Full Paper: A Generative AI Approach to Better Teamwork in First-Year Engineering

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William Church

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Abstract

This Full Paper describes a new method of facilitating teamwork in a first-year engineering course using generative AI. This work discusses enhancements to the group-formation step of the process leveraging generative AI tools and technologies to facilitate maintaining personalization and student identities when creating small groups. Through student data collected at different stages of the project development cycle, and specific prompts used to interact with generative AI, it was possible to customize and personalize the teamwork groupings, recommendations, feedback mechanisms, and individual evaluations in a scalable way across the entire class. This process provided the opportunity for individual student perspectives, wishes, and experiences to be considered and incorporated into the group formation activity. Student reflections on the use of generative AI for group formation, including when compared to an opportunity for self-selection of teammates, were mixed with the majority recommending a mixed-methods approach of the use of AI but with a "human in the loop" component.

Introduction

This work is inspired by, and builds upon, the many existing techniques and tools currently supporting engineering instructors with incorporating teamwork into their classrooms. This ranges from the forming of teams, overseeing of team dynamics, supporting interpersonal dynamics within teams, and evaluation of team members (e.g. CATME: Purdue University [1], Tandem: University of Michigan [2]). For the team formation step, recognizing that the manual processing of student survey data can be laborious and difficult [3], several new digital tools have been created to try and create idealized matching of students via algorithmic analysis of survey data and assist in unburdening "the time struggle of instructors while still forming well balanced groups."[4]. The introduction of generative AI, which can perform thematic and sentiment analysis on large amounts of raw, unformatted data (e.g. generated by students) can provide a new methodology for accomplishing this task at scale. This work explores the use of generative AI in team formation in a first-year introduction to engineering class and, after doing projects both in the AI-formed teams and in self-selected teams, had students reflect on and compare the experiences.

Course Description

The introduction to engineering section in which this work took place is one section (of 30 students) in a first-year engineering program at a small, private engineering school in the northeast part of the United States. All incoming (undeclared) engineering students select from a

range of 14 available sections each independently designed and taught by separate instructors. While each section has its own theme, topic, and content area (this particular section uses simple robotics as the discipline to introduce engineering design), one commonality across all sections is a requirement to include group work as a component of the class. In the class examined here, the first 8 projects (some short daily in-class challenges and some week-long assignments) were conducted individually and the Project 9 design challenge (design a robotic arm to transport a ping-pong ball) and Project 10 assignment (design an interactive Halloween-themed exhibit for inclusion in an on-campus haunted house) were both longer (week to week-and-half) group projects that happened mid-to-late October of the Fall 2023 semester. Group formation for Project 9 was done by the instructor (see the *Generative AI Supported Group Formation Process* section below) and groups were self-selected by the students themselves for Project 10.

Framing

The theory underlying this work is that more insightful (and transparent) formulation of groups would create successful cooperative interdependence, collaboration leading to enhanced productivity and overall effectiveness in achieving shared objectives [5]; and by leveraging generative AI technologies these tools and techniques could be both scaled across larger numbers of students and open to a wider range of instructors. This initial experiment, creating 10 groups of 3 students each, demonstrates the feasibility of this methodology. A subsequent group project where students choose their own partners enabled direct reflection on both experiences, despite different assignments, group sizes, and scopes, to compare their perceptions of the AI-generated group outcomes. A project postmortem analysis of individual reflections was evaluated in order to give a more meaningful summative feedback on the experience. This in turn was used to generate other formative suggestions for future implementations.

Summary of Pre-Survey Questions Used for Group Formation

The 5 open-ended question pre-survey was designed to obtain a comprehensive understanding of the students' experiences, perceptions, and attitudes for group formation. In addition to two Likert-scale based self-reported LEGO building and coding proficiency questions (from earlier in the semester), students were asked to describe both successful and unsuccessful past collaborative experiences, and the role they played. The survey further prompted the students to identify their strengths and areas for improvement in the class, and it invited them to envision their ideal group dynamic and their role as a team member in order to optimize group compositions. (See Table A.1 for *Pre-Survey Questions* in Appendix.) The hope was this set of questions would provide a well-rounded perspective of the students' attitudes towards group work and the role they have played (or would play) in projects.

