Motivation and Gender Dynamics in High School Engineering Groups

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Research indicates that various societal, educational, familial, and identity-related factors affect girls’ STEM motivation disproportionately to boys, particularly in engineering [i, ii, iii, iv, v]. A lack of prior experiences with building and tinkering, low teacher self-efficacy in engineering pedagogical content knowledge, and a lack of real world connections can all have a significant impact on girls’ participation and motivation on engineering tasks. Situated in self-determination theory [vi] and the stereotype inoculation model [vii] this qualitative study explores how the motivational conditions of autonomy, competence, and relatedness are manifested in the behaviors of students working in small groups on a series of engineering design tasks within their science class, with a focus on how the group’s gender composition affects these behaviors and potentially modifies or reinforces other variables affecting girls’ enactments of motivation. Participants include six small groups of high school students, representing varying gender compositions, from three biology classes in two rural New England schools. Thematic analysis of both classroom observations and focus group interview responses indicates that manifestations of autonomy differ along gender lines, with girls showing more task-oriented and facilitative behaviors and boys exhibiting more exploratory and directive behaviors. Competence and relatedness, in contrast, appear to manifest differently between groups of varying gender composition, with female majority groups showing more cohesion and whole group problem-solving and collaboration than those with gender parity. Student reflections about their experiences with the engineering tasks, however, showed significant differences between the genders regardless of group composition or enacted behaviors. Girls expressed low competence and task-value for the engineering tasks, while boys indicated much higher confidence and connection to prior experiences that supported their engineering competence. Implications from this study are two-fold: providing opportunities for collaborative group work and attention to gender composition will provide greater access for all students to the conditions required for motivation, particularly with regard to relatedness. In order to positively impact girls’ perceptions of competence, however, practitioners will need sufficient support and professional development in order to increase their own engineering self-efficacy so that they may better present engineering tasks in a manner that promotes equal access to all students and combats existing barriers that girls may bring with them into the STEM classroom.

Introduction and Problem Statement

For more than half a century, researchers and educators have grappled with the phenomena of gender inequities in various STEM domains (science, technology, engineering, and mathematics). While all students continue to show decreased interest in STEM beginning in the middle school years and continuing beyond, this crisis is affecting girls disproportionately to boys [iii, v].
Further, this crisis is affecting girls differently across the various disciplines and sub-disciplines of STEM [iii]. A variety of factors, from societal stereotypes to familial expectations and educational structures, contribute to this decrease in girls’ STEM engagement, resulting in not only decreased motivation throughout their school years but in an under-representation of women pursuing careers in such fields [iii, v, vii].

While some areas of STEM, such as the life sciences and social sciences, do show a balance between male and female participants [viii], this is not the case in many other domains. Engineering, in particular, is one in which women remain a distinct minority, representing merely ten percent of the overall engineering workforce [viii]. This phenomenon represents not only a lack of access for women to these careers, but also a failure of educational and societal systems to support girls along an engineering trajectory earlier on in their lives.

With the recent adoption of the Next Generation Science Standards [ix] in many areas across the country and their call for the incorporation of engineering design and practices into the science classroom, teachers at all grade levels have embarked on the heavy undertaking of updating and improving their curricula. As girls show a clearly identified decline in STEM motivation and self-efficacy throughout their middle and high school years [iii, v], it is imperative that more is understood about the factors that impact their engineering motivation, as well as the manner in which they interact with engineering concepts and processes, in order for these efforts to succeed. Examining how student behaviors manifest motivation in an engineering context may help teachers understand how to structure and design these experiences to better meet the needs and preferences of their female students. Not only is it
critical for their classroom motivation and success at this adolescent stage, but it will speak directly to issues of recruitment and retention for females along an engineering pathway.

Literature Review

Stereotypes and Prior Experiences

From early childhood, boys and girls experience all domains of STEM differently. Societal stereotypes about “who does science and engineering” impact the expectations and exposure to opportunities parents provide for their children, with boys having far more experience with tools, materials, and toys that encourage experimentation and tinkering [x]. They are more likely to engage in informal engineering activities, in which building and taking apart are key components of learning about engineering design and scientific inquiry [iii, v]. In contrast, girls tend to engage in experiences that involve animals, gardening, and other aspects of life sciences, which often focus on helping others instead of pursuing their own questions and problem-solving [iii, v, xi]. These discrepant experiences play a significant role in contributing to the differing attitudes and self-efficacy in the various domains of STEM by the time students enter middle school.

