

## **The Evolution of Engineering Design Courses to a Hybrid-virtual Environment to Increase Student Engagement and Satisfaction**

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## **Abstract**

Engineering Design courses with teamwork elements face critical logistical issues that become increasingly prevalent on a large scale. These issues become exacerbated when the course is cross-disciplinary or includes external partners. This paper discusses the suite of virtual tools utilized to support senior capstone design courses to manage logistics. We report on student satisfaction associated with team formation, project selection, and project presentation aspects.

For each of these aspects, an interactive, virtual conferencing platform is utilized in which participants can freely move between small informal groups at any time. This platform's structure is designed to mimic a traditional in-person exhibition. Participants can listen to presentations at tables, ask questions, talk individually, and move to a different location at their discretion. The platform relieves the logistical burden of gathering people from geographically separate locations in the same space while retaining much of the freedoms and interactions associated with in-person events.

A separate online web portal, which acts as a database for projects and students, was created and made available to augment the real-time online team formation process. Students can use this portal to learn about the projects, propose project ideas, highlight projects that interest them, and share their skills and experiences. This platform reduces the amount of time and resources needed to provide students the information necessary to make well-informed decisions when attending the project selection and team formation conferences.

Giving students preferential control relieves the burden on faculty for large scale team formation and project selection. The faculty could then focus primarily on managing the project bid delegation based on a decision flowchart outlined in the paper. Having access to a combination of interactive synchronous and asynchronous online tools can help students make well-informed decisions about teammate and project preferences.

At the end of the semester, students attend the capstone design exposition to present their project outcomes to the public, including judges, sponsors, guests, and students. This experience helps students gain a hands-on learning environment to practice communications with a wide range of audiences. Utilizing a virtual and interactive conferencing tool increases accessibility to the capstone design expo. It enables participation when circumstances such as budget restrictions, geographic separation, or social distancing requirements could make it otherwise infeasible. This paper reports on the perception and impact of all these tools on student satisfaction in the course.

## **Introduction**

### *Background*

Capstone Design courses are commonly implemented in undergraduate engineering curriculum to satisfy ABET accreditation requirements [1] and are an effective method to provide students with experience developing solutions for real-world design problems. Past research [2, 3] shows

the merit of these Capstone Design courses and describes the function of these courses. Across various Schools and Colleges, Georgia Institute of Technology (Georgia Tech) has over 1000 students from around 200 teams to work on their course projects each semester (except Summer semester). Therefore, creating teams and distributing projects between these students becomes a large endeavor. The limited time available to disseminate information about the projects, form cohesive teams, and assign projects is a primary bottleneck in schools with large Capstone Design courses. For a single semester offering of Capstone Design, there is strong need to reduce this time for “administrative overhead” so that students could spend more time being productive while working on the projects. The challenge further compounds itself when the end objective is to form blended teams comprising of students from across multiple schools.

To assist with the logistics of running a capstone design course, an online web portal (the capstone marketplace) was created to act as a showcase of available projects to students while augmenting real-time online team formation processes. [4-6] Students can use this portal to learn about and propose projects as well as share their skills and experiences, reducing the amount of time and resources needed to provide students the information to make well-informed decisions when attending the project selection and team formation conferences. This platform has been in use at the institute for over six years now while being updated and revised.

The utility of the online database and the virtual, interactive conferencing tool are analyzed for their effectiveness in fostering successful semesters. Student strategies for team formation during the beginning of the course and which strategies students would consider in future team developments are compared to determine if students’ perception changes throughout the semester.

The COVID-19 pandemic offered a unique opportunity to experiment with innovative tools to support the capstone design course. Large in-person classes during Fall 2020 and Spring 2021 were moved to be hybrid virtual and online. Hence, for team formation, a virtual conferencing platform (Gatherly.io) was utilized in which participants can freely move between small informal groups at any time. This platform's structure is designed to mimic a traditional in-person exhibition. Participants can listen to presentations at tables, ask questions, talk individually, and move to a different location, on a virtual map, at their discretion. The platform relieves the logistical burden of gathering people from geographically distinct locations in the same space while retaining much of the freedoms and interactions associated with in-person events.

### *Related Work*

There has been much examination on ways to address team formation and project assignment process in Capstone Design projects. Some researchers argue that team formation should be faculty driven [7], citing that faculty assignment simulates real-world scenarios by making students work with people they are not familiar with. They tested this hypothesis by comparing faculty selection against a linear programming optimization algorithm, which considers students’ project interests, skills, and GPA. They report positive results regarding faculty team formation; however, the scale of the team formation process varies significantly from the one presented here, leading to high faculty overhead in order to facilitate this. Additionally, the team formation process proposed here also enables students to create their own projects and teams, giving the

students more autonomy over what they wish to work on. A panel session at the 2010 Capstone Design Conference [8] reported that self-selected teams are more cohesive and manage deadlines more effectively but tend to display clique behavior and lack a variety of skill sets. By providing students visibility to prospective member's skills, the authors here intend to mitigate this effect. Research suggests little statistical difference in student satisfaction between student-led and faculty-led team formation [9] with over 80% of students in both groups reporting that the team-forming process should be used in the future while over 80% of the students were happy with their project and team after five weeks.

Another method of forming teams is algorithmically, a technique utilized by CATME, a popular and widely reported on team formation tool [10, 11]. CATME has a Team-Maker tool that assigns students to teams according to student preferences and instructor-specified criteria. The algorithm can be adjusted to fit a wide array of needs by evaluating weighted multivariate criteria, demonstrating powerful team formation capabilities. Using an algorithm to determine teams, however, does not challenge the student to make decisions on prospective team members. The algorithmic team formation method was not utilized in Georgia Tech's capstone design courses considered for this research, enabling students to reflect and learn from the decisions they made during their team formation process.

The team formation and project selection methodology utilized here is built upon the foundation of prior research documented in [12]. The researchers describe a system with a high level of student autonomy in which project interests and skills of other students are available to them. a high level of success in their workflow with a vast majority of students receiving projects which they prioritized. This document differs in that the project interest system presented here does not have a rating system, and additional tools are available to the students to assist with team formation. The capstone expo is a key element of the course in which students are able to more effectively collaborate on projects and present their conclusions [13].