Generative AI Supported Group Formation Process

This research first explores the various strategies used by the instructor in this introductory engineering design course to introduce the use of OpenAI's ChatGPT to the team facilitation process. Due to the capabilities of large language models (LLMs) to process, summarize, and identify thematic commonalities across large collections of rich text, traditional simplistic surveys (e.g. consisting of numeric self-reported Likert scales, known to have limitations in this type of data collection) were replaced by open-ended short-answer questions where students reflected, across a variety of dimensions, on prior group work experiences in their lives (see pre-survey question summary above). This provided the opportunity for deeper insights into the individual abilities, personalities, experiences, and needs of each student with regards to their engagement in group work. Generative AI was used to create anonymized class-wide trends that were then shared with students to form mutual class-wide understandings and develop a common collaborative culture prior to the start of group work. The chatbot's inherent clustering capabilities was then leveraged to form initial teammate groupings (see Figure 1) based on individual recommendations.

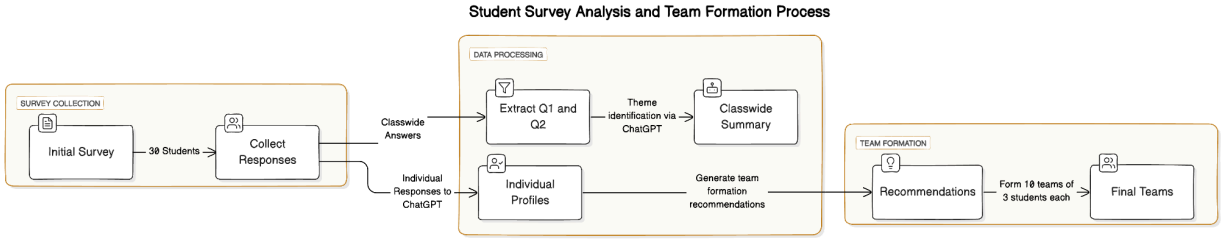
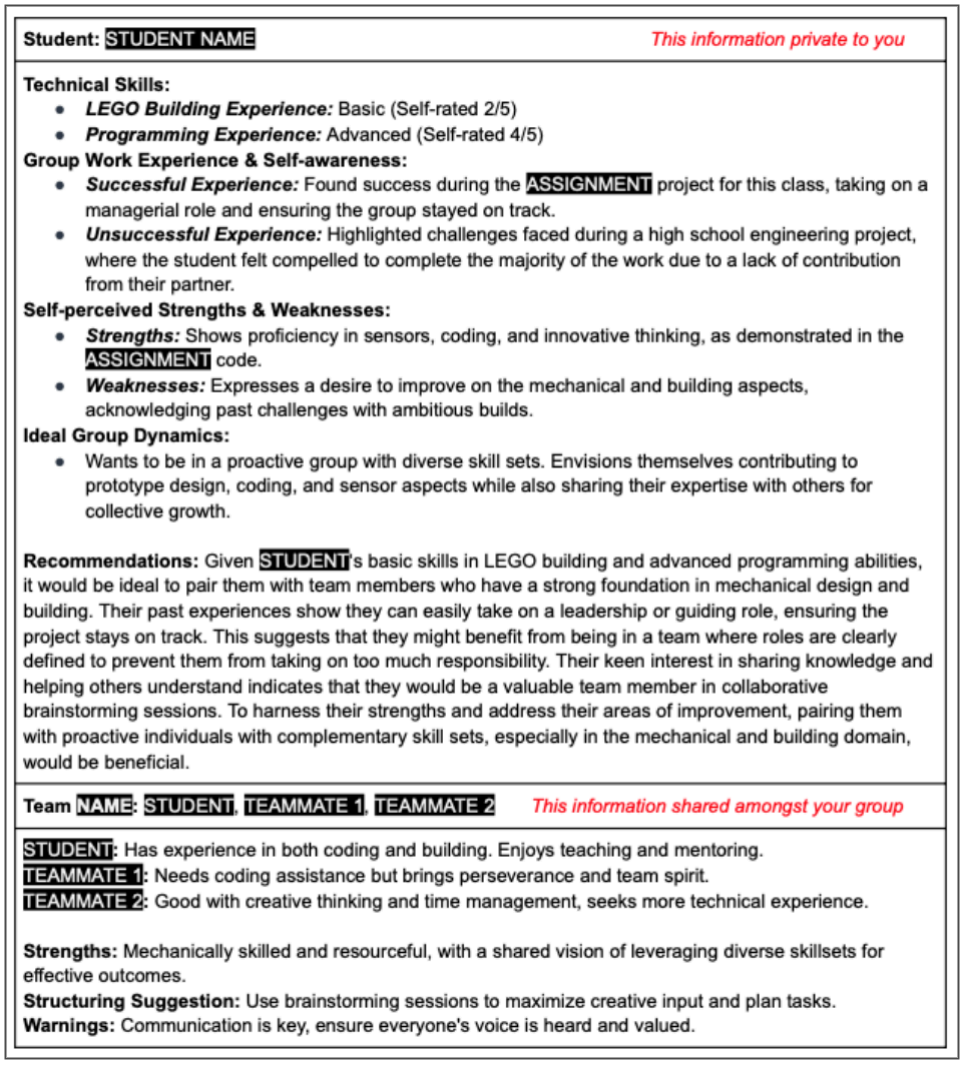


