Design and Technology Education: An International Journal

28.2

Exploring Girls' Narratives in Competition-Based Educational Robotics

Thomas Kennedy, Memorial University of Newfoundland, Canada

Abstract
The purpose of this study was to explore the perceived sense of comfort and belonging of girl participants, aged 15-16, engaged within a school-based offering of the Marine Education Advanced Education (MATE) underwater remotely operated vehicle (ROV) program (MATE-ROV). MATE-ROV is a competition-based educational robotics (ER) program that can offer experiences in the design, fabrication, and testing of an original ROV similar to what one would experience in relevant sectors of the marine industry. A qualitative case study design was selected to document and analyze participant narratives and explore their sense of belonging within the intragroup and intergroup contexts. With a purposeful sample of 5 (N=5), the study gathered data using a three-phased approach with data collected through the use of questionnaires, interviews and observations. The study sought to answer the overarching research question: How do experiences in educational robotics impact feelings of comfort and belonging for girl participants? Three primary findings emerged from this qualitative study. First, intragroup relationships foster a connected social identity that can support comfort and belonging. Second, a connected social identity does not automatically build a perceived expansiveness in comparable groups. Third, successful domain performance or effectiveness does not compensate for the potential impact of stereotype threat.

Keywords
Case Study, Social Identity Development, Educational Robotics, MATE-ROV, STEM Capital

Introduction
The Marine Education Advanced Education (MATE) underwater remotely operated vehicle (ROV) competition, or simply MATE-ROV, is an international program designed to engage participants in technological activity grounded in marine-based disciplines. School-based, educational robotics groups work over an extended period to design and prototype an original ROV-based solution to perform underwater tasks or missions. Each year, new parameters are published in a scope document that outline the limitations where each innovative solution can be quite different. The MATE-ROV program offers a unique opportunity where participants are able to work collaboratively within their local setting but also compete at a regional competition against other schools, a comparable structure to varsity athletic programs. Participants can therefore develop technological capacity and gauge their place within the larger population at competition.

Calipso Robotics is one such school-based MATE-ROV program at a small K12 school (student population 155) in eastern Canada. Over the course of three years, an anomaly occurred within the local group whereby the team became all-girl despite being open to boys as well. The phenomenon became more irregular as the group competed at provincial competition as the first all-girl team and even earned top score in the product demonstration in their third year of competition. The following qualitative case study captures their unique narrative as they reflect on their sense of comfort and belonging in robotics and their experiences within the local school-based program (intragroup) versus their experiences at competition amid the larger population (intergroup).

Literature review

Educational Robotics (ER) is a means to offer early experiences in science, technology, engineering, and mathematics (STEM) (Cano, 2022) where participants actively engage in some aspect of designing, prototyping, programming, and controlling a robot. Zuhrie et al. (2021) published a literature review to highlight emergent themes across the field of study. Their review supported two foundational elements common to the majority of ER programs. First, they are based on a project-based learning approach but programs can range from the assembly of a kit to the innovative prototyping of an original system. Second, they foster some degree of STEM-based skill development that can range from programming to construction to electronics. ER programs have gained a foothold in many schools as large-scale competitions gain popularity on an international level (Cano, 2022; Sullivan & Bers, 2019; Zuhrie et al., 2021). Competition-based ER was noted to develop “practical skills through the direct practice of … operating robots” (Zuhrie et al., 2021, p. 6). Brancalião et al. (2022) processed 673 papers that covered 50 competitions in their comprehensive literature review. Their work found that robotics competitions commonly featured aspects of industry. Participants build a robot to perform some activity based in real-world problems, work in teams, and develop hard and soft skills.

Research can be found that explore comparable contexts to this study, experiences of similarly aged participants engaged in ER programs that feature competition. One of the largest ER competitions is the Vex Robotics Competition (VRC) (Brancalião et al., 2022). Stewardson et al. (2018) published a study to look at participation in VRC which boasts over 18 000 teams worldwide. Their work connected the concept of self-efficacy as an indicator to predict success. The study found that the number of seasons of participation had a positive impact on perceived self-efficacy, a construct that is essential for choosing pathways that lead to further STEM-based activity and even careers. Another study based within the realm of VRC sought to examine the experiences of male and female participants to gain insight regarding the causes of attrition amongst girls across school-based programs. Sullivan and Bers (2019) conducted their study based on the experiences of program mentors and participants engaged in VRC across the United States. Their findings confirmed the lack of girls at the mentor and participant levels. It was also noted that girl participants had greater concern regarding the social repercussions associated with participation in ER, an area where they lacked confidence. They expressed fear of embarrassment and estrangement. They also communicated a perceived sense that the boys were entering with more experience, especially as it relates to aspects of fabrication.

