Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #45628

WIP: Belonging in Engineering? A Grouping Strategy Comparison

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Work-In-Progress: Belonging in Engineering? A Grouping Strategy Comparison

1. Introduction and Purpose

This work-in-progress paper investigates how grouping teams by specific characteristics could affect feelings of belonging in engineering. A national (US) focus on broadening the participation in engineering endeavors to move beyond the commonly reported bachelor's degrees proportions awarded to women and to minorities of all genders [1]. For instance, ASEE-reporting institutions in 2020 noted the bachelor's degrees awarded, without regard to major type, were 23.5% female and 29.2% Hispanic, Black, Asian and Native races (e.g., non-white races) [2].

Table 1: Percentage of Engineering Bachelor's Degrees Disaggregated by Gender and Race, Summary of ASEE data from 2020

2020 %s	Female	Male	Race total %s (both Genders)
White	11.6	41.3	52.9
Multi-racial	4.2	13.6	17.8
Hispanic	2.7	8.9	11.6
Black	1.1	2.7	3.8
Asian	3.8	9.6	13.4
Native	0.1	0.3	0.4
Gender total %s (all Races)	23.5	76.4	

One method by which universities seek to increase these proportions is by bringing teamwork into their freshman (first-year) programs. The word "freshman" is used as an inclusive term to recognize that some students may not be in their first collegiate year, especially if they did not pursue a traditional four-year pathway [3]. The hope behind groupwork in early engineering coursework is that establishing a community of practice early will motivate students to master the rigors of engineering content and enable them to persist until obtaining a degree [4], [5], [6]. When the student's engineering identity is fueled by recognition, engagement, and competent performance early on, that student is more likely to persist [7], [8], [9]. Feeling as if one belongs in engineering builds that engineering identity, especially in female engineering students [10].

1.1. Background

A large southwestern university that is a Hispanic-Serving Institution (HSI) uses teamwork in their introductory freshman engineering courses. One of the goals for this is to establish a community of practice among the students that instills a sense of belonging in the college of engineering. However, it is left to the individual professors as to how to arrange these groups, or to allow students to self-select. During the fall 2023 and spring 2024 semesters, the author

allowed students to self-select their groups (i.e., “no” grouping strategy was used by the course instructor). Despite having a moment where all students stood up to allow for rearrangement (assuming friend groups would move), most students stayed at their original tables. Student feedback at the end of the semesters was not overly positive about the group experience, so the author wondered if more strategic grouping could not only improve team performance, but also guard against the so-called “sophomore slump” by creating an environment whereby the students developed an early community of practice [11], [12], [13].

1.2. Research Question

This study seeks to understand how different grouping strategies in introductory engineering courses affect the teamwork success and sense of belonging in engineering students.

In this study, teamwork success is defined by course grade and self-reported opinions on effectiveness, while belonging is rated with a series of post-course reflection questions focusing on both team and college belonging. Different grouping strategies are anticipated to develop different senses of belonging along gender and racial demographics.

2. Methods

A pilot phase for the grouping strategies and belonging feedback attributes was run during the fall of 2024 in a computationally-oriented freshman engineering course. To minimize variability due to professor interaction (e.g., the author), three sections of that course taught by the same professor each used a different grouping strategy. The well-known idea of forming groups based on similar racial and/or gender characteristics stems from “similarity” enhancing the feelings of belonging [14], [15] as there is “sanity in community” [16]. This study required and received IRB approval for demographic questions to be used in this study.

The Entry-to-a Major process for freshman students at this university ensures that several disciplines of engineers take the same “core” freshman courses. Acknowledging that a true community of practice would need to account for engineering disciplinary interest, desired major is also included in the grouping strategy [17].