A quantitative study done by Kahle and Lakes [xii] showed that at age nine, girls still expressed an equal desire as boys to engage with science and engineering activities, but also reported experiencing far fewer of these than did the boys. By age thirteen, the girls in this study continued to report fewer STEM experiences than boys, but also were no longer were as
interested in them. They had begun to question their own self-efficacy and showed significantly more negative attitudes and a very narrow scope of the various STEM domains.

This disparity in interest and experience shows up in the classroom as well. Research indicates that boys demonstrate a greater sense of confidence in STEM domains and report feeling more comfortable in school manipulating materials, asking questions, and challenging ideas [xiii]. Teachers also reinforce this behavior by having higher expectations for deeper levels of thinking and problem-solving in science and engineering for boys than girls [xiii]. The concept, then, of a successful male STEM student is one who is outspoken, highly involved, and readily questioning and challenging ideas. This, however, does not match the notion of a successful female STEM student. Research shows that teachers consider girls to be successful in STEM when they are hardworking, responsible, behaviorally appropriate, and on-task [vii, xiv, xv, xvii]. Girls who question the ideas or tasks presented, or who follow their own line of investigation rather than the activity laid out, are considered difficult and, at times, annoying [xiv, xv].

As such, and likely due to differences in prior engineering experiences, girls are more likely to use materials in strict adherence to the teacher’s and task’s directions. Gail Jones and her colleagues [xix] found significant gender differences in the manner in which boys and girls played and tinkered with tools in the STEM classroom, with boys far more likely to invent and explore and girls highly bound to the parameters of the activity the teacher had provided. Interventions such as providing the condition of teacher training and collaborative small group work have been found to be ineffective in changing these tendencies. In an exploration of boys'
and girls’ performance behaviors in the classroom, Jovonavic and King [xx] found that girls were far less likely to handle equipment and more likely to take on passive roles, such as writing and note-taking, than boys, even with these interventions in place.

Impact of Educational Factors

Classroom pedagogy and teacher self-efficacy also contribute to unequal gender participation in STEM classrooms. Common in many high schools, a dry, textbook-based delivery of science and engineering concepts is in direct contrast to the socially-relevant and cooperative learning environment that most girls prefer [iii, xviii]. Further, the current role of engineering remains inconsistent in many classrooms, despite the call of NGSS. While it is true this curricular shift may still be novel for both teachers and students, literature indicates that professional development and support for pre-service teachers in the area of engineering education remain limited [xxi]. Many teachers report feeling unprepared and unconfident in their abilities to teach engineering, both in terms of content and pedagogy, with female teachers showing significantly lower engineering self-efficacy than their male counterparts [xxi]. As teacher self-efficacy is shown to greatly impact student motivation and achievement across genders and disciplines [xxii, xxiii], this finding has alarming implications for how all students, but girls specifically, may experience and respond to inconsistent engineering instruction in their STEM classrooms, particularly when girls may be entering already at a disadvantage to their male peers in this domain.
Finally, real-world connections provided in the classroom to both science and engineering content impact how girls perceive and interact with these domains, particularly beyond the elementary school years. As girls enter middle school and continue through high school, they place greater value on societal issues and the well-being of their world and community. Yet when science concepts and engineering problems are presented in isolation from the people and other social elements they impact, the validity and importance of these domains becomes questionable for girls [xi, xiii, xiv].

This disconnect between school STEM and real-world science and engineering has important implications for understanding girls’ decreased motivation in engineering versus the life sciences. The life sciences provide girls with the desired connection to helping others that is so critical to their values. While this may additionally reflect stereotypical gendered roles that girls assimilate through their home culture and upbringing [xi], it also represents a trajectory of choice and interest that is consistent from childhood through adulthood. Conversely, however, girls do not see the same intrinsic value in engineering when it is not aligned with their personal goals [xi]. Without a transparent connection to the human experience, girls consistently show less motivation, achievement, and confidence in engineering than in the life sciences and as compared to their male counterparts.

These intersecting factors arising from societal, familial, and educational contexts all commingle, creating a scenario in which girls experience engineering as male-dominated, disconnected to societal issues, and unengaging in the classroom. Understanding how to reshape the engineering experience in science classrooms in order to better include females
requires a broader look at the conditions required for motivation and an understanding of their place in supporting girls’ participation in engineering.