A Sociological Perspective

As participants collaborate, they form a group of individuals that are interdependent for the attainment of a common goal. Literature to explore the sociological perspective of group dynamics pre-dates any implementation of ER programming. Turner (1982) noted that interdependence leads to cooperative social interaction and cohesion where members become bound to each other, the group as a whole, and the activity at hand. Intragroup relations can be characterized by (1) a perceived similarity of members, (2) social cohesion, (3) positive self-esteem, (4) emotional empathy, (5) cooperation, and (6) uniform attitude / behaviour (Turner, 1982, p.29). Intragroup relationships denote the dynamics within a single group. It involves the behaviours, attitudes and general group cohesion of a single unit. The cohesion that forms during group activity can support feelings of comfort and connectedness. Wenger (2000) described the intragroup connectedness as “a lived sense of belonging (or not belonging)” (p. 239), a construct that is strengthened through shared histories and experiences. But, his work noted that connectedness is just one of three qualities that support a balanced social identity. The expansive and effective pillars support the building of positive self-concept within the larger community. An expansive identity is one that would be accepted within comparable groups that value similar competencies. An effective identity supports engagement with performance within this intergroup context.

Wenger’s (2000) work suggested that a balanced social identity is a construct that is grounded and strengthened in local experience but universal enough to foster a sense of belonging within the greater domain. Individuals move away from their immediate peer group to interact with others that may share similar values. Intergroup experiences describe the behaviours, attitudes, perceptions, and interactions between two or more distinct groups. These experiences can be limited in non-competition-based programs as groups are not given the opportunity to interact with their counterparts from other schools or regions. This limitation can often negatively impact intergroup perceptions. Brown and Ross’ (1982) earlier work commented on this limitation, noting that feelings of bias and antipathy between groups are proportional to perceived threat to their social standing. ER programs such as MATE-ROV afford participants unique intergroup experiences where they are able to situate themselves within the larger field of robotics and evaluate their self-concept and sense of belonging.

STEM Capital

Archer et al. (2015) sought to understand how the various types of capital support engagement and participation in science. Their work focused on the scientific forms of cultural and social capital, or *science capital*, and its uneven distribution within society. The study calculated a science capital score based on survey data from 3658 participants, aged 11-15 years, basing their analysis on indicators regarding scientific forms of cultural capital; science-related behaviours and practices; and science-related forms of social capital (p.929). Participants were placed into three groups according to their exhibited level of science capital: low, medium, and high. Low science capital was defined as those students with limited scientific literacy, less engagement with extra-curricular science activities, and social networks with limited science-related jobs. High science capital was defined as those students with developed scientific literacy and access to science-related cultural and social resources (p. 936). Higher levels of science capital were found to be more concentrated among boys. Archer et al. (2015) found a direct correlation between science capital and science identity whereby participants with high science capital were secure in their perceived belonging in the field and felt the identity was validated by others. Those participants with low science capital felt that others did not view them as a science person (p.938). Similarly, students with higher science capital were more confident in their science abilities. The authors noted a trend for medium science capital student, 67% of their participants, to be representative of a larger sample and remained unsure of their science identity despite having medium level of confidence in their abilities. Low science capital students, 27% of their participants, were identified as primarily female and while they may find science interesting, they do not consider themselves to be that type of person.

Later research conducted by Archer et al. (2020) continued to explore the factors shaping aspirations and identities building on his conceptualization of *science* capital and even acknowledging a broader notion of *STEM* capital (p.8). The second phase of their large-scale study in England, ASPIRES 2, found that high levels of science capital were likely to translate to positive attitudes towards the four subcategories of STEM. As the findings of ASPIRES 2 underscored the impact on the larger field of STEM, it brings the relevance closer to the current study. The longitudinal research supported the trend that boys, in particular, having family members with science qualifications and / or jobs were more likely to aspire to a career in science. Additionally, Archer and colleagues wrote of the trend for engagement to be shaped by the participant's science-related self-concept. Science self-concept was determined to decrease as students progressed through secondary school, aligning with the age of the participants in this study. The survey data showed that while STEM clubs were associated with higher trends of positive attitudes, the responses from some girls described their discomfort in attending such programming when they were dominated by boys. But, when science is largely considered a masculine pursuit, it is not surprising that the science self-concept of girls was reported to be significantly lower than the boys.

Gendered Programming

Exposure to technology activity could work to establish an early sense of belonging in technical work. Sultan et al. (2023) conducted a study of a three-day technology camp for Swedish teenage girls where activities were re-designed to be girlified – "the act of making otherwise not gendered artefacts girly…transformed from a male or neutral to a more feminine coded object (Discussion, para. 2). The authors found that participants who had already established a self-concept of being technical did not find the efforts to girlify the activity appealing. Their findings also highlighted the social connection that exists between participants whereby participants feel a sense of belonging and technical capacity because of a supportive social context.

Girls are rarely the dominant demographic in STEM-based programs without gender-based interventions. Kim et al. (2018) published an empirical research focused on the STEM-based experiences of girls which highlighted the importance of supportive relationships. Interpersonal connections work to foster the development of self-esteem and counter the trend for girls to inaccurately rate their own competencies. They proposed that programs must create and maintain a balanced perspective of what constitutes the ingroup or prototypical identity to combat the attrition of girl participants. Cano (2022) conducted a recent mixed-methods study to design a methodological approach for teaching STEM-skills through ER with a gender focus. Their study highlighted the trend for females to develop a sense of estrangement in STEM-based contexts and to be more passive when tasked with the fabrication of robots. The findings underscored the potential for gender-focused ER-based workshops to foster interest and curiosity in girls where they noted an increase in participation. Hernandez et al. (2017) reported results of a theory-driven mentoring program to support female students enrolled in post-secondary STEM majors. The findings of their study were based on their mentorship of eighty-five participants and suggested that to develop professional identity, learners must see themselves as professionals, become a part of the community and be recognized by their mentors. They found that girls can experience social barriers that "undermine their scientific development, motivation, and persistence in STEM education and career pathways" (p. 10). Girls who received explicit mentorship reported higher levels of scientific identity and interest.