All students in the course participated in the pre-survey in order to determine groups for the semester from their major choice and demographics. For each section, student responses were grouped by varying response orders (via Excel’s sort levels). One section was sorted first by race, then by major, and finally by gender (RMG). Another section was sorted first by major, then by gender, and finally by race (MGR). The other section was sorted first by gender, then by major, and finally by race (GMR). Groups of four “similar” students were formed when possible; however, a few three-person groups were necessary due to class sizes. Students then proceeded through the semester with the normal teamwork activities as they learned to code in Python and discovered more about the various majors at the university.

The post-survey allowed students to self-report team satisfaction and efficacy, as well as answer several belonging questions with a 4-point Likert scale [18]. The student demographics were also

confirmed and actual course grade for each student was recorded. Questions were drawn from several teamwork/self-peer evaluation reflection tools commonly used in college courses, as well as belonging reflection tools from unique perspectives [19], [20]. This author found that a readily available template for feelings of belonging in engineering was lacking in the scholarship of teaching. Thus, the post-course questions used are presented in the appendix, and discussion is most welcomed on their usefulness.

A self-generated Python file processed and anonymized the data for analysis in this study. Part of the data cleaning did update answers left blank to "No Answer", or a student selecting more than one race to be counted as "Multi-racial," for ease of reporting. During the post-survey administered concurrently, but separately, from the end-of-course feedback, students were given the opportunity to opt-out of the study. Thus, given the response rates for each section, not all student experiences may be reflected in the results. The trends still provide insight that can guide the study's next phase of more automated grouping (e.g., a Python script instead of Excel sorting) as well as refinement of teamwork effectiveness and belonging questions.

3. Results and Discussion

Before discussing the results of the grouping strategies, it is useful to note the demographics differences between the three sections of the course. Due to the small study size, analysis by gender and race could yield potentially identifiable information, necessitating discussion by only the demographic of gender, but not of race, and certainly not disaggregated responses by both demographics.

These RMG, MGR, and GMR sections were respectively 21%, 27%, and 17% female, with a racial distribution of 41%, 52%, and 49% non-white students (e.g., Hispanic, Black, Asian). Note that while there is a perception that Asians are well-represented in engineering, the numbers reflect a more complex dynamic [2], [21]. The response rates for RMG, MGR, and GMR sections were 87%, 85%, and 88%, respectively, thus the reported numbers from the sample of students opting-in do mirror the class population. As can be seen in the table that follows, possibly unique to this university and professor, there were no native students in these three course sections for the fall of 2024.

Table 2: Student Demographics (e.g., Race or Gender) for Those Who Opted-In, by Course Section

Student Demographics *	RMG	MGR	GMR
Asian	19	14	22
Black or African American	1	1	0
Hispanic or Latino/a	7	8	15
White or Caucasian	32	16	30
Multi-racial (biracial or mixed)	6	4	8
Other	0	1	0
No Answer	1	0	0

* No students identified as "Native American, Alaska Native or American Indian, Native Hawaiian or Pacific Islander".

Student Demographics *	RMG	MGR	GMR
Total Students	*66*	*44*	*75*
Biologically female	14	12	13
Biologically male	51	30	62

* Only three students identified as "Nonbinary, Gender non-conforming, or otherwise", so they had to be excluded for potentially identifiable context.

The three different sorting orders did create different team dynamics. The most obvious of results is that the RMG and MGR sections did not have any all-female groups. Additionally, the GMR sort did not have any groups with a single female. In the table that follows, the numbers of groups for each type of 3- or 4-person team are listed for each section.