### *Hybrid Course Format*

Due to constraints on in-person interaction during the fall 2020 and spring 2021 semesters, the use of online tools to facilitate learning in Capstone Design are even more prominent and critical. The shift of learning materials to a virtual format forced the design of the course to adapt to these new circumstances and create ways for students to learn remotely. However, online tools have been in use at Georgia Tech for some time now to assist with team formation and project selection, and the current circumstances have provided an opportunity to refine the features of these online tools.

Students enrolled in the Inter-disciplinary Capstone Design course (students in Mechanical Engineering, Biomedical Engineering, Electrical Engineering and Material Science Engineering), the Mechanical Engineering specific Capstone Design course, and the Electrical & Computer Engineering specific capstone design course utilized the web-based capstone marketplace to assist with team formation and project selection. These students used the same course format and suite of web-based tools, so they will be categorized as students that utilized the IDCD (Inter-Disciplinary Capstone Design) format in this study. IDCD students were provided two primary tools: the capstone marketplace site, and the virtual, interactive,

conferencing platform (Gatherly.io) to find projects and team members of interest. The students were required to form their teams and find their projects within approximately one week at the start of the course. The timeline for spring 2021 IDCD students detailed in the appendix figure A1.

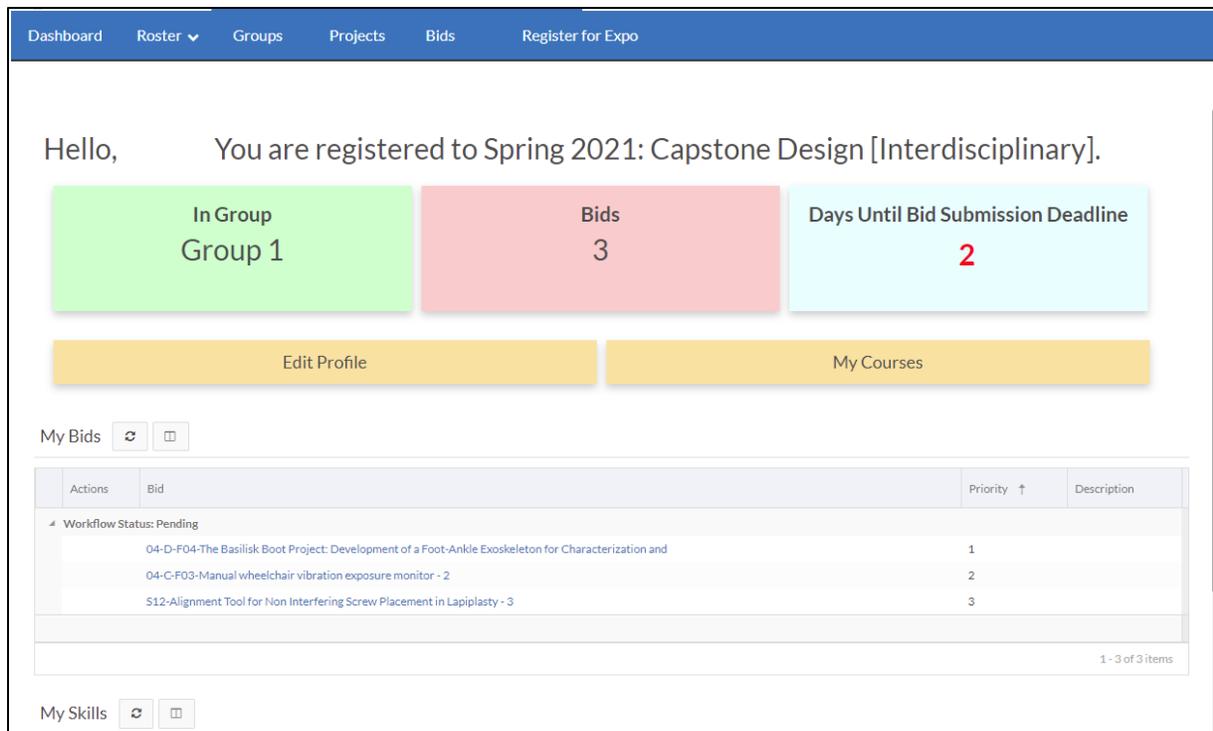
Students in courses that attended the capstone expo but did not use the same online tools will be classified as “other” students in this paper and includes students from courses specific to only Biomedical Engineering, Electrical Engineering, Industrial Engineering, or Industrial Design disciplines as a reference. The other students used a combination of different techniques to form teams and find projects, from a pre-capstone design course, faculty assigned teams, or other online tools.

## **Experimental Methods and Project Approach**

### *Capstone Marketplace*

In the capstone marketplace, the student begins by creating their profile, which contains information about their registered course section, skills and experiences. Students can then individually express interest in any projects in the site or create their own project. This information is visible to all other users for other students to evaluate potential team members and projects. Prior to the project bid process, team formation is required in order to ensure that students adequately evaluate their project options based on their team’s collective skillsets and experiences, while also enabling faculty to evaluate bids holistically between teams.

The capstone marketplace gives students access to a vast array of information about their peers and the status of the course. The dashboard displays their status in the project selection process where they can view information about groups, projects, and bids. Student schedules, unlike with CATME, are not considered as the students had a common studio and lab times for the capstone design courses studied in this research. The page is dynamically updated depending on the current stage of the course. In the first stage, users are not in teams yet, so they see information about their group prospects (invitations and join requests) and their project interests. Once they have joined a team, they move onto the next stage, where their focus is drawn to the team’s bids and bid priorities. After their bids are evaluated by faculty and projects are assigned to teams, the student can begin work on their capstone project. The detailed timeline for the start of the course is outlined in appendix figure A1. Figure 1 shows the dashboard screenshot for a student after they have a group and are ready to bid on projects.