**Theoretical Framework**

To explore the conditions surrounding girls’ participation in engineering, a framework of motivation provides a meaningful lens with which to make sense of this phenomenon and begin to imagine relevant implications. In this way, future directions and structures in the STEM classroom will be grounded in appropriate theory to meet students’ basic motivational needs. Ryan and Deci [vi], in their theory of self-determination, assert that three conditions are necessary in order for an individual to experience intrinsic motivation in any context: autonomy, competence, and relatedness. People must feel they have choice and ownership over their experience, they must perceive some level of confidence and ability to succeed, and they must have some level of connectedness to others in the same realm. In the classroom, these conditions speak to several concrete practices. Open-ended tasks in which students have the ability to approach solutions in their own manner can support the condition of autonomy by providing students with an appropriate amount of freedom and control over their process. Ensuring that such tasks are meaningfully embedded within content and scaffolded with sufficient structure and background knowledge to provide students with the foundation necessary for them to feel that they can accomplish the task may fulfill the condition of competence.
For group work to provide the condition of relatedness, however, individuals must feel they are legitimate members. The work of Nilanjana Dasgupta and her colleagues [vii, xxiv] further explores this concept of relatedness and group membership in their stereotype inoculation model. Dasgupta focuses particularly on the role existing social stereotypes within a particular setting play in individuals’ achievement in that context. She argues people tend to pursue achievement in domains in which they feel the most comfortable fit, and that fit is often based on group stereotypes. She posits, however, that individuals can be “vaccinated” against these stereotypes by having ingroup peers and experts with whom they relate and identify in achievement settings, which then allows them to achieve in situations in which they would typically be marginalized [vii].

This model may be effectively applied to the scenario of girls in the STEM classroom. If a girl, due to societal stereotypes, feels that she is less capable on an engineering task than her male counterparts, she may enact stereotypical behaviors and attitudes expected of her. If she is placed in a female majority group in this context, however, she may feel a greater sense of group comfort and belonging initially due to her common gender identity with the other group members. This in itself may allow her to engage more actively because she has accessed group membership on a primary level, as well as experiencing less immediate exposure to stereotypical behaviors of the dominant group (boys, in this case). Dasgupta and her colleagues tested their model in a variety of STEM settings, particularly in engineering, and found that female gender majority did, in fact, increase feelings of group membership, vocal participation, and confidence, as well as decreased anxiety for the female group members.
The work of Dasgupta and her colleagues and the framework established by self-determination theory provide a structure with which to examine the phenomenon of girls in the engineering classroom. While Dasgupta’s work [xxiv] focused specifically on women at the university level, and Jovanovic and King [xx] explored performance behaviors in small middle school science groups, no studies have thus far examined the impact of group gender composition on the motivation of high school students within a STEM domain.

The purpose of this study was to explore if a female majority had the potential to modify other factors impacting girls’ participation in engineering by pursuing the following research questions: How is motivation manifested in small groups of high school students as they work collaboratively on engineering design tasks? How are these motivated behaviors different between genders and between groups of varying gender composition? How do students perceive their experiences with these engineering design tasks, and how do patterns in their reflections differ between genders and between groups of varying gender composition?

Methodology

To answer the research questions, a qualitative research design was employed. This study was embedded in and used data from a larger NSF-funded project that explored small group affective, cognitive, and social dynamics of students in high school biology classrooms while working on a series of STEM tasks. This NSF project provided the optimum setting to address this study’s research questions in that it used engineering tasks that supported students’ autonomy and competence by allowing choice and varied approaches but also connected to students’ existing biology curriculum and prior knowledge from the class. The
inclusion of engineering design in the biology classroom also provided a clearer basis for comparison in that it examined girls’ engineering participation in a science domain that was typically preferential to them, as opposed to confounding multiple STEM areas in which girls express less interest. Relatedness was supported through the small group structure but included varying gender configurations for the purposes of this study.

Setting and participants

This study took place in three classrooms from two rural New England high schools over the course of their 2015 spring semester in biology. Participants included six student groups, two per class, from three separate biology blocks, which were formed by researchers in conjunction with the classroom teachers to create groups of four that represented varying gender composition: three groups with female majority (75%) and two with gender parity. The remaining group was intended to represent a female minority, but the girl in the study did not receive parental consent and thus was removed from the group. This sixth group was, therefore, composed of three boys. Both biology teachers (one teacher taught two biology classes) received professional development in the implementation of three engineering design tasks (cleaning up an oil spill, designing a pill coating, and creating a mechanical heart valve). All three tasks were aligned to the Next Generation Science Standards and fit within the teachers’ established biology curriculum. As part of the study, teachers agreed to implement these three tasks with their classes during the semester, embedded within the appropriate biology content, and to participate in two separate interview sessions with project researchers.
Data collection

Qualitative data were collected through (i) videotaped observations of all six student groups during their work on the three engineering design tasks (total of 18 hours of videotaped data), (ii) student focus group interviews with each group midway through the semester and at the culmination of the project, and (iii) teacher interviews at the same time as student focus group interviews took place. Student interviews focused on students’ experiences completing the tasks and working with their specific groups in order to provide greater insight into the themes and trends from the observations, and teacher interviews provided further information on their implementation of the tasks.