Table 3: Counts of Groups' Gender Profile, and percentages of Grade Distribution, by Course Section

Group Genders	RMG	MGR	GMR
All Female	0	0	3
Mixed (one male)	2	3	1
Mixed (equal)	3	2	1
Mixed (one female)	6	2	0
All Male	10	7	17
Total Groups	*21*	*14*	*22*
Course Grade	**RMG**	**MGR**	**GMR**
A	36%	41%	49%
B	39%	30%	32%
C	18%	23%	13%
Not passing	6%	7%	5%

In all three groupings, over three quarters of the students received an A or B, with over 90% "passing" the course. The similarities in grades/grade distributions would appear that the grouping strategy did not affect actual student performance. However, the opinions on team effectiveness did differ by gender within the course sections, as well as between the grouping strategies in different course sections. Males were least satisfied in the MGR section (e.g., they more often rated that their team worked "poorly" or "adequately" together in class), and females were least satisfied in the RMG section. Surprisingly, the highest percentage for both genders evaluating their teams as working "well" or "extremely well" was in the GMR section. Unfortunately, the timing of this course towards the end of the school day may have contributed to this satisfaction.

As can be noted from the survey in the Appendix, responses for seventeen dimensions of belonging were rated on a 4-point Likert scale, where answers of "disagree" or "strongly disagree" were phrased to indicate a negative (e.g., not belonging) while the "agree" and "strongly agree" answers indicate a positive (e.g., belonging). Future work might try rephrasing

the questions; however, varying the sentiment between questions would have made the current analysis too cumbersome to be useful for implementation in the spring semester.

The following table looks wholistically at the belonging responses disaggregated by gender via a heat map methodology and two viridis colors [22]. This visualization allows quick, intuitive comparison of the three grouping strategies with regards to how wanted the students feel, with darker yellow being more negative and darker blue being more positive. When gender was the first or second sort order, the female students responded more positively (e.g., more and darker blue) than when it was the final sort. It is easily noted that the GMR sort yielded the most approval from the female students, and it is surprisingly the male favorite as well. While RMG is the least positive from a female perspective, it does not appear to impact the male perspective.

Table 4:Belonging Questions Heatmap, by Course Section and Gender

Belonging - % positive	RMG		MGR		GMR	
	female	*male*	*female*	*male*	*female*	*male*
1. Students in engineering respect one another.	93%	98%	100%	97%	100%	100%
2. My team respected one another.	100%	96%	92%	97%	100%	100%
3. Students in engineering get along well with other engineering students.	93%	98%	100%	100%	100%	100%
4. I got along well with my group members.	100%	96%	100%	93%	100%	98%
5. I have lots of chances to be a part of class discussions or activities in this class.	79%	82%	100%	83%	92%	90%
6. My team worked on listening to each other and understanding what others were trying to say.	93%	94%	92%	90%	100%	98%
7. I feel socially accepted in Engineering.	93%	96%	92%	97%	100%	98%
8. I feel socially accepted by my group members.	93%	98%	100%	90%	100%	100%
9. Team assignments connected what I am learning to future engineering (e.g., life outside the classroom).	93%	88%	83%	87%	100%	85%
10. My group members really support my learning in this class.	71%	94%	100%	93%	92%	94%
11. My group members showed respect for all students' cultural beliefs and practices.	100%	98%	100%	97%	92%	98%
12. I was comfortable talking to my team about coursework and team lab activities.	100%	96%	100%	97%	100%	97%
13. My group members promptly responded to my phone calls, messages, or emails.	86%	94%	92%	73%	100%	94%
14. Me attending class was important for my team to do well.	86%	84%	100%	80%	100%	98%
15. Me attending class was important for me to do well.	93%	90%	92%	87%	92%	95%
16. My participation was actively sought out and encouraged by others.	64%	94%	83%	93%	100%	90%
17. One or more of my group members followed up with me if I had to miss class.	64%	86%	83%	83%	100%	85%

Most interesting to this author were the final two belonging questions, when considering the interpersonal aspects of the groups. As the GMR was the only section with all-girl groups, and no group with a female by herself, this appears to be the class where team members were more

likely to "follow up" with each other outside of class. As the RMG section had the most "Mixed (one female)" groups, the darkest yellow squares stand out as flagging the potential group type to avoid when striving to improve feelings of belonging in female engineering students.