**Figure 1. Screenshot of the landing page for student upon login, which shows the dashboard Layout.**

Outside of the dashboard tab, there are also the roster, groups, projects, bids, and expo registration tabs in the capstone marketplace. The roster allows students to view fellow student skills, experiences, and majors. This roster view provides a unique value over the typical view of class attendees/participants that might be accessible from the conventional LMC (Learning Management Systems) tools used by universities. The roster contains a menu for skills, in which students can view all the skills entered the marketplace, filter out which skills they are interested in, view how many students have those skills, and see lists of students that display each skill. The groups tab shows the groups that have been created, what which projects each group has bid on, the members of the group, and provides students with options to request to join a group or create their own. The projects tab displays a student's assigned project if they have one, their project interests, and the projects that are available to them. Students only see projects approved for their major so they can focus on what is relevant to them. Each project contains information about the number of bids, the number of interested students, recommended schools, and who proposed the project. By clicking on the project, students can see more details about the project and its requirements. The projects tab visible to students allow them to view project information, express project interests, and place bids. It displays how many students are interested in the project and how many bids are received so students can gauge the competitiveness of each project. A screenshot of the projects tab is shown in Figure 2 to visualize the interfaces the students utilize from a student's perspective that has been assigned a project by faculty.

Dashboard Roster ▾ Groups Projects Bids Register for Expo

## Projects

My Project: [05-B-E16-Soft Case Military Applications Through 3D Printing](#)

Detailed Search

Project Interests

Project ↑	Workflow Actions	Interest (Double-Click)
01-B-E23-Universal Molle bag		
05-B-E16-Soft Case Military Applications Through 3D Printing		
05-B-E17-Gripper Applications Through 3D Printing (CANCELLED/DEFERRED)		
05-B-E19-Firearm Accessories - Military and Consumer Applications (CANCELLED/DEFERRED)		

Projects Accepted Projects

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Project	Submitted By	Required Schools	Suggested Schools	Bids	Inter
Project Status: Accepted					
03-F-F07-Sensing the Subnivean	Georgia Tech	ECE	BME,ME	1	26
05-B-E19-Firearm Accessories - Military and Consumer Applications (CANCELLED/DEFERRED)	BASF	ME	MSE	1	20
01-E-E09-Compact Pruning device	TTI	ME		1	16
05-B-E15-LED Heat Reduction Application	BASF	ME	MSE,ECE	0	13

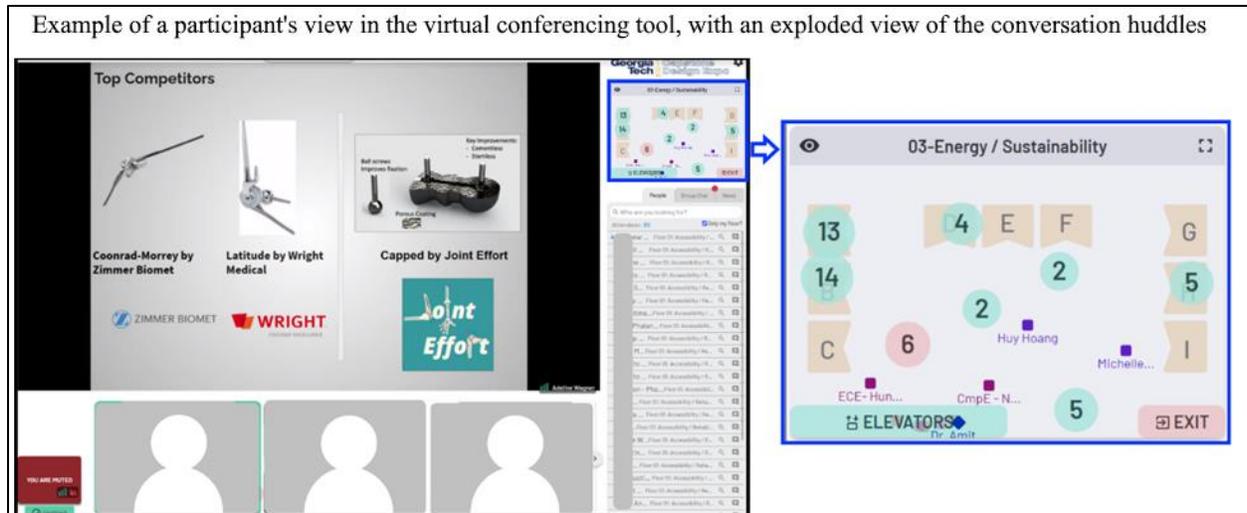
**Figure 2. Screenshot of the Capstone Marketplace website showing the Projects tab for a student.**

In order to assign projects to teams based on their bids, a methodology is used to ensure the best fit for the project assignment process, outlined in appendix figure A2. First priority bids are examined first, with bid assignment descending to lower ranked bids afterwards. Bids are evaluated based on the following criteria: if sponsors have expressed interest in groups, if students have articulated how their skills and experience are applicable to the project, if the students have a good understanding of the project, and if students have discussed the project with the sponsor previously. If a team loses out on a bid for a project, all of their lower bids receive an increased priority of one. This bid selection process was developed over years of experience at the institute.

### *Virtual, interactive conferencing tool*

The virtual, interactive, conferencing platform (Gatherly.io) is utilized during three different sessions in the beginning of the semester, in which student mingling and project presentations are done. In this tool, participants can freely move from one area to another at any time by using the location selection panel. If more than one participant is in the same area, they will be linked into a conversation huddle that operates similarly to other conventional video calling tools in which audio and video are displayed, alongside screensharing functionality. This tool differentiates itself from other conferencing tools in that it allows participants to freely move between different locations or conversation huddles. In the tool, tables are outlined as tan polygons on the floor, which have projects associated to them. If a student is interested in meeting with others that have similar project interests, they can join the respective table, or they can meet in any areas outside of the designated table areas if they wish. Students can travel

between floors by moving to the elevator in the bottom left of the location selection window, allowing them to visit floors that correspond to different project categories. An example conversation huddle is shown in Figure 3, which displays a student in a conversation huddle on the third floor, corresponding to Energy/Sustainability related projects.



**Figure 3. Virtual conferencing tool layout displaying what a participant would see (left) in the site, with an exploded view of the location selection window (right).**

The first time the students can utilize this tool is the optional social mixer in the beginning of the course, where students are given the opportunity to find potential team members. Prior to this social mixer, faculty provide a very brief overview of the course and the timeline for the first few days of the semester, while emphasizing the needs to form teams and identify projects. IDCD students that utilized the tool in the spring 2021 semester were asked to specify one of five desirable skills: CAD, CAE/CFD, Electronics, Fabrication, and Programming. Each of these skills is associated with a different color which is displayed to other students for quick visual reference. The student is also able to append their major to the beginning of their display name. This combination of information allows for students to quickly identify prospective team members in the location selection screen. Students can then move to different areas in the platform to meet with potential new team members they found in the conferencing tool, the capstone marketplace, group chat, prior acquaintances, or to tables associated with specific projects.