Yet, literature also proposes that efforts to create gender-focused programming can perpetuate stereotypes and appear condescending. Watermeyer's (2012) three-year ethnographic and longitudinal study found that same-sex programs in STEM "served not to reverse but reproduce and accentuate the manifestation of gender inequality" (p. 696). Gender-focused programming seek to stimulate scientific interest amongst girls but risk imposing gendered identity and perpetuating the ingroup. At the institutional level, Allen and Eisenhart (2017) proposed that the historical narrative has contributed to poor identity development for girls in STEM-related disciplines. Their ethnographic and longitudinal study focused on four young women as they "negotiated STEM-related identities in the discursive and practice contexts of their lives at school" (p. 407). Findings from their study highlighted the need to address the intersection of gender and STEM more explicitly at the institutional level to allow opportunity to those groups that remain underrepresented. Their work noted a similar concern that addressing girl STEM identity development with gender-based solutions may be misleading and assumptive. Later work by Goreth and Vollmer (2022) echoed a similar position that the existing gender gap in technological domains cannot be reduced to gender-focused programming. Their findings highlighted that the interest in STEM is strengthened through technical socialization and compulsory technology education courses, regardless of gender identity. The authors noted that the implementation of technology education curriculum for all could help sensitize supporters to the topic to help establish the self-concept of girls in STEM (p.1693).

Sparks (2017) warned that assumptions made of individuals based on their demographic do not account for their lived experiences. His work explored the potential for gender-based solutions to impede girls in STEM in two ways. First, it may steer them away from gender specific programming where they do not feel comfortable. He noted that interventions cannot be reduced to a pipeline perspective that "erroneously suggests that the more girls who are stuffed into one end, the more that will turn out of the other end of the pipe to complete their degree and chose STEM as a lifelong career" (p.12). Second, individuals may respond by adapting to the gendered spaces by temporarily suspending aspects of their identity to conform to their environment and ensure acceptance. For example, a girl engineering student may feel they must enjoy video games and be 'geekish' to fit the prototypical identity or risk social repercussions. Earlier literature on stereotype threat offers a similar perspective, where stereotype threat is the "socio-psychological ... situational threat ... that can affect members of any group about whom a negative stereotype exists" (Steele, 1997, p. 614) where an individual "is concerned about being judged or treated negatively on the basis of this stereotype" (Spencer et al., 2016, p. 416). Pressure to outperform and disprove stereotype threat, especially by the vanguard, can be daunting. Spencer et al. (2016) named three aspects of stereotype threat that can lead to underperformance. First, underperformance may result from extra pressure to succeed. Second, underperformance may result from threats to self-integrity and belonging where participants may self-handicap to protect themselves. Third, underperformance may result from priming the stereotype. Beyond the potential for underperformance, Spencer et al. (2016) also noted the potential for stereotype threat to influence an individual's sense of belonging and their motivation to engage and commit to any given domain.

The literature review was a scoped exploration of potentially meaningful themes associated with the context of this study. It sought to examine existing themes within the field of study in relation to (1) educational robotics, (2) social identity, (3) STEM capital, and (4) gendered programming. The review has offered a preliminary lens to examine the lived experiences presented by the study participants.

Research Question

The purpose of this study was to capture, analyse, and discuss the narratives of a group of girls engaged in educational robotics at the intragroup and intergroup contexts. Their narratives can speak to the unobservable, their perceived sense of comfort and self-concept. Sparks (2017) noted that the first step to addressing the attrition of girls in STEM-related activity is to conduct more qualitative studies to explore the development of identity within these contexts.

This study was conducted to explore a sociological perspective as participants reflect on their intra- and inter-group belonging. The findings of this study offer insight that is applicable to comparable programming across jurisdictional boundaries (i.e.. Ministries of Education, School Districts, School Boards, Schools). The main research question that guided this study was: How do experiences in educational robotics impact feelings of comfort and belonging for girl participants?

Methodology

A qualitative case study design was selected to analyse emergent themes from an in-depth exploration of participant experiences within an educational robotics program. Flyvberg (2011) noted the potential for case study to emphasize an intentional object of study, a phenomenon that justifies further exploration. The ER program at the centre of this study exhibited an all-girl ingroup which did not align with the trend for robotics to be a typically masculine activity. The case fulfilled the three conditions outlined by Yin (2014) whereby (1) the study's research question seeks to understand a singularity, (2) the study does not separate the phenomenon from its context, and (3) the study focuses on a contemporary case rather than an historical one. An understanding of this phenomenon may offer insight for similar programs that seek to address the underrepresentation and attrition of girls.