Figure 1. Survey Analysis and Team Formation Process

Group Formation Results

Across the class, overall summaries of "Successful Group Work" and "Unsuccessful Group Work" were shared with everyone. For each individual student, an "Individual Assessment " (including ChatGPT's summary of their technical skills, experience reflections, strengths and weaknesses, and recommendations for team formation) were shared privately, similar to CATME's successful confidential comments [6]. Amongst the team of three students, personalized strengths and weaknesses were identified and shared internally to each group. General teamwork strategy summaries and warnings, generated from both internal and external sources, were also shared. The first two pages of an example report, provided to the whole class, can be seen in the appendix (Figure A.1). A detailed example of one student's report (the third page highlighting individual and group assessments), with identifying information covered with black boxes, can be seen in Figure 2. Each student received a similar, customized third-page with detailed information.

Of the 30 first-year engineering students enrolled in this section, 21 consented to IRB-approved research around their course activities and submissions. For the analysis here, the reports and survey data from those consenting students are used in the analysis.



Student: STUDENT NAME *This information private to you*

Technical Skills:
- ***LEGO Building Experience:*** Basic (Self-rated 2/5)
- ***Programming Experience:*** Advanced (Self-rated 4/5)

Group Work Experience & Self-awareness:
- ***Successful Experience:*** Found success during the ASSIGNMENT project for this class, taking on a managerial role and ensuring the group stayed on track.
- ***Unsuccessful Experience:*** Highlighted challenges faced during a high school engineering project, where the student felt compelled to complete the majority of the work due to a lack of contribution from their partner.

Self-perceived Strengths & Weaknesses:
- ***Strengths:*** Shows proficiency in sensors, coding, and innovative thinking, as demonstrated in the ASSIGNMENT code.
- ***Weaknesses:*** Expresses a desire to improve on the mechanical and building aspects, acknowledging past challenges with ambitious builds.

Ideal Group Dynamics:
- Wants to be in a proactive group with diverse skill sets. Envisions themselves contributing to prototype design, coding, and sensor aspects while also sharing their expertise with others for collective growth.

Recommendations: Given STUDENT's basic skills in LEGO building and advanced programming abilities, it would be ideal to pair them with team members who have a strong foundation in mechanical design and building. Their past experiences show they can easily take on a leadership or guiding role, ensuring the project stays on track. This suggests that they might benefit from being in a team where roles are clearly defined to prevent them from taking on too much responsibility. Their keen interest in sharing knowledge and helping others understand indicates that they would be a valuable team member in collaborative brainstorming sessions. To harness their strengths and address their areas of improvement, pairing them with proactive individuals with complementary skill sets, especially in the mechanical and building domain, would be beneficial.