This tool is used again when project sponsors are placed at each of the designated project tables and gives students an opportunity to talk to the individuals pitching or sponsoring certain projects. This platform is utilized in the beginning of the semester again following the project presentations, for another social mixer session. The conferencing tool gives students the ability to meet with other students virtually and easily, given the large number of students participating in the course and accommodates the restrictions on meeting in-person. The final time that the interface is utilized is during the capstone expo.

### *Capstone Design Expo*

Each semester, Georgia Tech hosts an expo which enables Capstone Design teams to showcase their projects to judges & attendees. There is a winning team selected from each school and an overall best project, all of which receive cash prizes for their performance in the expo. In the past, this event has been held in person with hundreds of attendees. During the summer and fall semesters of 2020, a different solution was created to allow students to showcase their projects, for which the virtual, interactive conferencing platform was utilized. The platform worked similarly as for the early project presentation and social mixer sessions, with the students acting as the project presenters at each table instead of the projects being pitched to the students [14]. Judges and attendees can go from table to table, assessing the projects and learning more about what the students worked on during the semester. Judges, attendees, and students joined the exposition with unique links that identified them with a separate color, as shown in appendix Figure A4. On each floor, twelve tables were present associated with up to twelve different projects that students were showcasing. The projects were divided up into eleven different floors based on project category, allowing participants to travel to individual floors based on their project interests, as outlined in appendix Figure A5.

### *Data collection*

In order to quantify student perceptions of the course, an optional end-of-semester survey was conducted for all students that participated in the fall 2020 Capstone Expo, and for IDCD students only in the beginning of Spring 2021. Students were recruited to participate in the survey and provided informed consent in accordance with the Georgia Tech's Institutional Review Board (IRB). The full list of survey questions can be found in appendix B. The survey focused on understanding student's perceptions on their team formation, project selection, and the virtual capstone exposition. Some survey questions were formulated to resemble prior team formation literature found in [9]. All students participated in the same capstone expo; however, only IDCD students used the online tools for team formation and project selection. In the fall survey, 99 of the 238 students who used IDCD tools responded and 71 other students who participated in different discipline Fall 2020 Capstone Design sections responded. In spring 2021, 154 of the 275 students who used IDCD tools responded. These three groups of students will be categorized as Fall IDCD, Fall Other, and Spring IDCD respectively. Survey questions were optional, and not all surveys were fully completed. For each survey question, all non-blank answers were included, including surveys which were incomplete. The majority of questions in the survey were created on a five-point Likert scale to facilitate statistical comparison of the students' answers. All answers to questions are evaluated on a 1-5 scale, or converted to a 1-5 scale, with 5 indicating an agreement or positive satisfaction rating and 1 indicating a disagreement or dissatisfaction rating. Table 1 displays answer choices for different types of questions, which are the standard answer types for questions posed in the survey unless stated otherwise in this paper.

**Table 1. Different question types and their answer’s numerical conversions.**

Generic Question Type:	Numerical rating to answer type conversion				
	5	4	3	2	1
How Important...?	Extremely important	Very important	Moderately important	Slightly important	Not at all important
How Useful...?	Extremely useful	Very useful	Moderately useful	Slightly useful	Not at all useful
How Effective...?	Extremely effective	Very effective	Moderately effective	Slightly effective	Not at all effective
How Satisfied...?	Extremely satisfied	Somewhat satisfied	Neither Satisfied nor dissatisfied	Somewhat dissatisfied	Extremely dissatisfied
Do you agree...?	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree

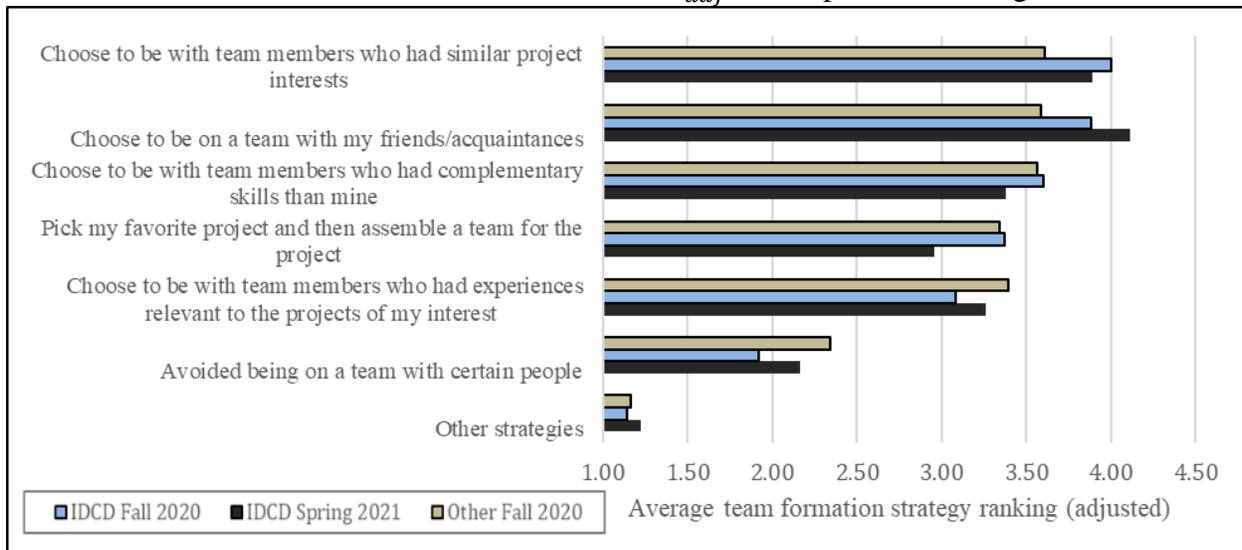
**Results and Discussion**

*Team formation strategies*

Students were asked to answer the following question: “What strategies did you prioritize the most during team formation?” The students were provided seven different strategies to rank in ascending order, which were rescaled to a descending five scale rank order using formula 1 as shown in [15].

$$I_{adj} = 6 - \left( \frac{(5-1)(I_{avg}-1)}{(7-1)} + 1 \right) \tag{1}$$

Where  $I_{avg}$  represents the average ranking of the student’s perception of each strategy during their initial team formation and  $I_{adj}$  represents an adjusted, descending five-point scale of the rankings. Using the  $I_{adj}$  values, the ranking of the student strategies for team formation were compared against each other to determine which strategies were utilized most frequently. The answer choices students had to choose from and the  $I_{adj}$  data is presented in Figure 4.



