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Group Design Rotation in Engineering Education: Impacting Student Participation and Collaboration

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Abstract

The purpose of this study was to research the impact of classroom group rotation on student participation and collaboration during engineering activities. The action research plan was developed after identifying a need to increase group efficacy in a classroom setting that focuses on projects and problem-based learning and proved quite difficult to explore as social interactions and group dynamics tend to be fairly complex in nature. Student participant age and personal investment in the engineering academy supported their contributions as co-collaborators inspiring changes to group format and highlighted them as the primary source of both quantitative data from class surveys and qualitative observations based on interactions and comments. Comparisons were made between student beliefs before and after the group rotations based on survey results. Despite variations in group activities and structures, major findings supported small groups with frequent rotation, a variety of group structures based on individual classroom settings, and student choice to promote participation and collaboration during classroom activities.

Keywords

engineering education, collaboration, group work, STEM education, gender

Introduction

Collaborative learning structures are used in different education levels and content types. As a science, mathematics, and engineering educator for almost 20 years, I have witnessed different group traits and have struggled to ensure that students are using time and skills effectively when working together. Group work supports student learning by ensuring different skill sets, perspectives, and explanations are available to help learners connect with material while reinforcing the student-teacher's own knowledge. Creating balanced experiences and an equitable work environment drives teachers to try different methods of collaborative learning.

Due to the project-based nature of science and engineering, I rotate groups every quarter to increase student interactions and provide them with the opportunity to experience new roles within different groups to enhance their social and academical strengths. During the 2021-2022 school year, student groups remained more homogenous related to the desire to work with friends after experiencing months of virtual learning from spring 2020 through fall 2021. Resultant off-task behavior and unequal participation diminished student learning. The action research question for this investigation was: "What is the impact of rotating classroom groups on student participation and collaboration during engineering activities?" The ability of students to work together to master engineering content is critical for active learning and is considered an essential skill within the engineering workforce where engineers need to collaborate effectively to solve problems in teams.

This study took place during three block classes composed of 58 tenth grade students and one eleventh grade student and included 49 boys and 9 girls, a gender imbalance typical in engineering based on research. The course, Principles of Engineering, is the second engineering course offered at a suburban high school in South Florida with approximately 2,400 students in grades 9-12 (237 in the Engineering Academy). This school parallels diversity found within many South Florida communities; student ethnicity distribution is as follows: 47% White; 34% Hispanic; 12% Black/African American; 4% Asian; 2% Multiracial; 1% American Indian (Public School Review, 2022). Approximately 40% of students are economically disadvantaged based on the percentage of students receiving free or reduced-price lunch at school and the school has maintained "A school" status since the 2016-2017 school year. The engineering curriculum is based on a national program, Project Lead the Way (PLTW), which offers a scaffolded activity – project – problem-based approach to learning. The program format is a computer-based curriculum that embeds hands-on activities with opportunities to explore group rotation periods through frequent collaborative activities.

The traditional engineering class unit flows from teacher introduction of content through PowerPoint modules with student notes and whole class problem solving and discussion. Students then work on problems in smaller groups to practice concepts and calculations with teacher support and oversight. These activities then develop into a build, or project, that students work on in groups demonstrating understanding of applied concepts and appropriate calculations to justify their designs. While the content rotates, since it is an engineering survey course, the module flow has been established from the beginning of the year, so students know to expect multiple opportunities to practice and explore course content within a unit. Student interest in content is evident as it is a choice program selected by students and their families upon application to the school. This investment along with student age supports student participation as co-collaborators in this action research study to improve the learning environment through thoughtful design of collaborative groups. While all students are invited to participate in the action research study surveys it is not required, students shared input based on their desire to contribute to the study, not out of pressure which could invalidate results. While the surveys and associated research components are optional, all students will participate in the classwork and group rotations associated with the class curriculum design.

