their group dynamics to create a positive learning environment.

In conclusion, this discourse analysis of two girl-girl partner target groups and a larger group of six girls, was conducted using Purzer's Team Interaction Observation Protocol with 35 discourse codes revealing insightful finding to the way girls work at the middle school level. The girls demonstrated the ability to engage easily in collaborative exchanges by seamlessly building upon each other's ideas and creating a supportive and engaging environment. While much off-task discourse occurred, the girls demonstrated the ability to refocus to complete their tasks and used off-task conversations to build community. The girls also asked clarifying task questions in which they used to complete their assigned task responsibilities and fill in gaps of their understanding.

Acknowledgements

We wish to acknowledge our student participants and teacher partners. We acknowledge support from the U.S. Department of Defense [Contract No. W52P1J-22-9-3009], Indiana Economic

Development Corporation [Contract No. A281-3-IPF-1028 424208], and U.S. Department of Defense through Applied Research Institute [Contract No. SA-22036.001].

References

[1] Şe. Purzer, "The Relationship Between Team Discourse, Self-Efficacy, and Individual Achievement: A Sequential Mixed-Methods Study," *J of Engineering Edu*, vol. 100, no. 4, pp. 655–679, Oct. 2011, doi: 10.1002/j.2168-9830.2011.tb00031.x.

[2] A. M. Clark and R. Kajfez, "The Impact of Girl Scout Engineering Experiences on the Identity Development of Middle Schoolers," *Journal of Pre-College Engineering Education Research (J-PEER)*, vol. 12, no. 2, Jan. 2023, doi: 10.7771/2157-9288.1346.

[3] R. H. Tai, C. Qi Liu, A. V. Maltese, and X. Fan, "Planning Early for Careers in Science," *Science*, vol. 312, no. 5777, pp. 1143–1144, May 2006, doi: 10.1126/science.1128690.

[4] M. Menekse, S. Purzer, and D. Heo, "An investigation of verbal episodes that relate to individual and team performance in engineering student teams," *IJ STEM Ed*, vol. 6, no. 1, p. 7, Dec. 2019, doi: 10.1186/s40594-019-0160-9.

[5] L. D. Baber, M. J. Pifer, C. Colbeck, and T. Furman, "Increasing Diversity in the Geosciences: Recruitment Programs and Student Self-Efficacy," *Journal of Geoscience Education*, vol. 58, no. 1, pp. 32–42, Jan. 2010, doi: 10.5408/1.3544292.

[6] N. Asper and B. Sepahpour, "Utilizing Team Building Skills In Engineering Projects," in *2003 Annual Conference Proceedings*, Nashville, Tennessee: ASEE Conferences, Jun. 2003, p. 8.1273.1-8.1273.13. doi: 10.18260/1-2--11567.

[7] T. Monroe-White and E. McGee, "Toward a Race-Conscious Entrepreneurship Education," *Entrepreneurship Education and Pedagogy*, vol. 7, no. 2, pp. 161–189, Apr. 2024, doi: 10.1177/25151274231164927.

[8] L. S. Vygotsky and M. Cole, "Mind in society: The development of higher psychological processes." Harvard University Press. 1978

[9] M. J. Nakkula and E. Toshalis, "Understanding youth: Adolescent development for educators." Harvard Education Press. 2020

[10] B. Barron, "When Smart Groups Fail. Journal of the Learning Sciences," 12(3), 307–359. 2003 https://doi.org/10.1207/S15327809JLS1203_1

[11] N. M. Webb, "Information processing approaches to collaborative learning." In The international handbook of collaborative learning, pp. 19-40, Routledge, 2013

[12] E. Mercier, M. H. Goldstein, Preethi Baligar, and Robin Jephthah Rajarathinam, "Collaborative Learning in Engineering Education," *Routledge eBooks*, pp. 402–432, May 2023, doi: https://doi.org/10.4324/9781003287483-23.