Participants

The participants of this study formed a purposeful sample where eligibility was based on candidate membership in the educational robotics program, Calipso Robotics, from 2016-2019. There were 5 candidates eligible for the study with all 5 (N=5) agreeing to participate. Miles et al. (2014) noted that it is common for qualitative studies to work with such small groups especially as it highlights a phenomenon. All participants were in grade 10 (age 15/16) at the time of the study and reflected on their experiences from grades 7-9 (ages 12-14). The participants were assigned pseudonyms - Chloe, Olivia, Isabella, Jessica, Emily - in order to reference specific experiences across the data analysis narrative.

Data Collection

A multiphase design for the data collection process was adopted for this case study where the focus was to gather thick, richly descriptive data to document the lived experiences of each participant. All instruments used to collect data were original and drafted to include protocols.

Phase I began with a questionnaire. The protocol featured prompts such as: "How did you get started in robotics?", "Please describe your experiences within the extra-curricular robotics program.", and "Please describe your comfort level participating in technical activities like robotics and competing at the provincial level.”. The questionnaire was distributed to participants digitally and designed to aid in the initialization of participant profiles and gather preliminary perspectives.

Next, phase II continued with an interview that was designed to be semi-structured and flexible. The protocol was drafted to probe for deeper understanding. The interview was conducted in a face-to-face, one-on-one capacity where each participant was able to offer their narrative independently of the group. The protocol included questions and prompts such as: “In what ways did collaboration with peers influence your experiences?”, “What factors have influenced you to come back [to educational robotics] each year?”, and “In what way, if any, do you adopt a different identity when engaged in [educational robotics]?”. Phase II also included observations of the participants as they engaged in their program. Observation is a method commonly used in case studies (Merriam & Tisdell, 2016) which can be used to discover the complex interactions within the context of the study (Bloomberg & Volpe, 2016).

Phase III marked the final step in the data collection process where participants were given the opportunity to review their data. Each participant completed this phase with no edits to be made to the data. This step was an important piece to ensuring the data captured an accurate representation of their lived experience and voice.

Data Analysis

Miles et al. (2014) stressed “the apparent simplicity of qualitative data masks a good deal of complexity” (p.11). As expected, the data collection process of this study produced a large amount of raw data. An analysis plan was created to remain consistent in handling the voluminous amount of participant narrative. The plan was based upon the work of Braun and Clarke (2006) that suggested steps for thematic analysis to ensure a systematic approach.

Table 1. A thematic analysis plan based on the work of Braun and Clarke (2006).

Step	Description
Step I: Familiarization	• Exporting the questionnaire data from the online form. • Transcribing the interview data. • Reading and re-reading the data, noting initial ideas.
Step II: Generating Codes	• Importing data documents into Nvivo software. • Searching for segments that captured an idea or topic • Assigning nodes in a systematic fashion across the data
Step III: Searching for Themes	• Collating nodes into candidate themes • Gathering all data relevant to each candidate theme.
Step IV: Reviewing Themes	• Exporting candidate theme document for review • Checking the candidate themes against the coded data • Generating thematic maps of interconnected node data
Step V: Defining and Naming Themes	• Analyzing to refine the specifics of each theme • Reflecting on the overall story the analysis tells • Generating names for each theme.
Step VI: Producing the Report	• Writing the final analysis • Exporting appropriate maps and figures • Selecting meaningful and purposeful extracts • Producing a scholarly report of the analysis

In Step I, the data analysis began with a focus on familiarizing myself with the data. Braun and Clarke (2006) underscored the importance of immersing yourself within the data to ensure familiarity with its "breadth and depth" (p. 87). I began by preparing questionnaire data and printing a physical copy for a pen-and-paper analysis of initial ideas. I searched for segments and the use of keywords, making notes along the margins of the document. The notes made from the questionnaire data was reviewed before moving forward with the interview stage to ensure my protocol was relevant and suited to their experiences. After conducting the interviews, I transcribed all digital recordings myself, a process which was highlighted as an important step to familiarization (Braun & Clarke, 2006). The transcription documents were printed and analysed in a similar fashion to the questionnaire data. All audio recordings of the Phase I interview were also reviewed closely for any errors. Preliminary notes taken throughout this step were used as references to begin the coding process.

Step II of the data analysis process began with the generation of initial codes from the data. Braun and Clarke (2006) noted the importance of giving full and equal attention to each data item while coding. Once the questionnaire and transcription documents were imported into my qualitative analysis software, Nvivo, I coded the data manually, ensuring that all data across the entire set was coded and collated. The software referred to the codes as nodes, objects created and pinned to emerging ideas or themes from within the raw data. Nodes were applied to segments of data that captured an idea or topic which ranged from a few words to larger segments of text. Ryan and Bernard (2003) suggested processing techniques for working through qualitative data. I conducted a digitized version of their *cutting and sorting* technique where I leveraged the tools embedded in Nvivo to identify quotes and expressions within the data. Once coded, I could query the database to determine emerging trends across the entire data (see Figure 2).