Literature Review

The benefits of group work are well documented in different fields but the combined psychological and learning effects make these studies complex (Johri & Olds, 2011; Salas, Reyes, & McDaniel, 2018; Strom, Hendon, Strom, & Wang, 2019; Wieselmann, Dare, Roehrig, & Ring-Whalen, 2021). Various studies attempt to explore design features and individual personality styles to maximize the efficacy of collaborative groups, but there is no singular, clear solution (Meslec & Curseu, 2015; Van den Bossche, Gijselaers, Segers, & Kirschner, 2006; Wieselmann et al., 2021). Additionally, group work studies specific to engineering education are uncommon, although implications that extend towards this study can be found by broadening the scope to understand the collaborative effects on STEM education (Johri & Olds, 2011; Ryberg, Davidsen, & Hodgson, 2018; Wieselmann et al., 2021).

Collaborative learning supports communication, teamwork, and curricular knowledge which are foundational skills in engineering education (Johri & Olds, 2011; Meslec & Curseu, 2015). Group learning provides students with opportunities to explore ideas in teams and drives communication around the topic being explored. Small groups and teamwork are central to STEM learning environments where activities support student learning through experience and interaction (Wieselmann et al., 2021). The sharing of ideas makes teams more effective than individuals by exponentially increasing the ideas and perspectives within the team, students are stronger together (Salas et al., 2018). The diversity of technology available in education today also requires coordination. This leads students to navigate and modify workspaces based on needs and preferences both physically and virtually (Ryberg et al., 2018).

Despite the advantages provided by team diversity, many articles point towards balanced groups, shared cognition, psychological safety, and team development to support collaborative learning designs (Meslec & Curseu, 2015; Salas et al., 2018; Van den Bossche et al., 2006). In addition to the development of a balanced group structure, shared cognition is critical to the attainment of learning outcomes (Luo, Lee, & Hua Koh, 2015; Van den Bossche et al., 2006; Wieselmann et al., 2021). Multiple studies demonstrate evidence that competition within groups can hinder or inhibit collaborative learning possibly by disrupting the process of shared cognition in the group (Luo et al., 2015; Van den Bossche et al., 2006; Wieselmann et al., 2021).

Methodology

Students were already familiar with each other, so a digital personality assessment tool was employed to support the creation of groups while avoiding teacher bias regarding former student groupings from that school year. The initial survey included a personality test from the website 16personalities.com (NERIS Analytics Limited, 2022). After determining their predominant characteristics, students would submit their individual personality profile name and rank their engineering skills (leadership, drawing and recording, mathematical calculations, and device construction) with 1 indicating their strongest skill and 4 indicating their weakest skill in the *Personality Test and Skill Analysis Survey*. The personality types found on this website are divided into four groups (analysts, diplomats, sentinels, and explorers) and student groups were developed to maximize balance from these groups by including students from different categories. Six groups were created in the larger classes (periods 6 and 7) and four groups were arranged in the smaller class (period 2). This method of grouping was used for the first two group research iterations. The third iteration allowed students to pick their own partner or choose to work individually per the rules of the competition associated with that assignment.

Students also completed a *Student Design Group Survey* to provide each student's initial perspectives on groups to form a baseline on how these ideas change over the course of the study and provide student voice about what types of assignments work best, what aspects they consider most valuable, and any limitations they encountered regarding group work. Some questions included “Do you prefer working individually on engineering classwork assignments?”, “Do you prefer working as a group on engineering classwork assignments?”, and “Do you feel pressure associated with selecting people to work with in groups?” These questions included answer selections such as never, sometimes, often, and always. A separate question asked “what do you think is the ideal group size for an engineering activity?” with the possible options: 2; 3; 4; 5; 6. There were also several free response questions that asked students to share which types of assignments are best completed individually and by working in groups, what they considered to be most valuable about group work, limitations of group work based on their experience, types of group work they would like to explore in class, and additional comments of concerns.