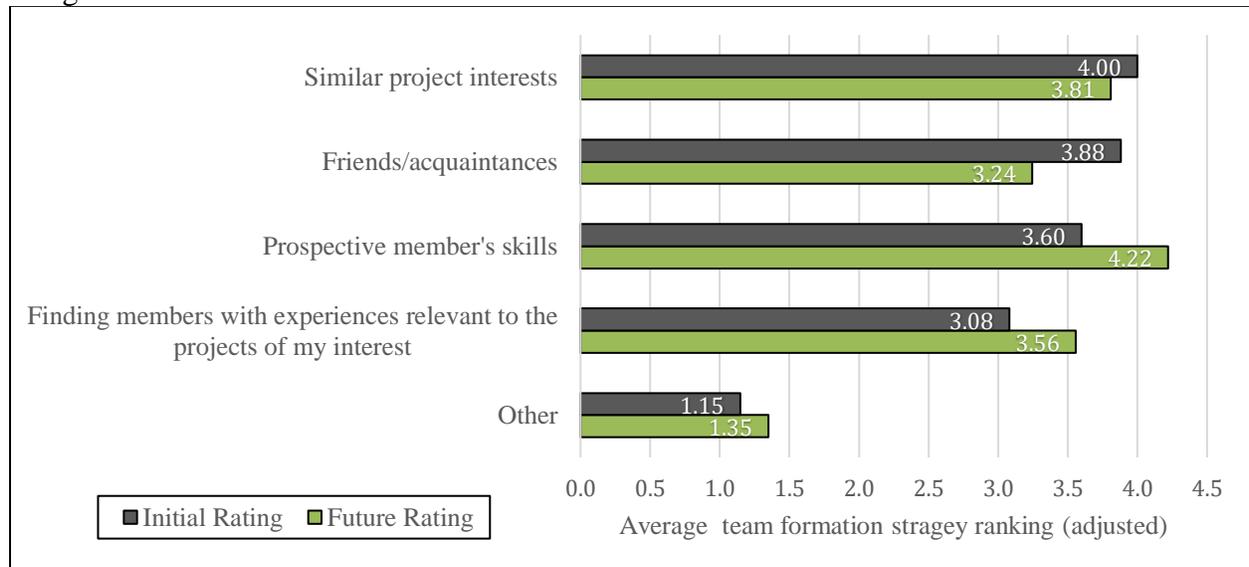
**Figure 4. Team formation strategy ranking between sections showing the variety of students’ preferences for team formation strategies.**

The prioritization of the team formation strategies follows a similar trend for all sections, with similar ratings for most categories when considering both the fall and spring IDCD sections compared to other sections. The data indicates that students prioritized project interests and prior friends/acquaintances as top strategies for team formation across all sections; however, both IDCD sections rated those strategies more highly than other sections. Project interests may be more highly rated for IDCD students due to the project interest functionality of the capstone marketplace, which allows students to express interest in projects and view information about other student’s project interests. The spring IDCD students indicated they picked their favorite project as a much lower strategy in the spring of 2021, which is most likely due to the lower availability of external project organizations, with 20 in the spring opposed to 29 in the fall, even though the number of external projects in both semesters was around 43. Among all of the team formation strategies, none appeared to be the singular most popular method. Different students formed teams with different strategies, indicating that students will utilize a variety of team formation strategies if provided the resources.

To determine if students would change their team formation strategy in the future, they were asked: “With what you know now, what factors would you consider while forming your team for the course?” The students were provided six different factors to rank in ascending order, which were rescaled to a descending order using formula 2 as shown in [15].

$$F_{adj} = 6 - \left( \frac{(5-1)(F_{avg}-1)}{(6-1)} + 1 \right) \quad (2)$$

Where  $F_{avg}$  represents the average of the student’s perceptions of the importance of each strategy and  $F_{adj}$  represent an adjusted, descending five-point scale of the rankings. Collecting the data for both  $I_{adj}$  and  $F_{adj}$  together allows for a comparison between a student’s initial team formation strategy against which factors they would prioritize in the future. For fall IDCD students, both the  $I_{adj}$  (n = 71) and  $F_{adj}$  (n = 64) data was collected together and is reported on in figure 5.



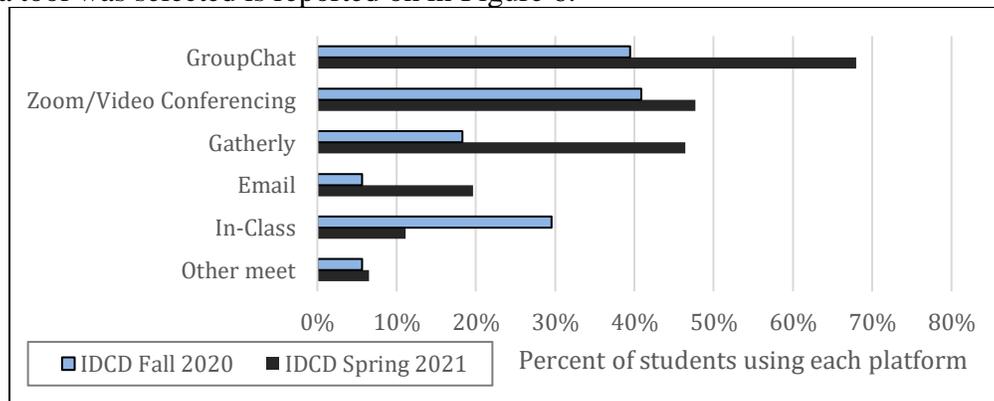
**Figure 5. Initial and future formation strategies: Student prioritization of different strategies for future team formation.**

The figure displays that students tended to favor finding others that shared project interests initially and would do the same in future team formations. Students also highlighted that in future team formations, they would form teams quite differently, prioritizing teaming with their friends less and focusing more on finding team members based on their skills or experiences. This shift in thought is most likely a reflection of challenges that students encountered during the project by lacking necessary skillsets or facing troubling team dynamics. This indicates that even though the capstone marketplace provides information about the skills and experiences of prospective team members, methods may need to be developed to encourage students to prioritize leveraging that information more in their team formation processes. The data also indicates that providing students with the freedom to create their own teams may have an additional educational benefit, with students displaying a change in their team formation strategy preferences following their experience in the capstone design course.