Data analysis

This qualitative study used template analysis, a form of thematic analysis, in order to search for themes and patterns in the data. As this study is grounded in a well-established motivational construct (self-determination theory), a priori codes were established in advance of the analysis process in order to directly acknowledge this framework. As such, a codebook (see Table 1) was created to identify student behaviors that manifested the existence of the conditions of autonomy, competence, and relatedness in order to create an overall picture of motivation within the context of gender dynamics in engineering. This codebook adapts behavioral indicators used by Jovanovic and King [xx], placed within these conditions as
outlined by Ryan and Deci [vi]. Underlined text in the table indicates the first author’s additions to the indicators, developed through the process of gaining familiarity with this study’s data.

<table>
<thead>
<tr>
<th>Active</th>
<th>Autonomy</th>
<th>Competence</th>
<th>Relatedness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Directing</strong></td>
<td>• Instructing group members</td>
<td>• Explaining a scientific concept or idea to the group</td>
<td>• Collaborating with other members of the group</td>
</tr>
<tr>
<td></td>
<td>o Task directing</td>
<td>o Explaining a scientific concept or idea to teacher</td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Discrete directing</td>
<td></td>
<td>• Hands-on collaboration</td>
</tr>
<tr>
<td></td>
<td>o Refocusing</td>
<td></td>
<td>• Discussing, talking with peers about the task</td>
</tr>
<tr>
<td></td>
<td>• Making decisions</td>
<td></td>
<td>• Seeking agreement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Inviting collaboration</td>
</tr>
<tr>
<td>Passive</td>
<td>• Following another student's directions</td>
<td>• Listening to explanations</td>
<td>• Working independently</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Expressing lack of understanding, “I don’t know” or “I don’t get it” types of comments</td>
<td>• Not interacting with peers</td>
</tr>
<tr>
<td>Active</td>
<td><strong>Manipulating</strong></td>
<td><strong>Suggesting</strong></td>
<td><strong>Assisting</strong></td>
</tr>
<tr>
<td></td>
<td>• Handling materials/equipment</td>
<td>• Offering suggestions regarding the execution of the activity</td>
<td>• Helping another student with equal ownership</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Global suggestions</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>o Discrete suggestions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased frequency/duration of speaking time</td>
<td></td>
</tr>
<tr>
<td>Passive</td>
<td>• Observing the activity</td>
<td>• Lack of suggestions or contributions</td>
<td>• Helping a student who is directing</td>
</tr>
<tr>
<td></td>
<td>• Hands-on playing</td>
<td>• Limited frequency/duration of speaking time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Record-keeping, note-taking only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td><strong>On task</strong></td>
<td><strong>Requesting explanation from peers</strong></td>
<td><strong>Reading directions</strong></td>
</tr>
<tr>
<td></td>
<td>• Engaged in activity, not distracted</td>
<td>• Rethinking issues by asking for clarification from peers</td>
<td>• Reading/listening to directions as whole group</td>
</tr>
<tr>
<td>Passive</td>
<td>• Off task, distracted, unengaged in activity</td>
<td>• Immediately asking for teacher’s help</td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Social conversations within group</td>
<td>• Copying without intent to understand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Social conversations with other groups</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Playing with non-task items</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Unengaged in task</td>
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</tbody>
</table>

Table 1: Behavioral Manifestations of Autonomy, Competence, and Relatedness
Prior to coding, interviews were transcribed fully; and from the videotapes, Elaborated Running Records [xv] were created. Elaborated Running Records (ERR’s) are comprehensive written descriptions of the videotaped data, capturing not just the conversations and dialogue among the participations but the behaviors and actions as well. The first author analyzed interview transcripts and ERR’s using the six-step process associated with thematic analysis. These steps, while being outlined as a linear process, are in reality highly recursive, with repetition of steps occurring throughout the analysis. Data were initially flagged for occurrences that manifested autonomy, competence, and relatedness. These initial flags were then further delineated and described by the behavioral indicators as outlined in the codebook, with reference to gender, individual student, and context of the behavior. These indicators were then examined among the students within the groups and then across groups in order to identify trends in how the behaviors were both enacted and received, between genders and between groups of varying gender composition. Finally, counts of the specific behavioral indicators were conducted for each student in order to gain insight into the overall frequency of the behaviors both between genders and across groups. For the purpose of this paper, teacher interviews are included to provide more context and elaboration to the analysis of the student data.