The first student group was together for approximately one month and involved the physical creation and testing of balsa wood trusses for design efficiency. The *Student Team Analysis- Truss Design* survey helped identify whether or not team members were absent during that group session, overall experience, suggestions, and comments. There were also 18 questions about the group with Likert scale responses from strongly agree, agree, neutral, disagree, and strongly disagree. Questions were worded using a positive tone about the group so students relaying a positive experience would respond with strongly agree or agree while a negative team experience would elicit a response of disagree or strongly disagree. These questions were inspired by a tool previously used in group analysis research by Van de Bossche et al. (2006) to provide insight to team learning behaviors, interpersonal beliefs, interdependence, cohesion, group potency, shared cognition, and team effectiveness. Some of the Likert scale questions included: I like my team; This team is united in trying to reach its goals for performance; This team can get a lot done when it works hard; We have completed the task in a way we all agree upon; As a team, we have learned a lot; I would want to work with this team in the future; Information from team members is complemented with information from other team members.

The second group iteration included the physical analysis of material properties, note taking sessions, and a lab simulation analyzing the tensile properties of different materials. Students were grouped with the materials group for approximately 2.5 weeks and were told that they would be grading their teammates at the end of this iteration. Spring break did occur just after the formation of these groups and there was a noticeable amount of absences before and after the break due to student travel and illnesses. At the end of the group activities students completed a formal assessment on material properties and were asked to review their experience using the *Student Team Analysis- Materials* survey. This survey had the same layout and questions as the *Student Team Analysis- Truss Design* survey but also asked students what grades they would give their teammates to increase student accountability during this iteration.

The final iteration of the engineering group study allowed students to choose a partner or elect to work independently on the assignment. The final assignment included the analysis of materials and construction designs available on the Bridge Builder 2016 platform (ASCE Florida Section, 2021). Due to the quick revisions, possible through the *Bridge Builder 2016* platform, this was the shortest group activity at approximately one week long for the in-class activity.

Finally, students completed the *Student Team Analysis- Bridge Builder Competition* survey similar to the *Student Team Analysis- Truss Design* survey, but the new questions on this survey asked students if they chose to work with a partner and why or why not. The *Post Student Design Group Survey* also asked which group had the best student participation and why, which group activity students enjoyed the most and why, what factor they believe most directly impacts student participation when working in groups, and what factor they feel most directly impacts group collaboration for engineering groups.

Data collection was facilitated by student surveys and a teacher/researcher journal where student groupings, observations, quotes, and other information were recorded regularly. The journal provided an opportunity to record interactions and occurrences that could impact the results and provided deeper insight into findings. The pre and post student group surveys provided a comparison for student perceptions about ideal group structures before and after the different group activities and to provide comments and suggestions regarding groupings while the individual group surveys for each iteration allowed for a more in depth understanding of the effectiveness of the group from each student's viewpoint. Together these tools provided comprehensive insight into group structure overview as seen by the teacher and students at different stages of the study.

Results

In answer to the research question, "What is the impact of rotating classroom groups on student participation and collaboration during engineering activities?", several major findings emerged. The data indicates that: *1)* smaller groups that change more regularly support increased participation and collaboration; *2)* all classes do not demonstrate the same response to group formation styles, which ultimately impacts student participation and collaboration; *3)* students want to choose their partners and so allowing them some choice increases participation and collaboration during assignments. Each of these findings were supported by multiple forms of data collected throughout the research process and will be explored separately illuminating the details of supporting evidence.

Small Groups and Frequent Rotation

Initially students indicated a preference for larger infrequently rotated groups, 57% indicated a preference for rotating groups quarterly and the majority selected 4 (57%) or 5 (19%) as ideal group size. After the research iterations, 46% of students recommended a monthly rotation while quarterly and biweekly rotation each received 21.6% of student votes. Students commented that "Group change should be from activity to activity … it does not matter the time spent on it" highlighting the importance of regular group rotation within a classroom setting. During the research period there was a decrease in ideal group size based on student experience and perception regarding participation and collaboration. There was a clear shift towards smaller groups as the percentage of students recommending larger groups decreased while the percentage increased for three-person student groups moving from 16.7% to 37.8%. Another student commented, "If the project and group was smaller, the members of the group would have things to do. But when it is a large group working on a smaller project, most of the members [don't] contribute as much as they would [in smaller groups]." This comment demonstrates student awareness regarding participation during group activities and indicates that students recognize the importance of ensuring everyone is on task to maximize learning.