Team NAME: STUDENT, TEAMMATE 1, TEAMMATE 2 *This information shared amongst your group*

STUDENT: Has experience in both coding and building. Enjoys teaching and mentoring.
TEAMMATE 1: Needs coding assistance but brings perseverance and team spirit.
TEAMMATE 2: Good with creative thinking and time management, seeks more technical experience.

Strengths: Mechanically skilled and resourceful, with a shared vision of leveraging diverse skillsets for effective outcomes.
Structuring Suggestion: Use brainstorming sessions to maximize creative input and plan tasks.
Warnings: Communication is key, ensure everyone's voice is heard and valued.

Figure 2. Example of Third Page Showing Individual Assessment (top) and Group Assessment (bottom), with sensitive info blacked out

Evaluation Methodology and Student Feedback

A post-survey was issued after the two projects to collect data on students' perceptions of the experience. Several questions were asked as means of evaluating their perspective, emotions, and experiences working both in an AI-formed group and self-selected group. To summarize, the survey asked students to describe their comfort levels and feelings about the AI-driven process compared to a more instructor-led approach. The survey also prompted students to critically evaluate the accuracy and relevance of the AI's individual assessments and grouping recommendations, as well as their emotional responses to these automated descriptions. For

instance "*Briefly, how do you **FEEL** about this. Describe the emotions you have reading this automated description of who you are.*" Students were also asked for feedback on the AI's ability in assessing group dynamics, and the efficiency in providing structuring suggestions and warnings and were asked to reflect on the actual experiences of working in both types of groups, highlighting the strengths, weaknesses, and any notable successes or issues. Finally, the survey encourages students' to share their perspectives on how AI could better support collaborative learning and group work. (See Table A.2 for *Post-Survey for Evaluation of the Experience* in Appendix.)

The survey responses were imported into NVivo, a qualitative data analysis software, which allowed meaningful categorization and assisted in recognizing the most salient themes from which several trends emerged.

Trend 1: Overall, the process worked

In general, students were happy with the process and (at this point in the semester, after having done several weeks of generative AI supported engineering design themselves) didn't have major issues with the instructor using this technique. As one student pointed out, this may have been because things went well so they weren't blaming the automated grouping ("*I think I was pretty comfortable in terms of how this process happened. Obviously, I'd probably be saying something completely different if the AI got something really wrong, but overall I don't particularly care how the groups are made as long as they are made well.*")

Trend 2: Students felt comfortable, although hesitant, with the accuracy of the AI's summary

Students felt that the system accurately reflected who they were, although they acknowledged this was most likely because it was mostly rephrasing or parroting back what they wrote ("*[...] it wasn't very groundbreaking. For the analysis, it mostly just reworded what I inputted in the form.*"). Some students felt it wasn't in-depth or captured who they fully were, recognizing it was based on limited input information ("*I don't love that we have all been summed up in a single sentence.*" or *"It makes me feel a little misunderstood -- I feel like AI chose to emphasize certain parts of my survey that don't encompass who I am to myself."*) and suggested inputting more information ("*Maybe longer descriptions from students would help*"). Others mentioned AI's known tendency to exaggerate and hallucinate which led some students to be skeptical or distrusting of the information *("I think it did a bad job at communicating my strength and weakness in the team formation information as it lied. It said I was an excellent coder which I am not").* And finally several were worried that, if used more widely in the future, students would "scam the system" by inputting false information or simply not be truthful creating inaccurate results ("*The problem is that some people will lie on the report for the point of not admitting that they're bad at something.*").

Trend 3: Automated groupings remove social anxiety around picking partners

The first-year engineering students, in just the second month of their first semester, are still trying to negotiate the dynamics of college-life and the classroom dynamics of engaging in engineering education. Several reported relief at having the generative AI system form groups on their behalf *("I generally appreciate being grouped by a higher power, since that frees me of the stress of finding one"),* thus alleviating the need for them to have to determine this themselves ("*I also like when the AI creates the groups because it removes some of the social pressures of choosing groups.*").