The IDCD platform did not collect or disclose GPA to students during team formation, but a survey question was asked to determine whether students believed knowledge of GPA would help in team formation in the future. The adjusted rank of the prospective member’s GPA rating was found to be only 1.82/5.00, indicating that students found that this would be a less valuable metric for team formation.

*Meeting potential team members*

Students were asked “How important was it for you to ‘meet’ (physically or virtually) with your prospective team member before committing to the team?” in order to evaluate their perceptions on meeting with prospective team members. IDCD students reported an average importance of meeting with prospective team members as 3.31 and 3.58 for the fall and spring semesters respectively. They were also asked “How did you “meet” or interact with your prospective team members prior to forming your team?” with the options of group-chat, Zoom/Video Conferencing, Gatherly, Email, In-Class, and Other (Fill in the blank). Students could select each of the tools that they used to meet with their prospective team members, and the percentage of the time a tool was selected is reported on in Figure 6.



**Figure 6. Meeting tools. The percentage of students that reported using each platform to meet with prospective team members showing increased used of GroupChat and video conferencing methods (i.e. Zoom and Gatherly).**

It is evident that group-chat and Zoom/Video Conferencing are the most frequently used tools to meet with prospective team members in the remote setting. It is also apparent that spring students used group-chat more frequently and in-class meeting less frequently than those from the fall. The increased use of group-chat in the spring semester is likely due to the students creating their own group-chat for the entire section, which was not done in the fall. The lower response rate of students meeting with their teammates in class during the spring semester is likely due to the increasing prevalence of remote learning during the prior semesters. In the Spring 2021 semester, students reported meeting with prospective members through the interactive conferencing platform (Gatherly.io) much more than in the fall. Figure A6 in the appendix outlines the attendees for one of these social mixers over time. Two main factors likely contributed to this: Gatherly.io was utilized for three sessions in the spring, as opposed to two in the fall, and additional functionality was added to the app in the spring. Students were able to highlight their skills and majors in the spring (as outlined in the methods), in addition to the private chat and project locations available in the fall.

Students were asked in the spring “What features of the social mixer (on Gatherly Platform) did you actually use in finding prospective team members?”. Twelve responded that they used the color-based skills feature, 24 responded that they used the major-appending feature in student names, 18 said they direct messaged other students, and 46 said they utilized common project interests. This is reflective of the team formation strategies utilized in the capstone marketplace, where project interests were used the most. Additionally, 23 students answered “No” to the question of “Assuming all other online tools were available; do you believe that you would have been able to find your team members without the use of social mixer on Gatherly Platform?”. This indicates that 15% of the spring IDCD students perceived the interactive conferencing tool as a critical component to their team formation in the spring. This is true even though the average usefulness of the platform was rated slightly lower in the spring, with an average of 3.65 compared to 3.83 in the fall. The difference on reported usefulness could be due to the higher overall use in the spring, with 46% of the students reporting use of the platform to find team members compared to 18% in the fall.

Due to the barriers of meeting in person during both the Fall 2020 and Spring 2021 semesters, students were not able to meet with prospective team members easily. The online platforms gave students an opportunity to interact and evaluate potential new team members remotely and rapidly, giving them more holistic metrics to create teams. The data also indicates that it would be beneficial to continue providing the conferencing platform to the students as an optional tool for them to use to form their teams in the future, as it allows for students to meet with prospective team members rapidly filter out and meet with other students.

### *Student Satisfaction*

Creating teams and finding projects in the very beginning of the semester can be a stressful and exciting time for students. A key objective of our survey was to understand students’ emotional state regarding different aspects of team formation and project selection. Spring 2021 IDCD students were asked “How would you describe your emotional state during the start of the semester with regards to the following topics?” The topics, answer choices, and number of responses per answer choice are outlined in Table 2, with the average answers of each topic

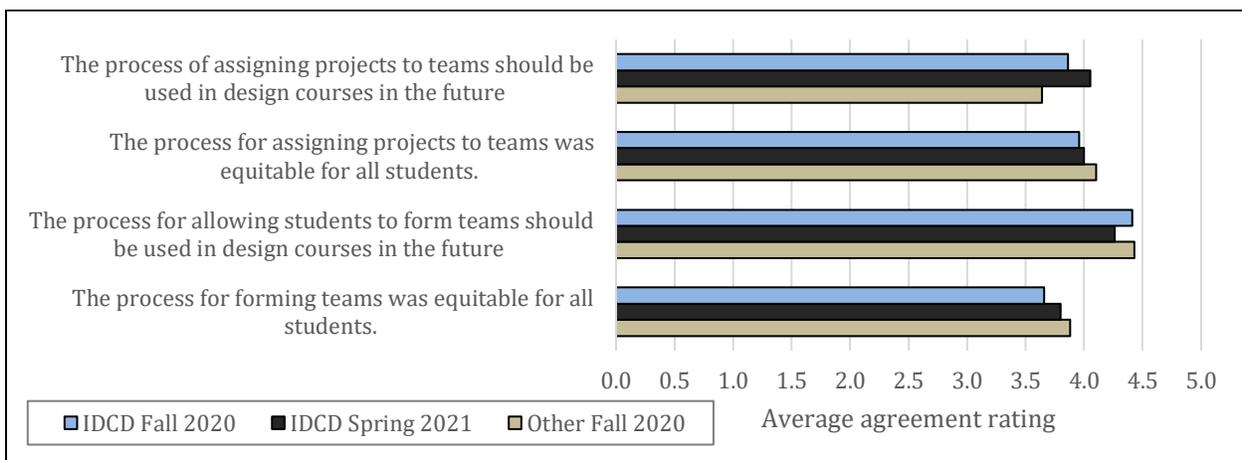
derived from the average of the count of each emotional state multiplied by the corresponding numerical values.