One interesting phenomenon from the team "active participation and fully prepared" question of the feedback is that not only did both males and females tend to rate themselves positively (e.g., excellent, satisfactory, or ordinary), across all grouping strategies the "4th team member" was consistently the most negatively rated (e.g., marginal, superficial, or unsatisfactory). This could be a result of the question format, which did not provide group member names but generically numbered responses. It remains uncertain whether this phenomenon needs to be addressed, especially since it would likely generate suspicions about confidentiality if actual group members' names appeared in a feedback form.

4. Conclusions

As a work-in-progress, the conclusions for this study are not finalized and will be updated. Specifically, not enough data was collected to report belonging along racial demographics; thus, only gender results are discussed. The author did notice a rise in team participation during in-class discussions for all three classes over the semester when the groups self-selected. While actual course performance (e.g., grade distributions) did not vary by grouping strategy, the opinions on team effectiveness were impacted. Moreover, it does appear from this pilot study that having a single female in a 4-person team does not typically engender feelings of belonging, unless there is a racial and disciplinary match to the male group members. For instance, with one of the eight "Mixed (one female)" groups with just such a demographic, each student mentioned specifically to the author that this had been their best team experience. Still, moving forward, this author will be committed to developing grouping procedures that eliminate the group type "Mixed (one female)," as the RMG section did have the most of those types and had the more negative female belonging ratings for the most questions. Consequently, any type of grouping strategy is to be commended and is consistent with the presumption that college teaching practices affect experiences with teamwork [23], [24].

Additionally, any engineering professor looking to apply the grouping strategies based upon these initial findings must carefully consider their institution's cultural context, as it may differ from a large southwestern university known for its engineering program and Entry-to-a Major process for freshman students (i.e., mixed engineering disciplines in the first few engineering courses).

5. References

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6. Appendix A

Post-survey questions and answer choices are published here for dissemination.

Simple-Survey Consent

To better understand how my students experienced this class, I want to collect a bit of background data and feedback on your experiences (e.g., coding, ETAM [entry to a major], demographics, etc.). Please read the following consent information:

1. <IRB-approved consent file> Your selection documents your consent to take part in the research study.
   If you wish to participate, please click the "I Agree/Opt-in" button and your survey responses will be included in the research.
   If you do not wish to participate in this study, please select "I Disagree/Opt-out" button. If you chose this option, your survey responses will not be included in the research.
   <radio buttons, required, continue survey>
   - I Agree (Opt-in)
   - I Disagree (Opt-out)
2. Please provide student details:
   - First name: <free response short answer>
   - Last name: <free response short answer>
   - University email address: <free response short answer, required >
   - UIN: < free response number answer, required>

Engineering & Teamwork Information

For these questions, there are no right or wrong answers. Just choose according to your own thoughts and feelings.

3. Please choose the answer that best describes your Python / coding experiences after this semester of class:
   - I am very uncomfortable with programming
   - I am somewhat uncomfortable with programming, but this python experience helped a little
   - I am somewhat comfortable with programming, and with python
   - I am very comfortable with programming, with python and/or other programming languages
4. What is your desired (or current) major (e.g., what is your first choice ETAM)? Please choose one, as the next question is about how confident you are in your choice.
   <select from list of 22 Engineering majors per ETAM>
   - Aerospace Engineering (AERO)
   - Architectural Engineering (AREN)
   - Biological & Agricultural Engineering (BAEN)
   - Biomedical Engineering (BMEN)
   - Chemical Engineering (CHEN)
   - Civil Engineering (CVEN)
   - Computer Engineering (CPEN)
   - Computer Science (CPSC)
   - Data Engineering (DAEN)
   - Electrical Engineering (ELEN)
   - Electronic Systems Engineering Tech (ESET)
   - Environmental Engineering (EVEN)
   - Industrial Distribution (IDIS)
   - Industrial Engineering (INEN)
   - Interdisciplinary Engineering (ITDE)
   - Manufacturing & Mechanical Engineering Tech (MMET)
   - Materials Science & Engineering (MSEN)
   - Mechanical Engineering (MEEN)
   - Multidisciplinary Engineering Technology (MXET)
   - Nuclear Engineering (NUEN)
   - Ocean Engineering (OCEN)
   - Petroleum Engineering (PETE)