Trend 4: Several recommended a hybrid methodology

While the advantages and successes of leveraging a generative AI technique was acknowledged, ultimately the students recommended overall a hybrid methodology that kept a "human in the loop" in order to confirm groupings ("*let the AI make groups based on [student suggestions] (and the teacher can oversee this process to make sure everyone has someone).*"), ensure minimal issues, and check over the work ("*AI could be used to give initial ideas for groups, but I think a person involved in the process should make the final decision.*")

Conclusions

Analysis and evidence from this work demonstrates the following: the generative AI system was able to successfully process the input data and generate the requested reports (class-wide summaries, individual assessments and recommendations, and group formations with characterizations and suggestions). Implementation details in the procedure section of the paper document instructor techniques for chatbot interactions to facilitate higher-quality output (e.g. adjusting chatbot responses to protect student identities and deliver results in more appropriate ways). Student reflections after both assignments indicate overall student approval of the AI-formed groups, with multiple students highlighting the alleviation of social anxiety when the AI identified groups for them. However, student sentiment included wariness of a fully-automated system (multiple requests for "human in the loop") and concerns over the AI summaries and decisions being based on so little input information (which also was prone to having errors, false information included, or being manipulated by students self-reported responses). After completing a project with groups selected by AI and then a project with groups formed via self-selection, students proposed a hybrid approach that allows some automation but both teacher-informed influence and includes more student choice. This paper hence recognizes the potential of generative AI in supporting group formation, but simultaneously acknowledges the call for further research with expanded data-sources, attention to self-report issues, and complementary "human in the loop" interactions to address student concerns.

References

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[3] D. Mburasek and O. Musimbi, “Development of a Tool for Team Formation in Engineering Education,” *Int. J. Eng. Manag. Res.*, vol. 11, no. 6, pp. 62–69, doi: https://doi.org/10.31033/ijemr.11.6.10.

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Appendix

Table A.1. Pre-Survey Questions Used for Group Formation

1. *Please briefly describe a situation in your life where you thought group work was successful and what role you played in contributing to that success.*
2. *Please briefly describe a situation in your life where you thought group work was unsuccessful and what role you played (or should have played) in that situation.*
3. *Based on your work thus far in [this course], what do you think are your strengths in this class?*
4. *Based on your work thus far in [this course], what do you think are your areas for improvement and things you want to work on in this class?*
5. *Briefly describe the kind of group you'd like to work in, and how you'd see yourself fitting into that group.*

Appendix (continued)

Table A.2. Post-Survey for Evaluation of the Experience

1. *How comfortable are you with this process as it happened? Please describe how you feel with regards to AI doing the majority of analysis and grouping vs it being done manually by the instructor (the instructor reading your responses, manually forming groups).*
2. *Please reread the "individual assessment" (private to you) portion of the analysis. How do you think the AI did in capturing who you are? How accurate or complete do you think it is? Read the "recommendations" for how to group you with others and evaluate/comment on if this resonates with you or not and where it might be right or wrong.*
3. *Briefly, how do you **FEEL** about this. Describe the emotions you have reading this automated description of who you are.*
4. *Read the Team Formation information (the info shared amongst your group). Please comment on how the AI did in terms of describing individuals, its assessment of the group's strength, its "structuring suggestions," as well as the warnings it gave. Describe how you think it did in terms of generating those components.*
5. *Now reflect on the actual experience of "group work" for* Project 9: Robotic Arm. *How did it go? What were the strengths of your group? Where/when/how did things go well?*
6. *Continue to reflect on the group work for* Project 9: Robotic Arm. *What were the weaknesses of your group? When/how did things not go well? In hindsight/reflection, what would have been better for your group to have done to achieve better results?*
7. *You formed your own self-picked groups and worked on* Project 10: Haunted House *together. Please describe the group dynamics and how that project went, highlighting any successes or issues.*
8. *Describe in what ways, if any, you think the prior group work (AI assessment, forming groups, and working on* Project 9: Robotic Arm*) may have influenced your subsequent group experience for Haunted House. Or if you think the experience was independent of that (e.g. things would have happened the same despite the discussions of group work, structure, etc).*
9. *Is there anything else regarding group work you'd like to include here. Perhaps your thoughts on how AI could better support group work. Or how you think the class should be structured differently with regards to group work.*