**Table 2. Student emotional state regarding different aspects of the beginning of the semester.**

How would you describe your emotional state during the start of the semester with regards to the following topics?	Count of Anxious/Stressed	Count of Calm	Count of Excited/Eager	Average
<b>Corresponding Numerical Values (w)</b>	<b>-1</b>	<b>0</b>	<b>1</b>	<b>-</b>
Overall state of mind	58	69	24	<b>-0.23</b>
Finding out what my project would be	40	63	48	<b>0.05</b>
Finding out who my teammates would be	55	66	30	<b>-0.17</b>
Amount of personal autonomy over the choices of team and project.	31	88	31	<b>0.00</b>

The table indicates that students were equally divided between anxious/stressed and eager/excited about the level of personal autonomy they had over the choices of team formation and project selection. This is important because it shows that students are not anxious due to the amount of autonomy they have and outlines their confidence to utilize the tools provided with competence. Students indicated their overall state of mind to be the most anxious/stressed during this time, which could be due to the short timeframe in which students are required to perform these duties that will determine their success over the course of the semester.

To determine whether the emotional state of students during the beginning of the semester was reflective of the equitability and utility of the tools available to them, students in all groups were asked to what degree they agreed or disagreed with a set of equitability questions. The questions and answers are outlined in figure 7 following the prompt of “Please mark the response that most closely reflects your opinion for the following statements:” following the answer choices outlined in table 1.



**Figure 7. Equitability questions and their averages for each student group.**

The data indicates that both the IDCD and other students somewhat to strongly agree on the notion of their team formation processes to be used in the future on average. This appears to be in contrast with the prior question; however, where students from both groups rate the equitability of team formation lower than the suggestion of using it in the future. Additionally, students from both groups reported to slightly agree on average with the equitability of the project assignment process and whether the process should be used in the future. The data from this table appears inconclusive, as students across all sections reported similar ratings for the equitability and future utility of the team formation and project selection aspects.

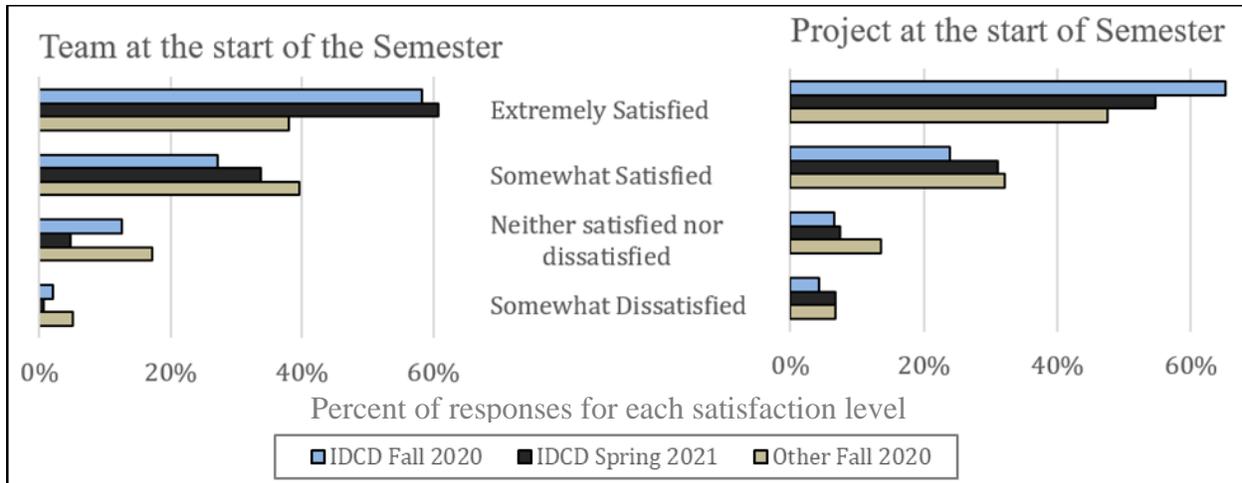
To determine student satisfaction with the course, students were asked about their satisfaction in the team formation and project selection processes during the beginning and the end of the project. The students were asked “How satisfied were you with your team during the... Start of the project, End of the project / Now”, and asked the same question about their project. Their answer choices for satisfaction are outlined in Table 1. The responses were compiled for students that utilized the IDCD tools in the fall and spring for team formation and project selection against other sections that did not use those tools and the results are shown in Table 3.

**Table 3. Student Satisfaction averages for their team and project during the beginning and end of the project.**

Row Labels	Average Team Start	Average Team End	Average Project Start	Average Project End	Response Count
Other (Fall 2020)	4.1	4.38	4.2	4.11	57
IDCD (Fall 2020)	4.42	4.52	4.5	4.37	46
IDCD (Spring 2021)	4.55	-	4.34	-	148
% Difference (Fall IDCD/Other)	7.80%	3.20%	7.14%	6.33%	-
% Difference (Spring IDCD/Other)	10.98%	-	3.33%	-	-

The data shows that in both groups, the teams were more satisfied with their members as the semester went forward and less satisfied with the project as the semester went forward. This could be due to the difficulty of the course, in which the teams bond over the challenges they face while becoming less enthusiastic about the project over time. For the team formation aspect, students that utilized the IDCD platform display slightly higher satisfaction ratings than the others in the fall, with a 7.8% and 10.98% higher rating for the team formation in the fall and spring respectively. This success is also reflected in the project satisfaction, with students reporting a 7.14% and 3.33% higher satisfaction rating on average for project assignment in the fall and spring respectively. The lower satisfaction of the project assignment in the spring may be due to the reduced number of sponsored projects available to the students in the spring semester compared to the prior semester.

This differences in student satisfaction between sections becomes more evident when comparing the number of responses for each satisfaction level. The percentages of response rates for each level of satisfaction are displayed in Figure 8.



**Figure 8: Comparison of the rate of responses for each satisfaction level and displays the differences between the sections.**

The figure displays the difference in response rates for the satisfaction levels for the students regarding how satisfied they were with their team and project at the beginning of the semester. From the data, no students reported being extremely dissatisfied with their team or project in any of the sections. IDCD students displayed significantly more satisfaction regarding team formation, with around 60% of IDCD students being extremely satisfied with their team at the start of the semester, compared to 38% from other students. This highlights the success of the tools and methods of the IDCD team formation process in facilitating student satisfaction by giving them the resources and tools to create their own teams. This is supported by the data presented in which IDCD students reported, on average, a calm emotional state about the amount of personal autonomy over their choices regarding their team and project, and somewhat to strongly agreed that the team formation methods should be used in the future.