[13] J. Schnittka and C. Schnittka, "'"Can I drop it this time?"' Gender and Collaborative Group Dynamics in an Engineering Design-Based Afterschool Program," *Journal of Pre-College Engineering Education Research (J-PEER)*, vol. 6, no. 2, Dec. 2016, doi: 10.7771/2157-9288.1120.

[14] C. M. Hawkins, "Globalization; Science, Technology, Engineering, Mathematics (STEM), Project-Based Learning; and 21st-Century Workforce Requirements: How they are Connected to the Irish Education System." Order No. 10801467, University of Southern California, United States -- California, 2017

[15] Hudson, Peter & English, Lyn & Dawes, Les. (2013). Female Students' Interactions in a Middle School Engineering Project: A Case Study. 29. 814-821.

[16] K. Lu, J. Teng, and N. Hao, "Gender of partner affects the interaction pattern during group creative idea generation," Exp Brain Res, vol. 238, pp. 1157–1168, 2020.

[17] J. M. Calarco, "'I need help!' Social class and children's help-seeking in elementary school," Am Sociol Rev, vol. 76, no. 6, pp. 862–882, 2011.

[18] J. M. Calarco, "Coached for the classroom: Parents' cultural transmission and children's reproduction of educational inequalities," Am Sociol Rev, vol. 79, no. 5, pp. 1015–1037, 2014.

[19] J. A. Bianchini, "Where knowledge construction, equity, and context intersect: Student learning of science in small groups," Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, vol. 34, no. 10, pp. 1039–1065, 1997.

[20] J. B. Bear and A. W. Woolley, "The role of gender in team collaboration and performance," Interdisciplinary science reviews, vol. 36, no. 2, pp. 146–153, 2011.

[21] J. M. Kittleson and S. A. Southerland, "The role of discourse in group knowledge construction: A case study of engineering students," J Res Sci Teach, vol. 41, no. 3, pp. 267–293, 2004.

[22] M. D. Repice et al., "Talking through the problems: A study of discourse in peer-led small groups," Chemistry Education Research and Practice, vol. 17, no. 3, pp. 555–568, 2016.

[23] R. Egger, A. Joshi, S. Mehrotra, Y. Zastavker, and V. Darer, Using Discourse Analysis to Understand "Failure Modes" of Undergraduate Engineering Teams, vol. 2015. 2014. doi: 10.1109/FIE.2014.7044436.

[24] K. N. Silvestri, M. E. Jordan, P. Paugh, M. B. McVee, and D. L. Schallert, "Intersecting engineering and literacies: A review of the literature on communicative literacies in K-12 engineering education," Journal of Pre-College Engineering Education Research (J-PEER), vol. 11, no. 1, p. 1, 2021.

[25] A. L. Darling and D. P. Dannels, "Practicing engineers talk about the importance of talk: A report on the role of oral communication in the workplace," Commun Educ, vol. 52, no. 1, pp. 1–16, 2003.

[26] M. T. H. Chi and M. Menekse, "Dialogue patterns in peer collaboration that promote learning," Socializing intelligence through academic talk and dialogue, vol. 1, no. 2, pp. 263–274, 2015.

[27] C. A. Chinn, A. M. O'donnell, and T. S. Jinks, "The structure of discourse in collaborative learning," The Journal of Experimental Education, vol. 69, no. 1, pp. 77–97, 2000.

[28] K. S. Taber, "The use of Cronbach's alpha when developing and reporting research instruments in science education," Res Sci Educ, vol. 48, pp. 1273–1296, 2018.

[29] M. Menekse and M. T. H. Chi, "The role of collaborative interactions versus individual construction on students' learning of engineering concepts," European Journal of Engineering Education, vol. 44, no. 5, pp. 702–725, Sep. 2019, doi: 10.1080/03043797.2018.1538324.