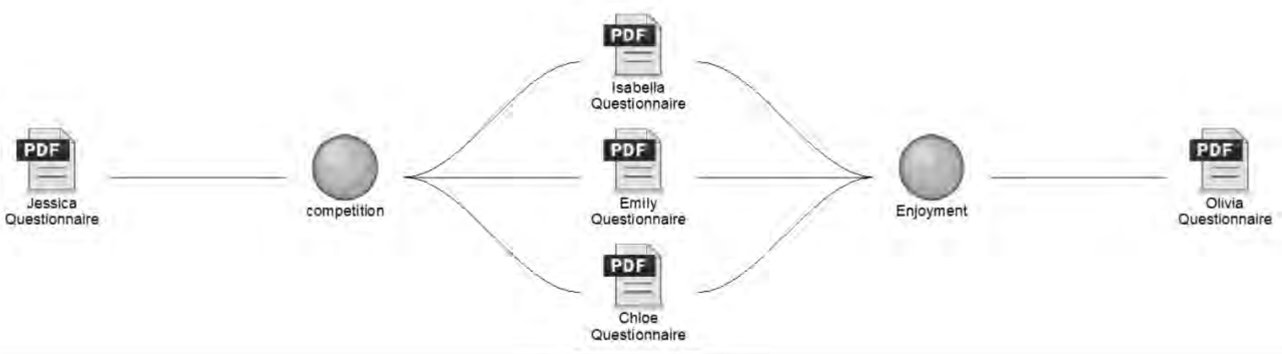

Figure 2. An example of software-based node comparisons of manual coding in Nvivo.

I also used Nvivo to create lists of keywords which Ryan and Bernard (2003) highlighted as an important technique to indicate what people are saying. This method generated nodes by exploring the exact words used by participants. Word-based techniques are a fast way to begin searching for trends in data at the beginning stages of research. It was important to code the raw data with as many different nodes as may apply during this step, often as simple as assigning a node to key words and longer data segments. The following nodes are a sample to represent my emergent coding of interesting features of the data:

- Skills Development
- Design Process
- Teamwork
- Friendship
- Enjoyment
- Competition
- Success

At Step III, nodes were clustered to form candidate themes. The nodes can have footings in various candidate themes as overlap across and within the narratives exists. For example, a participant could describe their enjoyment as it may relate to collaboration with peers, engaging in technological activity, and / or experiences at competition. Examples of some thematic categories included, but were not limited to:

- Enjoyment + Friendship + Belonging + Comfort → Peer Relationships
- Stereotyping + Competition + Peer Group + Discomfort → Estrangement
- Activity + Environment + Skills + Confidence → Belonging

Step IV of the data analysis process reviewed the candidate themes that emerged from the coded data during the previous phase. It was here that my process transitioned from manipulative techniques to observational techniques. Ryan and Bernard (2003) suggested that repetition was one of the easiest ways to identify themes where the more the same concept occurs in a text, the more likely it is a theme. Repetition was the primary observational technique adopted to legitimize candidate themes and was facilitated using the Nvivo software. Candidate themes that did not have sufficient support within the coded data were dismissed or integrated into other themes. Braun and Clarke (2006) described two levels to the review and refining of themes. The first level involves the review of the coded data to ensure that the generated themes are fitting. If the themes are coherent, the process moves along to the second level where the themes are reworked to become more appropriate. At the second level, themes are reanalyzed to ensure they accurately represent the coded extracts from the study. Themes were reviewed based on their accurate representation of the overall data set.

The final step of the data analysis plan, Step V, sought to define and refine the meaning of each theme and what aspect of the data set each one represented. Braun and Clarke (2006) explained that this phase should clearly identify the interest of each theme and highlight its importance through detailed written analysis. The refinement of the themes will ensure that the study's analysis is concise and interconnected. Participant narratives repeatedly focused on (1) the importance of intragroup connections, (2) the perceived deficit in expansiveness, (3) the importance of intergroup activity, and (4) the impact of the prototypical identity on perceived belonging. The following section is an overview of these central themes that represent the lived experiences of the participants engaged in this qualitative case study.

Analysis

The Importance of Intragroup Connections

All participants identified the presence of their peer group to be the primary reason for initial engagement in ER. They had been friends before engaging in the program and entered as a group. Beyond year one, participants attributed their re-engagement to be contingent on the continued participation of their friends. Participants decided if they were attending from week to week by first determining who would be present and who had other commitments. If too many participants were unavailable, the consensus generally leaned towards waiting for the entire community to be available. Moving forward with their activity was contingent on the presence of a near-full group of their peers.

When asked explicitly if she would have signed up without her friends, Isabella indicated that she was unsure:

> *I didn't really know much about robots, and like, that wasn't really what I was interested in until I started actually going to robotics and learned more about it. And that's what engaged my interest. So, if they hadn't joined in the first place, I probably wouldn't have either.*

The notion of comfort emerged as an important factor pinned to the presence of pre-program friends. It was highlighted that comfort was critical in taking risks and making mistakes within the technical work of the program. Emily highlighted that her comfort level was directly related to her engagement in technical activity amongst friends:

> *At first I was a little nervous about joining the team because I didn't understand the concepts, but after a while I started to get the hang of it and began to enjoy it a lot more ... my teammates helped me a lot with the learning process and it was very comforting.*

Chloe offered a similar emphasis on the comfort she experienced because of the co-participation of her peers and the freedom to make mistakes. She noted, "I'm not embarrassed if I get something wrong because I'm comfortable with my friends so it's like I'm safe to have an opinion".