Findings and Discussion
Thematic analysis of these data produced several significant findings. Behaviors that manifested the condition of autonomy appeared to differ along gender lines regardless of group composition, while behavioral manifestations of competence and relatedness seemed highly impacted by the group’s gender configuration. Most striking, however, is that group gender composition appeared to impact some student behaviors but not necessarily their existing attitudes or preconceptions about engineering. To illustrate this, patterns in students’ behavioral manifestations of the motivational conditions observed in the videotapes will be described and compared both between genders and across groups of varying gender composition. Themes that emerged from the student focus group interviews relative to the motivational conditions will be discussed in order to answer the research questions as well as to provide a broader picture of students’ experiences working on the tasks in their collaborative groups. Finally, themes in the teacher interview responses will be discussed in order to further contextualize the student data.

Classroom Observations

Active autonomous behavior was examined in this study with regard to three specific enactments: directing and decision-making, hands-on manipulation of materials and equipment, and on and off-task behaviors. While the individuals within the groups and the groups themselves presented a variety of profiles and variability in these categories, some overarching observations can be made. First, within each group, a hierarchy developed that remained constant throughout the duration of the six tasks. In other words, a student leader
(or leaders) emerged who maintained this status. In all five groups that contained females, one girl was shown to assume a leadership role, even if it was shared with another boy in the group. Consistent with this female leadership were the autonomous behaviors associated with it. Regardless of group composition, the female leaders in the group showed more directing and decision-making behaviors than the other group members, often facilitating decisions, refocusing the group, or taking control of the next steps of the task. Also related to gender, females were observed to perform more facilitative and organizing directing behaviors than boys, who more frequently exhibited directing behaviors that were demanding and discrete.

For example, girls in leadership positions guided their group toward task completion with a tone of inclusion, such as, “Guys, we have to get going,” or “I’ll show you what I’m thinking once we’ve got the stuff.” In contrast, directing behaviors from the boys were more often commanding toward their own specific agendas: “Bring me some scissors,” or “I need another tube.” As such, not only did a female member of each group (except for the all-male group) rise to a leadership position, she also guided her group in a way that encouraged whole group participation toward the goals of the task. This clearly supports the findings of Dasgupta and her colleagues (xxiii) in that it suggests females working in engineering scenarios were able to transcend more passive, stereotypical roles in their groups and assume more active, leadership positions among their peers.

Consistent across all groups, also, is the gender divide that occurred with regard to manipulating the equipment required for the task. While actual frequency of handling materials did not show a significant difference between genders or between groups of varying gender
composition, the manner and intent did. Girls, consistent with the findings of Jones and her colleagues (xix), used the materials of the task strictly in adherence with the teachers’ directions and with the task parameters. While boys were more likely to tinker with or explore the materials, girls maintained a focus on task completion and used the materials strictly to this end.

As an illustration, in the oil spill clean-up task, girls were more often observed to test each material specifically (cotton balls, Dawn dish soap, rubber bands, for example) to observe its potential benefit or use. Many of the boys, however, would explore the materials by mixing or combining them in a variety of ways, just to see what would happen and not necessarily with a task-oriented goal in mind. In many cases, the boys’ passive handling of materials behaviors far outnumbered their active ones; in other words, they were more likely to investigate the materials for their own sake rather than as intended for the task.

Passive handling behaviors continued to differ along gender lines in other significant ways. Girls, in almost all cases, exhibited passive handling behaviors in the form of simply writing, which were still aligned with task expectations, and were almost never observed to play with the materials in an exploratory manner. In contrast, boys exhibited far more playing behaviors than girls, which included using the equipment and materials in a manner that was not related to the task at all, such as making a basketball game out of the task’s supplies. Girls’ hands-on behaviors, therefore, tended to remain more task-driven and toward task completion than that of the boys, regardless of the group’s composition, showing a clear alignment once
again with the findings of Jones’ prior research describing the differences between boys’ and girls’ hands-on behaviors in science [xix].

Manifestations of competence and relatedness, however, did appear impacted by group composition in the context of these engineering tasks. Active competence behaviors were defined as explaining, suggesting, and requesting explanations from peers. In the female majority groups, girls, particularly those exhibiting leadership skills across other categories, appeared far more likely to explain their thinking and understanding of concepts to their peers, and these assertions far outnumbered their expressions of confusion or lack of understanding. This trend was not observed in the same manner in the gender parity groups, in which girls’ explaining behaviors were almost equally matched to their expressions of confusion. In other words, girls in the gender parity groups were as likely to say, “I don’t get it,” or “I’m confused,” as they were to explain their thinking about an idea, while girls’ vocal participation in the female majority groups was more often an assertion of understanding.