5. How confident are you in your first choice ETAM? Please choose one; enter one of the undecided/unsure options if you don't know.
    - My choice hasn't changed, I am very likely to list this major as my first choice ETAM
    - I now know about this major and am very likely to list it as my first choice ETAM
    - I like it, but I am willing to learn more about other engineering majors before ETAM
    - I am undecided about this major, but I do still want to major in Engineering
    - I am unsure about Engineering, I might switch colleges

Please answer these questions about your team's function. Focus your discussion on the *process* -- what you experienced, felt and thought while working together.

6. Overall, how effectively did your team work together in this class?
   <select one:>
    - Poorly / Adequately / Well / Extremely Well
7. How did you feel about working with your team?
    - <free response short answer>
8. Give one specific example of something you learned from the team that you probably would not have learned working alone.
    - <free response short answer>
9. Give one specific example of something the other team members learned from you that they probably would not have learned without you.
    - <free response short answer>
10. Give one specific example of what you think your team did well.
    - <free response short answer>
11. Give one specific example of what issues your team had (e.g., could have done better)?
    - <free response short answer>
12. What percentage of your team participated actively and was fully prepared most of the time? (rank yourself first, then your classmates, using the following definitions)
    <matrix: group member 1 (me), group member 2-4 & keywords>
    - Excellent: Consistently went above and beyond; tutored teammates, carried more than his or her fair share of the load; was crucial to group's success
    - Satisfactory: Usually did what he or she was supposed to do, acceptably well prepared and cooperative; contributed significantly to group
    - Ordinary: Often did what he or she was supposed to do, minimally well prepared and cooperative; contributed adequately to group
    - Marginal: Often failed to show up or complete tasks, rarely prepared; met minimal standards of group
    - Superficial: Consistently failed to show up or complete tasks, unprepared; was detrimental to group
    - Unsatisfactory: Practically no participation (not present, may have dropped class)
    - N/A (never had 4th member)

Belonging Questions

13. Please mark the following in terms of how strongly you agree or disagree with each statement.
    <Radio buttons for all questions in Matrix Table>
    - Strongly agree
    - Agree
    - Disagree
    - Strongly disagree
        1. **Students in engineering respect one another.**
        2. **My team respected one another.**
        3. **Students in engineering get along well with other engineering students.**
        4. **I got along well with my group members.**
        5. **I have lots of chances to be a part of class discussions or activities in this class.**
        6. **My team worked on listening to each other and understanding what others were trying to say.**
        7. **I feel socially accepted in Engineering.**
        8. **I feel socially accepted by my group members.**
        9. **Team assignments connected what I am learning to future engineering (e.g., life outside the classroom).**
        10. **My group members really support my learning in this class.**
        11. **My group members showed respect for all students' cultural beliefs and practices.**
        12. **I was comfortable talking to my team about coursework and team lab activities.**
        13. **My group members promptly responded to my phone calls, messages, or emails.**
        14. **Me attending class was important for my team to do well.**
        15. **Me attending class was important for me to do well.**
        16. **My participation was actively sought out and encouraged by others.**
        17. **One or more of my group members followed up with me if I had to miss class.**

Demographic Sampling

A few demographic questions are required for the study validity. We want to reassure you that your responses will not be linked to you personally, and that if any questions make you uncomfortable, you may skip those questions.