Isabella expressed that the reengagement of her teammates year-after-year was a motivational trigger for her own continued participation. Jessica and Chloe shared a similar perspective, in that their initial engagement was triggered by a shared interest amongst most of their friends and, like Isabella, were doubtful on their continued participation without their presence. When asked explicitly if she would return to the program without her friends, Isabella expressed uncertainty "I think, I ... maybe ... it depends. I think having my friends in robotics makes the experience better but I also just enjoyed being in robotics".

Two of the five participants noted the importance of peer group participation for their initial enrolment in the ER program but have since developed an interest that extends beyond their peers. Olivia noted that working alongside her friends as teammates made her engagement within maker activity fun and when asked explicitly if she would return without her friends, Olivia answered "yeah, because I like it". She had developed an interest in the activity that could exist without the co-participation of her peer group. Emily shared a similar perspective on the importance of her friends for her initial engagement but indicated she would continue to participate without them within her local program and went as far as to state she would engage within a similar group in other jurisdictions.

The Perceived Deficit in Expansiveness

One aspect of the study sought to explore how participants perceived their ability to join a similar program grounded in educational robotics, even another school group hosting a MATE-ROV club. Three of the five participants indicated they would not continue to engage in similar activity if they were to move to another school. Jessica noted that despite having participated over a three-year period and feeling comfortable within the program, she would not enroll in similar activity in another setting without her friends. Olivia also gauged her motivation based on the presence of pre-program friends and therefore decided that she would most likely not continue to engage in a similar program outside of her own school community. When asked explicitly, Olivia replied "If I knew people in robotics. If not, I probably wouldn't feel comfortable".

Chloe's reservations were grounded in her perceived competency and whether her abilities met the standard of the new group. When asked explicitly about her potential comfort in participating with another ER group, Chloe replied:

> *If I were to leave this group and me, by myself, go off, I wouldn't because I would feel more scared if I was to make a mistake and I would feel like they're smarter than me. In this group, I know that we are all equal, on the same level.*

Chloe's perspective highlighted the equal footing that newcomers share when entering educative maker programs and the comfort of co-participating with peers who were at her level. Isabella expressed a more open-minded perspective on transitioning into a parallel program. She explained that she would participate in a similar group depending on the participants. Ultimately, Chloe, Jessica, and Olivia remained attached to pre-existing relationships to support their sense of belonging and comfort. Isabella offered a similar perspective, but to a lesser degree.

Emily, on the other hand, said she would be comfortable joining a parallel program without the co-participation of her peer group or concern over who formed the ingroup of the other program. She explained that a parallel group would have participants that share her interest in the activity and knew that shared interests could make connections with a new peer group. Emily's perspective described her understanding that others engaged in similar activity would logically share interests with her and therefore foster a sense of membership.

Although participants described their identity to be dependent upon the support and presence of their co-participating peers, they were asked about their potential futures within the field. When asked explicitly "Have the skills you developed made you more open to a future in technical fields or STEM-related fields?", all five students foresaw no obstacles to potential aspirations in STEM. In the end, all five participants explained that their individual trajectories did not align with the robotics field due to personal preference rather than perceived inability.

The Importance of a Terminal Activity

The MATE-ROV competition was a terminal activity to end each season, an opportunity to interact with other school-based groups. Participants described the competition as a driving force that stimulated work ethic, interest and enjoyment in educational robotics. Though the competition had originally motivated her engagement, Olivia found enjoyment in the challenge it gave her on a personal level in terms of her skill development within the program. Isabella presented a similar connection to the importance of the competition but added that competing made her work harder in the program. For Jessica, "it makes building the robot much more fun knowing that we're going to go and compete". She emphasized the learning that is associated with her continued participation which, for her, held equal importance. Chloe underscored how competition aligned with her competitive nature thus becoming a trigger for her continued participation. She stated that competing added to the overall enjoyment of the program, paralleling the perspectives of her teammates Olivia and Isabella.

Olivia and Isabella framed the importance of competition as a glimpse at the real world. They articulated that their experiences at competition showed the importance of technological competency while also stimulating their interest in STEM-based activity. When explicitly asked to describe the success she experienced in robotics, Olivia stated "I learned how to wire a robot and understand a lot of it ... [I] learned how to work with people and drive the robot". She was the only participant to highlight skill development as an indicator of her success.

All five participants noted success at competition to be a motivational trigger for re-engagement in the program. Perspectives highlighted both the importance of externally measured success at competition with several participants also making connections with feelings of personal accomplishment. Chloe discussed her feelings of success within the robotics program, she measured success as the team's growth and capacity within the domain of robotics. The following statement illustrated Chloe's perspective on team accomplishment as a measure of success:

Before we even knew if we won or not, it was just an accomplishment compared to previous years. We had done so much. We didn't even need to win ... we knew that we were doing really well.

Adopting a similar perspective to Chloe, Jessica associated their win at robotics to feelings of personal pride in her team, commenting "it also feels great when you're walking around knowing that you have a winning robot".

Participants were explicitly asked whether success had become a required element to stimulate their continued reengagement. Isabella highlighted that while success is certainly a motivational factor, she would still participate in the program without it. She offered the following reflection

I came back every year because we were succeeding ... last year we got the highest score out of everyone else in the province ... since we keep getting better and better each year, it makes me want to go back and do even better than the year before.