Gender composition of the group also seemed to impact suggesting behaviors, with more equal distribution among all group members of suggesting occurring in the female majority groups. While suggestions were made primarily by males and female group leaders in the gender parity groups, there was greater participation among all group members observed in the female majority groups in terms of willingness to make suggestions about the execution and completion of the task. This was also observed in the girls who tended to be quieter group members: those in the female majority groups offered far more suggestions than those in the gender parity groups, even if the suggestions were discrete or related to a specific step of the
task. Together, these findings regarding explaining and suggesting behaviors, indicate that there was more active vocal participation and more frequent expressions of competence seen among all group members, but specifically among the girls, in the female majority groups. This was consistent with Dasgupta’s findings [xxiv] that a female majority in small engineering groups contributed to more frequent vocal participation of the female members than was seen in mixed gender groups.

The condition of relatedness also showed a striking difference between groups of varying gender composition, but this appeared also linked to gender itself. Active relatedness behaviors were defined as working interactively, assisting, and reading directions aloud. Relative to gender, girls showed far higher occurrences of these relatedness behaviors across all groups than the boys. These behaviors echoed the more facilitative nature of girls’ leadership style as well, with more frequent attempts to seek agreement and organization among the group members. Girls in all groups, regardless of composition, were far more likely to seek agreement with their group members before continuing on with the task, asking, for example, “Should we test it now and then fix it tomorrow?” or “Do you have any ideas of how we should start?” Further, this trend emerged even more dramatically in the female majority groups, with far more frequent attempts to foster collaboration as well as fluid pairings and whole group cohesion seen among the group members. Students in female majority groups were observed to work together either with changeable partnerships and roles depending on the needs of the task or with all four students equally involved at the same time on a step of the task. As such, the workload tended to be evenly distributed among the group members. In contrast, boys and
girls in the gender parity groups were seen to consistently split into same-sex pairs with far fewer occurrences of whole group collaboration than was observed among the female majorities.

In sum, while manifestations of autonomy appeared to differ more consistently between genders regardless of the group, competence and relatedness appeared impacted by the group’s gender composition, with increased vocal participation, confidence, and whole group collaboration seen in the female majority groups as compared to those containing gender parity. In the context of engineering specifically, this suggests that a female majority group may provide a scenario that supports girls’ more active participation and meaningful engagement on such open-ended design tasks. It also indicates that a greater representation of the girls, including those who may more typically be reticent in a STEM context, may feel more comfortable contributing when there is a female majority.

**Student Focus Group Interviews**

While enacted behaviors suggested a positive impact of female majority groups on girls’ engineering motivation, this did not necessarily translate to their reflections about the tasks themselves. Themes that emerged from the student interviews tended to fall within the realms of competence and relatedness, with competence showing a striking gender divide but relatedness remaining similarly described between boys and girls.

In terms of competence, without exception, the girls all described the engineering tasks as “frustrating,” while the boys said they were “easy” or that they liked them. Girls consistently
explained that the engineering tasks were too open-ended, without one right answer. One female student said she felt like the engineering tasks were simply “guess and check” and that she became extremely frustrated by their attempts that failed. Another said she felt “clueless” about how to start the tasks. Others described feeling like the engineering tasks came out of nowhere and were not tied into their curriculum, thus not serving a greater purpose toward their learning in the class.

Boys, in contrast, expressed enjoyment of the open-endedness and a sense of familiarity with problem-solving through doing. One student said he liked not knowing the answer to the engineering tasks ahead of time. Another appreciated the thinking and strategizing the engineering tasks involved. Others felt like there was a clear goal to the engineering tasks that they were trying figure out through the process, and that they enjoyed building, constructing, and working with their hands. Instead of describing frustration with failed designs as many of the girls did, they rather said that they “learned from their mistakes” and “took it one step at a time.” Thus, their overall attitude towards the engineering tasks was more open to its inherent structures and challenges.

Despite this difference in perspective, both boys and girls, regardless of group composition, did view the relatedness condition within the engineering tasks similarly. All students expressed an appreciation of the collaboration the tasks required. Many described how there were more jobs to be accomplished with the engineering tasks than in other science experiments and investigations, which may involve a lot of “watching,” and that this made it easier for everyone in the group to be involved. Similarly, both boys and girls expressed that the
open approach required as many ideas as possible, and this, too, provided greater opportunity for more students to participate.