[30] F.-C. Chen and T. C. Wang, "Social conversation and effective discussion in online group learning," Educational Technology Research and Development, vol. 57, pp. 587–612, 2009.

[31] B. Lehman, W. Cade, and A. Olney, "Off topic conversation in expert tutoring: Waste of time or learning opportunity," in Educational Data Mining 2010, 2010.

[32] R. K. Sawyer and S. Berson, "Study group discourse: How external representations affect collaborative conversation," Linguistics and Education, vol. 15, no. 4, pp. 387–412, 2004.

[33] E. A. Siverling, T. J. Moore, E. Suazo-Flores, C. A. Mathis, and S. S. Guzey, "What initiates evidence-based reasoning?: Situations that prompt students to support their design ideas and decisions," J of Engineering Edu, vol. 110, no. 2, pp. 294–317, Apr. 2021, doi: 10.1002/jee.20384.

[34] A. C. Graesser, M. Singer, and T. Trabasso, "Constructing inferences during narrative text comprehension.," Psychol Rev, vol. 101, no. 3, p. 371, 1994.

[35] D. A. Dickerson, S. Masta, M. W. Ohland, and A. L. Pawley, "How Can We Identify Teams at Risk of Marginalizing Minoritized Students, at Scale?," in ASEE Annual Conference proceedings, American Society for Engineering Education Papers on Engineering Education …, 2021.

[36] J. Schnittka and C. Schnittka, """Can I drop it this time?" Gender and Collaborative Group Dynamics in an Engineering Design-Based Afterschool Program," Journal of Pre-College Engineering Education Research (J-PEER), vol. 6, no. 2, p. 1, 2016.

[37] K. A. Smith, S. D. Sheppard, D. W. Johnson, and R. T. Johnson, "Pedagogies of Engagement: Classroom-Based Practices," *Journal of Engineering Education*, vol. 94, no. 1, pp. 87–101, Jan. 2005, doi: 10.1002/j.2168-9830.2005.tb00831.x.

APPENDIX A

Purzer's Coding Scheme: Team Interaction Observation Protocol

Purzer Appendix B Page 677- 679

1. Task-Oriented	**Code**	**Discourse Move**	**Description**	**Examples of Utterances**
	TAS	*TASK*	Repeating the task and requirements of the assignment to establish a direction	- "We are not evaluating yet, just brainstorming "
	DIR	*DIRECT*	Giving commands and directions. Asking someone to do something	-Chris, move the thermometer -Multiply it by 10.
	FOC	*FOCUS*	Bringing team back to focus (usually after an off-task discussion)	Let's identify the constraints now
	VOL	*VOLUNTEER*	Volunteering for a job. Taking the responsibility of a task or assignment.	I can buy the shaft.
	SUM	*SUMMARIZE*	Summarizing what is discussed before moving on the next task. Stating a group decision.	-So, we have different molds and different temperatures of the gel. - Ok, then, we are building a bridge.
	TAQ	*TASK QUESTION*	Checking if tasks are done.	Did you write your sections?
2. Response-Oriented	**IDE**	*IDEAS*	Introducing and sharing new ideas and suggestions.	I have stop sign.

	FAC	*FACTS*	Sharing scientifically correct information, data, and scientific facts with team members.	One “g” is 32.2 feet per second squared.
	UNC	*UNCERTAINTY*	An answer that shows uncertainty or lack of knowledge.	I don’t know
	ANS	*ANSWERING*	Answering team members’ questions by clarifying issues and providing examples.	You identify a weight for each criterion and multiply it by the score we have given
	EXP	*EXPANDING*	Expanding own contribution and providing additional information. Elaboration on a topic that is somewhat understood.	Constraints are like must do things. Constraints are different than goals.
3. Learning-Oriented	**REF**	*REFLECTING*	Reflecting on own understanding. Clarifying own thoughts during the process of orally sharing ideas with the team. Recognizing own misunderstanding. Reformulating own idea.	-But then I was like that would be like ice cubes and water expand when you freeze the, - I am having difficulty learning by trial and error.
	INFQ	*INFO QUESTION*	Asking for factual information.	Which page is it?
	CLQ	*CLARIFICATION QUESTION*	Requesting explanation & clarification. Asking for rationale (intention is understanding).	-What do you mean by...? -Why do you think so?