When asked if the absence of competition would deter reengagement, each participant decided it had become a secondary factor to stimulate their interest but was still a meaningful part of the experience. But, observational data conflicted with perspectives expressed by three of the five participants in the study. Chloe, Emily, and Isabella stated the absence of competition would not determine their engagement within the program yet, when the group was unable to attend the MATE-ROV competition due to a scheduling conflict, their participation ended. In this instance, participation was heavily weighted on the opportunity for product demonstration.

The Impact of the Prototypical Identity on Perceived Belonging

When asked to describe the other teams that participated in the robotics competitions over the last three years, all five participants described them as predominantly male, knowledgeable, and falling within a known stereotype. Isabella acknowledged the prototypical ingroup, "I would say that they're mostly boys and they usually look like the stereotypical nerd. So, they usually wear glasses and they really look like they know what they're doing". Chloe expressed reservation regarding her presence amid such a homogenous group but noted that the presence of her friends gave her comfort. Per her description, the other teams seemed to know more and were better suited for the competition yet, by her own words, she admitted "I don't know how much I know compared to others. I've never talked, we never talk to people when we go out for robotics. So, I don't know what other people know". The perception that other teams were more knowledgeable based on their prototypical identity was corroborated by Isabella, Jessica and Olivia. Yet, like Chloe, none of the participants could explain why they perceived the other teams to be better or more suited for the technical activity especially since they were experiencing measurable success at competition.

When prompted to reflect on their participation at competition, all five students described feelings of deficiency once they left the comfort of their local program. All five described their team as being all-girl and each one also commented on their assumed inexperience at competition. They all noted how other teams and even event organizers mistakenly interpreted their atypical girl team to be less knowledgeable when compared to their male counterparts. This perception was illustrated when Jessica stated:

[The other teams] look like they know what they're doing, more so than us. People probably think that we are not as good as we actually are ... A lot of people at the competition can't believe that we are an all-girls team and probably don't see us as doing anything with robotics.

Emily highlighted the error in their perceived in-experience when she highlighted that others would view their team as "no good" yet they earned the highest score at their most recent competition. To a similar effect, Isabella said

Sometimes we may look like we're inexperienced but that's not the case ... I really think it's a surprising factor for a lot of people because they think that just because we're girls, we aren't able to do the same things as the other teams but we usually excel.

Participants noted feelings of comfort, acceptance, and belonging within their local maker community of practice but all five of the participants agreed that, amid the larger community of practice, their all-girl status existed in clear polarity to the prototypical identity they experienced.

Discussion

Three distinct findings (F1-F3) have been drafted based on participant narratives and the thematic analysis of the richly descriptive data. The following section offers succinct findings statements paired with brief discussions.

F1: Intragroup relationships foster a connected social identity that can support comfort and belonging

As participants reflected on their experiences, their narratives highlighted the importance of peer relationships for both their initial engagement in educational robotics and motivation to participate year-after-year. This finding aligned with Wenger's (2000) notion of a connected identity whereby community members build a sense of comfort and belonging on shared histories and experiences. Connections can also be made with Archer et al.'s (2015) work on science capital, whereby the girls felt a sense of belonging as their peer group valued the activity. In this sense, the peer group served as the social capital to strengthen confidence in ER abilities and support ER self-concept.

Participants described a sense of social cohesion when reflecting on their intragroup connections. Their collective narrative aligned with Turner's (1982) work on social identity where he emphasized the importance of intragroup relations. His work highlighted social cohesion as a critical component to the interdependency of group members. As participants described their feelings of being bound to each other and the emotional empathy that came from their collaboration, their narrative seemed to mention all characteristics described by Turner (1982): a perceived similarity, social cohesion, positive self-esteem, emotional empathy, cooperation, and uniform attitude.

Feelings of comfort amid the intragroup allowed participants to work within a safe context. They were allowed to fail forward, highlighting the safety net created by a close group. It was noted throughout the data that comfort was a critical component in taking risks, making mistakes, and adopting the norms and practices that seemed unfamiliar at initiation. While estrangement and underperformance due to fear of social repercussions was a theme noted by both Stewardson et al. (2018) and Sullivan and Bers (2019) in their VRC studies, there was no supporting data within this study. The intragroup relationship offered the supportive construct that Kim et al. (2018) described as an essential element to foster the development of self-esteem in STEM-based activity.

F2: Connected identities do not automatically build a perceived capacity and belonging in comparable groups

An overreliance on the intragroup relationship can create an imbalance in the development of social identity. Wenger's (2000) notion of expansiveness underscored that "a healthy identity will not be exclusively locally defined [but] will identify with broad communities that lie beyond direct participation" (p. 240). The data showed that despite a level of competency developed over a three-year-period and successful performance at intergroup competition, four of the five participants stated that they would not participate within a comparable program without the presence of their friends. Participants felt uncertain about their acceptance as they continually mentioned the need for their peers to be present. The overall narrative underscored an interesting connection between their description of a strong connected identity and their perceived deficit of their expansive identity.