Reflections on the engineering tasks and process, therefore, were focused primarily within the realms of competence and relatedness and did not appear impacted by group gender composition but rather seemed to manifest some of the existing gendered attitudes and stereotypes that boys and girls bring to this domain. As such, group work with a female gender majority appeared to positively impact girls’ motivated behaviors more significantly than their perceptions and attitudes. While the group work structure itself appealed to all students, supporting prior literature that describes girls’ preference for a collaborative learning environment [iii, xviii], a female majority did not appear sufficient to alter their overall perceptions of engineering as a relevant endeavor, nor did it seem to impact how they described their competence and legitimacy within an engineering domain. These inconsistencies between girls’ behaviors and reflections, particularly in the female majority groups, are beyond the scope of this study to examine but would benefit from further longitudinal research to show if additional similar experiences would help change their perceptions over time.

Teacher Interviews

Teacher responses during the course of their interviews provided additional data to further explain and illuminate the student behaviors and reflections. Both teachers in this study were veteran high school science teachers but had little experience implementing engineering
design, only having just begun to incorporate it minimally due to their districts’ adoption of the Next Generation Science Standards. Consistent with prior literature describing a lack of teacher self-efficacy in engineering education [xxi], they both described that they were far more comfortable with science inquiry. As one teacher described, “Well, I knew I was way more comfortable with the inquiry stuff than the engineering stuff. So that may have kind of clouded my ability to take in information about what the kids were doing.” Similarly, the other teacher explained that the engineering tasks were “a step in the right direction” but that there was “definitely lots of room for improvement.” While a more specific analysis of the relationship between this lack of teacher confidence with regard to student motivation was not included in this study, this narrative certainly supports the connection described in the prior research [xiii] and raises the question of how teachers present and orchestrate engineering tasks when they lack experience and self-efficacy in engineering pedagogy. Of further concern is how this inexperience subsequently impacts students’ engineering achievement and motivation.

An additional theme that emerged from the teacher interviews was the complicated role of group work in the STEM classroom. Both teachers expressed a certain level of discomfort with the inclusion and orchestration of small group work in their classrooms. As one teacher said, “I was anxious because these were bigger groups than normal, and group work is not our norm.” Further, the other teacher described how she felt that group work was an important skill, but that it needed to be really be intentionally taught in order for it to be an effective instructional approach. “Group work needs to be taught – you can’t just expect students to do it. Students just do what they are supposed to do to get the lab done.” In both
cases, while the teachers recognized that group work had benefits for student learning and motivation, they also expressed it was not something that was a regular or intentional aspect of their classroom. Nor did either teacher reflect on the role of gender composition or of any gendered behaviors among the students in the groups. Interestingly, despite its apparent novelty, students of both genders unanimously reflected that they felt group work provided many benefits for their success with the tasks.

Perhaps most fascinating in the teacher interviews was a gender dynamic that occurred in relation to their reflections of the engineering process itself. In this study, one of the teachers was a male and one a female. Striking is that they each echoed the sentiments expressed by the same gender students in their classrooms. The male teacher described, similarly to his male students, that he felt the engineering tasks provided more opportunity for whole group involvement because much of the problem-solving process occurred through doing. “It’s easier to be hands-on with tinkering in engineering because that’s how you solve the tasks.” While this was a prevalent theme among the male students during the focus group interviews, this same aspect of the engineering tasks caused frustration and anxiety in the females, who felt like there was not necessarily a clear approach. On a different topic, but similarly echoing a gendered attitude, the female teacher in the study reflected on a perceived lack of real-world context with the engineering tasks. She described how, with two of the labs, it felt like “we’re going to stop and do this crazy task now.” However, with the oil spill task, she was able to bring in a current news event from California in which citizens were cleaning up an oil spill with only buckets and shovels, and she explained that this made the experience doing the task in her
classroom “amazing.” Like her female students, she valued the opportunity to make the task not just hypothetically but realistically connected to social and community issues. While these two scenarios are distinct in content, they both illustrate that teachers, like their students, bring their own gendered attitudes and experiences to the STEM classroom, and that this has the potential to impact how their students approach engineering design.

While teacher perspectives and reflections were not necessarily analyzed in terms of correlation to the student data, they give greater context to the experience of the students during these engineering tasks. Clearly connected to prior literature is an explicit expression of lack of engineering confidence and self-efficacy, as well as trepidation and discomfort with small group work. Of further importance is the gendered attitudes towards engineering that the teachers themselves hold, and although it is beyond the scope of this study to speculate, more research must be done to determine the effect of teacher attitudes on students’ engineering motivation.