14. How do you identify your gender? Leave blank if you prefer not to answer.
    <multiple answer>:
    - Biologically female
    - Biologically male
    - Nonbinary, Gender non-conforming, or otherwise
15. How do you identify your ethnicity? Leave blank if you prefer not to answer.
    <multiple answer>
    - Asian
    - Black or African American
    - Hispanic or Latino/a
    - Native American, Alaska Native or American Indian, Native Hawaiian or Pacific Islander
    - White or Caucasian
    - Multi-racial (biracial or mixed ethnicity)
    - Other
16. What is your College Generation Status? Leave blank if you prefer not to answer.
    <select from list>
    - I am a First-Generation College Student, (e.g., Parents: dropped out, OR HS only [both])
    - I am a Second-Generation College Student (e.g., Parents: Associates degree, College degree OR Advanced degrees [one or both]; Grandparents: dropped out, OR HS only [all])
    - I am a Third-Generation College Student (Parents AND Grandparents: Associates degree, College degree OR Advanced degrees [at least one in each generation])
17. What is your Immigrant Generation Status? Leave blank if you prefer not to answer.
    <select from list>
    - I am an Immigrant (e.g., I have/had a student visa or DACA status)
    - I am a First-Generation American (e.g., parent is an immigrant [one or both])
    - I am a Second-Generation American (e.g., grandparents are immigrants [one or more]),
    - I am a Multi-Generational American (e.g., great-grandparents or further back immigrated)
18. Please select the statement that best describes the home (primary residence) where you live, leave blank if you prefer not to answer: <select from list>
    - It is owned or being bought (includes paying a mortgage) by you or someone in the household (e.g., a family member pays)
    - It is rented for money by you or someone in the household (e.g., a family member pays)
    - It is occupied without payment or money or rent
    - I live with friends
    - I have no permanent residence
19. Please select the category that best describes your total combined family income for the past 12 months (i.e., yearly household income before taxes, including all sources: employment, social security, wages, public assistance/welfare benefits, help from relatives, alimony, bank interest, retirement accounts, rental property, investments, etc.). If you don't know your exact income, please estimate. Leave blank if you prefer not to answer: <select from list>
    - Less than $9,999
    - $10,000 - $19,999
    - $20,000 - $49,999
    - $50,000 - $99,999
    - $100,000 - $149,999
    - More than $150,000
20. The grade I am likely to get in this class:
    <forced answer to ensure they exit survey.>
    - Is good (A-B), and what I expected to get
    - Is not as good (B-C), and is consistent with my efforts
    - Is not as good (B-C), but does not reflect the effort I put into the class
    - Is not good enough for ETAM (D or less)

<End Survey> Thank you for your time spent taking this survey.

You have reached the end of the survey, and your responses have been recorded.

Please recall that if you selected to Opt-out, your responses will not be used in scholarly research, but they may be used to improve the class.

7. Abstract

Background:
This is a work-in-progress. A national (US) focus on broadening participation in engineering endeavors to increase the commonly reported bachelor's degrees proportions of approximately 20% awarded to women and 30% awarded to minorities. One method to address this is by bringing teamwork into freshman courses. The community of practice established will engender feelings of belonging in students, motivating them to master the rigors of engineering content and enabling them to obtain a degree.

Purpose:
This study strives to understand how an introductory course could affect the feelings of belonging in engineering by comparing several grouping strategies in freshman-level courses at a large southwestern public university.

Method:
Several different ways to group students were used to create teams and the interactions were directly observed. Additionally, pre- and post- course surveys were administered. The same instructor was used to provide consistency and potentially allow for grouping strategy to account for any variations in feelings of belonging in engineering.

Results:
The WIP results are thusly observational. Still, these are meaningful to the study by collecting team satisfaction data. Grouping strategy did not affect performance (e.g., grades) but did affect perception (e.g., opinion and belonging) for both males and females.

Conclusions:
Theories of belonging and advantages of teamwork in technical field are used to enhance the scholarship of teaching, as well as to set the stage for the continuation of the study. Different grouping strategies are explained and compared. While any strategy is better than none, instructors should avoid single-female groups.

Keywords: Engineering education, Teamwork, First-year Programs, Belonging