The perception that other teams were more knowledgeable and better suited for robotics based on their gender highlighted a perceived deficit in the effective quality of participant identity. The perceived deficit in expansiveness highlighted a marked discrepancy between the limited identity that students described and that which they demonstrated through performance. Their narrative aligns greatly with the findings of the ASPIRES work as Archer et al. (2020) described trends for science self-concept to decline in girls around the age of the participants in this study.

The fear of incompetency and discomfort were the strongest reservations regarding the ability to participate in a comparable program, even one based upon the MATE-ROV framework. Kim et al. (2018) noted a similar trend where girls inaccurately rate their own competencies. Participant narratives described an uncertainty regarding their value and ability to contribute to other programs and subsequent peer groups. The risk of perceived underperformance aligns with Spencer et al.'s (2016) notion of stereotype threat. Participants worry about the relationship between their performance and acceptance.

F3: Successful domain performance does not automatically reduce the impact of stereotype threat

Participants were able to test the effectiveness of their social identity as they competed at an intergroup competition. Wenger (2000) noted that an effective identity supports engagement with neighbouring communities and the ability to perform in an intergroup context. The intergroup context gave participants an insight into the prototypical identity associated with educational robotics and similar technological activity.

Experiences within the intergroup context internalized a sense of estrangement despite the participants demonstrating a strong effectiveness through measured success. Yet, the stereotype threat within the context of this study did not result in underperformance as suggested by the literature (Sparks, 2017; Spencer et al., 2016, Steele, 1997). But, there was a sense of discomfort. Time on the podium did not seem to reduce the overwhelming presence of the prototypical identity in educational robotics though the work of Stewardson et al. (2018) on experiences in VRC would have suggested otherwise. Participant self-efficacy did not support the perception of similar successes in comparable ER groups. Spencer et al. (2016) highlighted the potential for stereotype threat to undermine feelings of comfort and belonging while also fostering a sensitivity regarding any sign of estrangement. They contended that “events that might seem innocuous to others, such as … receiving a disapproving glance from an instructor, may undermine … motivation and commitment to the domain” (p. 424).

Brown and Ross (1982) mentioned the potential for groups that experience a threat to their social standing to experience feelings antipathy towards the ingroup. Although the participants did notice the dominant boy group at competition, they never expressed any bad feelings towards them. Similarly, the participants did not mention any attempts to conform to the stereotype and suspend aspects of their own identity, a potential coping mechanism suggested by Sparks (2017). Participant narratives did highlight an awareness as to the ‘geekish’ nature of their counterparts, but there was no reference to their own adoption of a similar identity. If anything, they noted how they were different.

Overall, the findings challenged my assumptions regarding the social identity the participants had developed within their educational robotics experiences. I had assumed that a strong, connected identity paired with success at competition had built a balanced identity for the participants and placed them within Archer et al.’s (2015) high science capital category. But, from an analysis of the data, their perceived sense of comfort and belonging was still susceptible to stereotype threat. Feelings of estrangement and limited ER self-concept were noted across the narratives of the study participants. A noted discrepancy emerged between the articulated expansive / effective deficit of participants and the successes experienced at competition. This finding underscored the importance of supportive structures to prepare participants for intergroup contexts even when experiencing achievement within the domain. Within the context of this study, students were motivated to disconfirm the negative stereotype and were successful. Yet, lingering feelings were articulated in relation to their discomfort. Stereotype threat continues to represent an obstacle for identity development as there remains the potential for underperformance within the added pressure to succeed.

Conclusion and Implications

Educational robotics programs such as MATE-ROV offer students early exposure to STEM-based experiences. The girl participants of this qualitative study participated in ER with marked success and no attrition. Their narratives spoke of a strong sense of connectedness and social cohesion within their immediate group, their narratives spoke of success at intergroup competition – all aspects to suggest a high level of STEM capital. Yet, there was consistent reservation when prompted to reflect on comfort and belonging within comparable groups. The findings of this study highlighted the importance of intragroup relationships as social capital in the development of a connected identity while acknowledging the stereotype threat and limited expansiveness felt by the participants.

Implications for ER groups – or similar STEM-based programming - are to explicitly prepare girl participants to work within the boy-dominated field by creating a context where both genders converge. Not all programming has access to large-scale competitions like VEX and MATE-ROV, so similar experiences must be created. Constructs could be embedded at the organizational level of programs such as MATE-ROV to address the trend in perpetuating the perception that boys form the prototypical identity associated with technical fields in robotics and similar. But, it must also me noted that efforts to simply girlify aspects of the programming can also be counterproductive. A balanced approach must be struck.

A known concern regarding case study findings is the ability to make generalization applicable to other contexts. The small sample size for this study allowed for a more comprehensive and in-depth exploration of each of the 5 participants experiences. The homogeneity of the group has also given the study a deeper understanding of a subgroup of the larger population. As ER competitions have grown in popularity on a global scale, small generalizations can be made for any program offering built upon comparable experiences in robotics.

Future research may extend on the findings of this study by exploring the narratives of groups engaged in MATE-ROV in other schools. Similarly, an exploration of experiences in comparable programs that offer STEM-based activity may offer a balanced perspective on social identity development, feelings of comfort and belonging, and the retention or attrition of program participants. Competition offers a unique experience of intergroup play which can be the basis for future research regarding stereotype threat and the experiences of other marginalized groups.

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