	INPQQ	*INPUT QUESTION*	Asking for peer's input, opinions, & ideas. Asking for a vote (intention is group thinking).	-What else can we add? -How about exploring this?
	APQ	*APPROVAL QUESTION*	Weak idea or proposal that shows some hesitation or seeks approval.	-We are using the metric system, right?
	RET	*RETRACTING*	Backing down on an idea usually in the face of a challenge or disagreement by a peer.	-Really? Ok, then. We can do that (your suggestion).
4. Support- Oriented	**AGR**	*AGREE*	Brief expression of acceptance or agreement with the team members' suggestions. Indicates understanding and is a sign of listening.	Yeah, ok.
	COM	*COMPLETING*	Completing peer's explanation or sentence. Can seem like an interruption but in a complementing way.	... then press the red button.
	SYN	*SYNCHRONIZING*	Repeating a peer's comment. Re-stating peer's comment or idea. Stating that he or she was thinking the same.	Yeah, I was also gonna ask how much budget we have.
	ADD	*ADDING*	Adding or elaborating on a peer's idea. Rephrasing or extending on peer comments, adding justification.	That would also be the cheapest option.

	PRA	*PRAISE*	Acknowledging team members' contributions to the project and praising their good or interesting ideas.	That is a great idea.
	SUP	*SUPPORTING PEER*	Protecting or defending a peer who is face with opposition by another person. Uses evidence to support a peer's assertion.	I agree with Chris, this should not be an issue if we heat the blade.
	PAR	*PARTIAL SUPPORT*	Partial support despite disagreement(goal is to have everyone's ideas incorporated)	We won't set it as a criteria but we will still try to do it
5. Challenge-Oriented	**DEF**	*DEFENDING OWN POINT*	When faced with opposition, defending own ideas by disagreeing with the opposiion, providing justification, and further explanation. Justifying own assertion with evidence.	I know. But if you've ever been to west campus, they have the same thing there and it works.
	ALT	*ALTERNATIVE*	Raises an alternative to peer's idea by using strong evidence and previous learning experiences.	Lab equipment is expensive but it would also be expensive to move a lab.
	CHA	*CHALLENGE*	Challenging a peer's assumptions.	Doesn't it sound like not caring for the baby?
	DIS	*DISAGREE*	Briefly rejecting or disagreering with team members' suggestions.	No, you don't need that.

	NEG	*NEGATIVE*	Negative Critisism: Rejection with overtones of a personal attack or disparaging remarks. Correcting mistakes in an offensive way. Making sarcastic comments or using humor in a negative way.	That doesn't make any sense. Gardening is a feminine thing. Freezing a chocolate is not allowed. Read the handbook.
	INT	*INTERRUPT*	Interrupting a team member's speech abruptly and disrespectfully to reject his/her idea.	... that won't work.
	IGN	*IGNORING*	Ignoring team members' questions or suggestions. Changing the topic.	(no response)
6. Disruptive	**OFF**	*OFFTASK*	Initiating off-task topics/discussions that are not related to the assignment.	I am hungry
	OFFTASK	*OFFTASK PARTICIPANT*	Participating in off task discussions.	You have a fish? I thought we are not allowed to have pets.
	PER	*PERSONAL*	Sharing personal information such as interests, values, and feelings.	-I don't break apart things. -My father bought a shock absorber last week.
	MIS	*MISTAKE*	Interpreting the task incorrectly. Conveying scientifically incorrect information, facts, calculations, etc. with team members.	2g is how fast the basket will drop.