Conclusions and Implications

Summary

Findings from this study support aspects of prior research but also raise new questions about girls’ motivation in engineering. Consistent with the work of Dasgupta [xxiv], a female gender majority did appear positively to increase girls’ active involvement, vocal participation, and enacted competence while working on the engineering tasks, thereby reducing overt manifestations of stereotypical roles. This study also updates prior research that suggests girls
exhibit fewer performance behaviors in STEM domains than boys [xx] by showing it is not the frequency but intent of these behaviors that is significant and discrepant between genders. However, inconsistent with Dasgupta’s findings, girls still expressed, regardless of group composition, a lack of competence with the engineering tasks or sense of their relevance. In this case, their reflections of this motivational condition did not align with their behavioral enactments of it.

Findings from this study continue to support prior literature that describes discrepancies between boys’ and girls’ approaches to STEM tasks. Consistent with the work of Gail Jones [xix], girls’ hands-on manipulation of the materials was bound by task parameters and teacher expectations, regardless of group gender composition. While this appeared as an active enactment of autonomy, its task-focus suggests that, for girls, the motivation was situated within completing the activity itself and not in the greater realm of engineering, consistent with literature describing girls’ STEM identity as being responsible and on-task [xv, xvii]. Further, despite the real-world contexts in which these tasks were embedded, girls expressed that they did not see their relevance, either to any societal issue or to their learning and the curriculum. This also aligns with the prior literature of Shakeshaft and Brickhouse [xiii, xiv] describing girls’ desire to engage in activities that are beneficial to their societies and communities. However, it also indicates that simply framing a task in a real-world problem may not be enough to increase their greater motivation and that a more personal connection to the engineering design problem, whether that means a clearer connection to their community, to current events, or to their own lives, may be required. Similar to Haussler and Hoffman’s findings [xxvi] regarding the
importance of real-world context for fostering students’ engagement, elevating girls’ science motivation beyond their course grade will require that tasks incorporate meaningful, practical, and perhaps even local applications.

The inclusion of small group work in conjunction with attention to group gender composition, therefore, may provide a positive and impactful first step toward increasing girls’ participation in engineering activities at the high school level. With greater relatedness and group cohesion seen in groups with a female majority, girls may be more willing to share ideas and make suggestions, thereby increasing their outward enactments of competence as well. There is much to still be learned, though, about motivating girls over time and in a broader way in the realm of engineering. While this study suggests that a female majority clearly supported girls in transcending many possible stereotypically gendered roles, particularly in terms of increasing their vocal participation and hands-on involvement in the activities, there is still a component yet to be uncovered that will support girls’ more intrinsic engineering motivation and confidence. The inclusion of the teacher perspective in this study indicates that how a teacher presents, orchestrates, structures, and embeds engineering tasks has the potential to greatly impact students’ experiences with them. Further, a teacher’s personal sense of confidence with both engineering design and with supporting the work of small groups in his or her classroom can shape how they provide access for all of the students in the classroom. Greater opportunity for teacher professional development and training in engineering education will provide positive steps towards increasing their engineering-specific identity. As
teacher competence in engineering education increases, so will they be able to more meaningfully support and encourage the work of their students in such contexts [xxvii].

*Implications for Further Research*

While this study provides first answers to the research questions, it also raises numerous new questions that offer next steps for future research. First, for the students and teachers in these classrooms, engineering design tasks were still novel and not a regular component of their science curriculum. Beyond the scope of this study, but necessary to consider, is the impact of the tasks’ novelty on the girls’ reflections, particularly in light of perhaps differing background experiences as compared to the boys. A longitudinal study over several years of exposure to engineering tasks would be a valuable way to more deeply understand the benefits of female majority groups for girls.

In addition, and as previously described, the newness of engineering tasks for the teachers had the potential to impact their ability to fully highlight the opportunities and connections embedded within the tasks. Necessary for further consideration is a look at how to ensure that the engineering tasks do not appear superficial and irrelevant to girls, if they are not initially motivated by the building and construction aspect in the way that boys are. While not part of this analysis, but imperative, is a better understanding of how the task design, as well as the teacher’s presentation of it, compound to impact girls’ engineering buy-in.

Finally, this study explored gender dynamics through the lens of supporting girls’ engineering motivation. Worth further research is a look at how group composition affects
boys also, including the experience of all-male groups and their impact on students’ motivated behaviors. To understand the role of gender majority groups in a classroom setting, it is necessary to explore if this positive impact works both ways, with both males and females. In other words, would such a model be sustainable in a classroom setting and be beneficial for all students?

The findings from this study reiterate that the more we understand about student motivation, about best practices for incorporating engineering design meaningfully and relevantly into the science curriculum, and about the gendered behaviors and approaches our students often embody (and that perhaps we ourselves exhibit), the better prepared we will be to design our STEM activities to meet the needs and preferences of our diverse groups of learners.
References