During the first group iteration where students finalized calculations and completed the truss design project it was noted in the teacher journal that students "rearranged seats to work closer" and "there was lots of movement among groups" (research journal, February 9, 2022). On the third day of the truss group, "Groups 1 and 2 merged to form one large group" (research journal, February 15, 2022). This change in group dynamics was related to proximity and student absences, but students continued to work together. This was ultimately harmful for the group as they did not follow directions for the assignment and missed points due to omitting required components. The smaller groups did allow for creative collaboration due to a similar shared space, but required members to be more productive, increasing collaboration and participation at the individual student level.

One Size Does Not Fit All

Across the study, the different classes demonstrated varied responses to iterations of the group formats and informed the finding that all classes do not have the same response to group formation styles which ultimately impacts student participation and collaboration. The smallest classes, period two, 14 students, and period seven, 19 students, regularly demonstrated the most negative survey responses regarding their groups, compared with the larger class of 25 students. The tone changed from iteration one to three related to the students' ability to select their own partner and decide if they wanted to work in a pair or individually. This shift was visible in all classes but was more dramatic for the small classes since they had more negative group-based experiences from the first two iterations. The diversity in class responses to the grouping strategies indicate that each student, class, year, and activity will have different preferences and structures that require consideration for group arrangements.

Student Choice is Important

Throughout the entire research process students continued to reiterate their desire to select teammates for groups. One student comment, "Group work is one of the most stressful things when you're in a group of people you don't really like," predicted the importance of student choice during assignments. Students regularly asked to select their own partners during the free response questions embedded in the surveys after each group rotation. Another student commented that "The idea of allowing people to choose their own groups is great, as it allows them to make their own decisions and it lets their grades reflect their actions." Both teacher observations and quantitative data from the survey continued to develop the argument for student choice in selecting groups.

Final comments from the *Post Student Design Group Survey* described the importance of communication and collaboration when working with groups. The process of rotating among different groups and working with a variety of students within their class appeared to strengthen student appreciation for group selection and the teamwork skills associated with effective groups. Additionally, there was clear recognition of the responsibility connected with teammate selection and the effort, learning, and grades that ensue as a result. Student awareness and ownership showed growth during their participation as co-collaborators in this study with suggestions and comments developing throughout the research process.

Reflections

There were complications with forming unbiased groups, student absences, and variable topics throughout the action research process. But trends still emerged: students wanted a choice in group formation; smaller, frequently rotated groups provided benefits; and different class periods responded to group formation and activities differently. These findings connect with educational reform by demonstrating the importance of shifting power within classrooms to students to create ownership of learning, foster opportunities for collaboration, and respect student individuality. Student comments indicated a preference for switching groups as assignments changed and noted that switching groups helped them make new friends and meet new people in the class, which is important for students to make fully informed decisions about potential teammate selection. Additionally, an increase in awareness regarding group rotation facilitated a shift from seeing peers as a source of potential assignment correction, based on responses from the initial *Student Design Group Survey,* to recognizing group work's value for idea building and collaboration during the research process, as evidenced by student comments from the *Post Student Design Group Survey*.

Other topics became apparent in student comments. Gender was regularly mentioned by female students and made me question the impact that has on them in a male dominated classroom leading towards a predominantly male profession. While the female students commented on the gender discrepancy within groups, this topic and awareness can move beyond gender binary and emphasizes the importance of healthy classroom cultures where all students feel valued and respected in the community of knowledge. High school students possess increased self-awareness and are at a point where they select courses and programs of study based on their interests. These qualities make them uniquely invested in their education and support their desire to ensure high-quality experiences in the coursework they have committed to learn about. The action research structure provides teachers with a way to collect data, analyze, and self-reflect on the courses they teach and methods they choose with the possibility of including students as co-collaborators so they can invest in their own education. This process can empower teachers and help support the academic choices they regularly make independently with full classroom authority. The action research process can also serve as a source of dialog for professional learning communities where teachers can discuss, research, and collaborate on best practices. Teacher-based experiences and knowledge drive professional development that helps reinvigorated teachers, so they are excited to continue making a difference in their classrooms. Action research provides an opportunity for teachers to share, grow, and directly involve students in the learning process in a way that is classroom specific.

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