Appendix (continued)

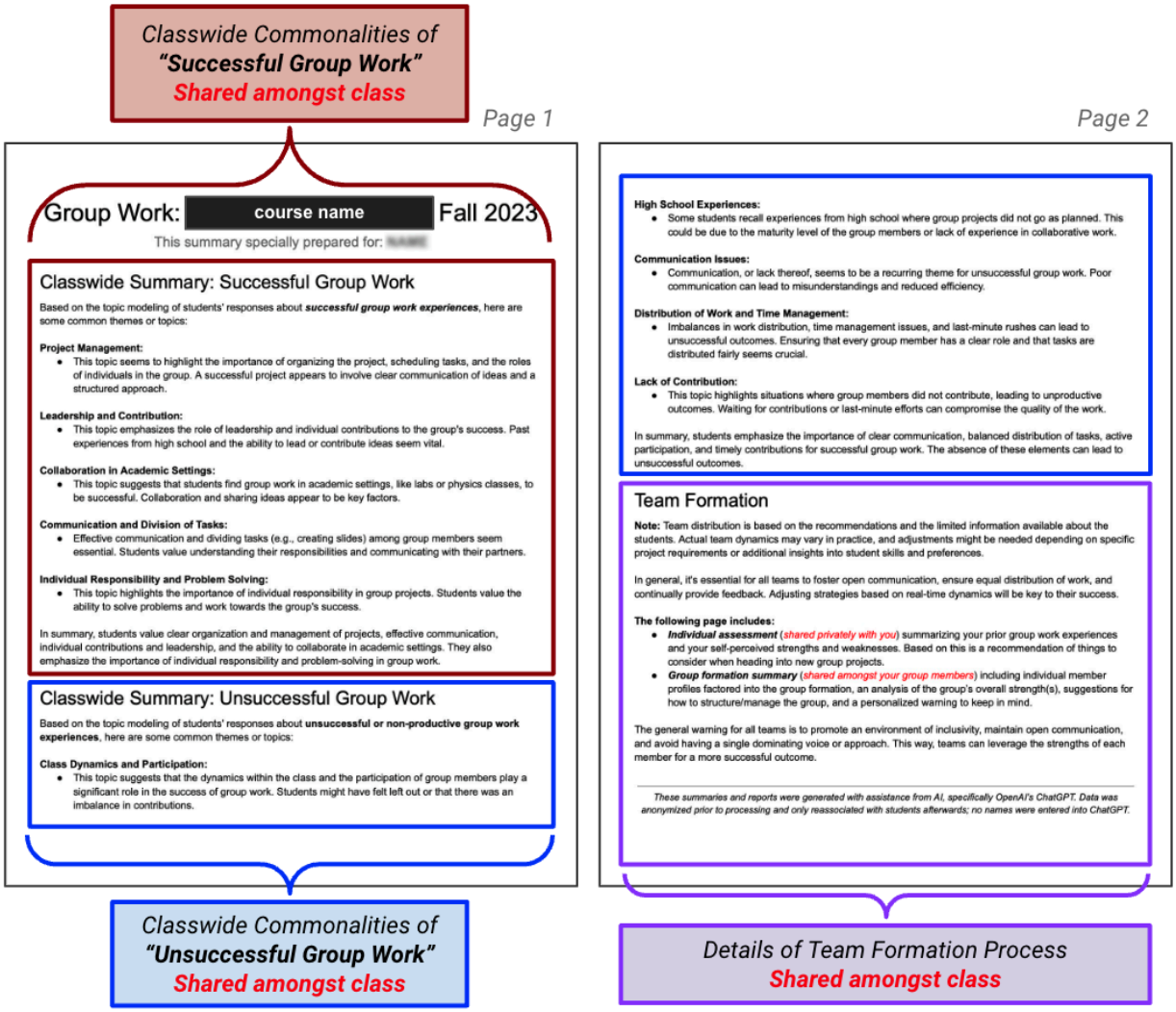

Figure A.1. First Two Pages of Example Teaming Reports Generated for All Students