#### *Virtual Capstone Design Expo*

In order to evaluate the effectiveness of the virtual expo, students were asked about the effectiveness of the expo and whether they agreed with a series of questions, with scores of 5 indicating highest agreement and scores and 1 indicating lowest agreement. These questions are outlined in Table 4 with the averaged answer values and standard deviations.

**Table 4: Capstone Design Expo questionnaire.**

Please mark the response that most closely reflects your opinion for the following statement: Participation in the expo...	Average Score	Standard Deviation
Was effective to enhance and grow your professional network	2.51	1.294
Was effective to practice and improve your communication skills	3.47	1.010
Increased team's confidence in pursuing projects beyond the course	3.75	0.900
Provided inspiration or new application ideas for the project	3.83	0.939
Helped improve the final project report/deliverables	3.91	0.883
Is recommended for future students	4.13	0.921

Table 4 clearly displays the drawbacks and benefits of the virtual capstone expo. The virtual expo was reported as being slightly to moderately effective at growing student's professional networks, with a lower average score than most other answers in the survey of 2.51. Students perceived the expo's effectiveness to improve or practice communication skills as slightly lower as well, with a rating of 3.47. The virtual format was identified as being the cause of the lower ratings in both cases. The rest of the prompts regarding the expo received more positive responses from the students; however, these prompts are applicable for both the in-person and remote expo. These prompts showed students recommending the expo to future students as well as highlighting its ability to improve the final project report and provide inspiration or new application ideas. This indicates that there is value in hosting the expo in general but highlight areas in which the virtual format of the expo does not meet the expectations of past expos.

Additionally, judges and attendees were asked to answer a short survey at the end of the expo to gauge their perceptions of the format. Eleven judges and attendees who previously attended an in-person expo in the past answered the question of "How would you compare the virtual capstone design expo with an on-campus, in-person expo?" with a rating of 2.45, indicating that the expo was perceived as somewhat worse to about the same as the in-person expo. Twenty judges and attendees that had not attended an in-person expo in the past answered the question of "How would you rate the Fall 2020 Virtual Capstone Design Expo?" with a score of 4.4, indicating that the expo was perceived between good and excellent. This data indicates that past experiences of successful, in-person expos may impact perception of the virtual format. Two students summarized the sentiments of the online exposition well: "Online Expos might not be a good idea, as the in-person social cues and networking is a large part of having a successful Expo" and "Very well done for the virtual format but of course we all miss the in-person capstone."

Due to the server-side limitations with the virtual conferencing platform, compromises were made regarding the number of attendees allowed and the cohesiveness of the floors in the expo. From a technical standpoint, students and judges desired the ability to browse projects at a high level and to see previews of projects before joining a table. The use of the virtual conferencing tool did provide benefits by allowing participants to join from remote locations, reducing the overall cost of the expo significantly, and allowing faster movement between project locations. The data indicates that even though participants preferred an in-person expo, they appreciated the continuation of the expo throughout the remote learning climate, which the conferencing tool was able to facilitate.

## **Conclusion**

For a large, interdisciplinary capstone design course, team formation and project selection requires a significant amount of organization and curation to ensure student satisfaction. Giving students preferential control relieves the burden on faculty for large scale team formation and project selection. Providing students with the means of contacting and viewing information about prospective team members' experiences, project interests, and skills in a centralized, online hub provides students with resources to form their own teams that would not be available otherwise. Consolidating this information for over 300 students across multiple disciplines would require significantly more overhead, making it nearly impossible for a project fair format or an in-person

social mixer to provide students the same level of autonomy over the team formation and project selection processes. Because of the students' autonomy, the faculty can focus primarily on managing the project bid delegation and ensuring the best-fit between projects and groups. Having access to a combination of interactive synchronous and asynchronous online tools can help students make well-informed decisions about teammate and project preferences, which is shown through the variety of strategies the students utilized. The quantity and quality of information accessible to students is only practical with an online portal, which is crucial to large-scale student-led team formation and project selection. The capstone marketplace proved to be a useful tool for facilitating the student's team formation, reflected by the satisfaction from the students over their project assignment and final group formation. Assisted by the virtual, interactive conferencing tool, students were able to meet with other students and make informed decisions about prospective team members.

For the fall IDCD students whose perceptions of team formation strategies were collected during the beginning and end of the semester, the data indicates these students would prioritize teaming with friends less and focus more on prospective member's skills/experiences in the future. This usually results from students facing challenging problems throughout the semester in which their team lacked an appropriate skillset. By giving students autonomy over their teams, they learn from the shortcomings of their team formation to better prepare for future team-based projects.

The conferencing tool appeared to be very successful in team formation facilitation, enabling students to meet with many other students quickly and efficiently through the online portal. For the online expo, students and attendees were pleased with the continuation of the expo through the virtual format when the in-person expo was not feasible. The researchers also found that participants believed that the ability to browse projects before interacting with the presenters was a critical element of an in-person expo, and that feature set will be available in the next virtual capstone expo. The virtual expo appeared to satisfy the expectations set for in-person expos, allowing students to present projects and mingle with the attendees and judges. Participants expressed concerns that the virtual expo did not allow in-person social cues like traditional expos, but would be a suitable alternative or complement for situations in which budget or distancing concerns are present.

On average, IDCD students reported being very satisfied with their projects and teams in the course, with most students being extremely satisfied, indicating success for the methods presented here. They reported using a variety of strategies to form their teams and indicated growth throughout the semester with their changes in team formation strategy preferences. Enabling students to create their own teams and find their own projects educates students on best practices for industry projects and enables less faculty overhead in managing the logistics of the course for large capstone schools. Work still needs to be done to refine the course methodologies, for which the survey results will assist the authors. A larger dataset will be created by surveying future semesters on their opinions of the course. A more well-defined control group for IDCD comparison will be created in the future. Overall, student satisfaction metrics indicate the success of the online tools for a hybrid-virtual capstone, and encourages their adoption in future semesters, even when remote learning is not mandatory.

## Acknowledgements

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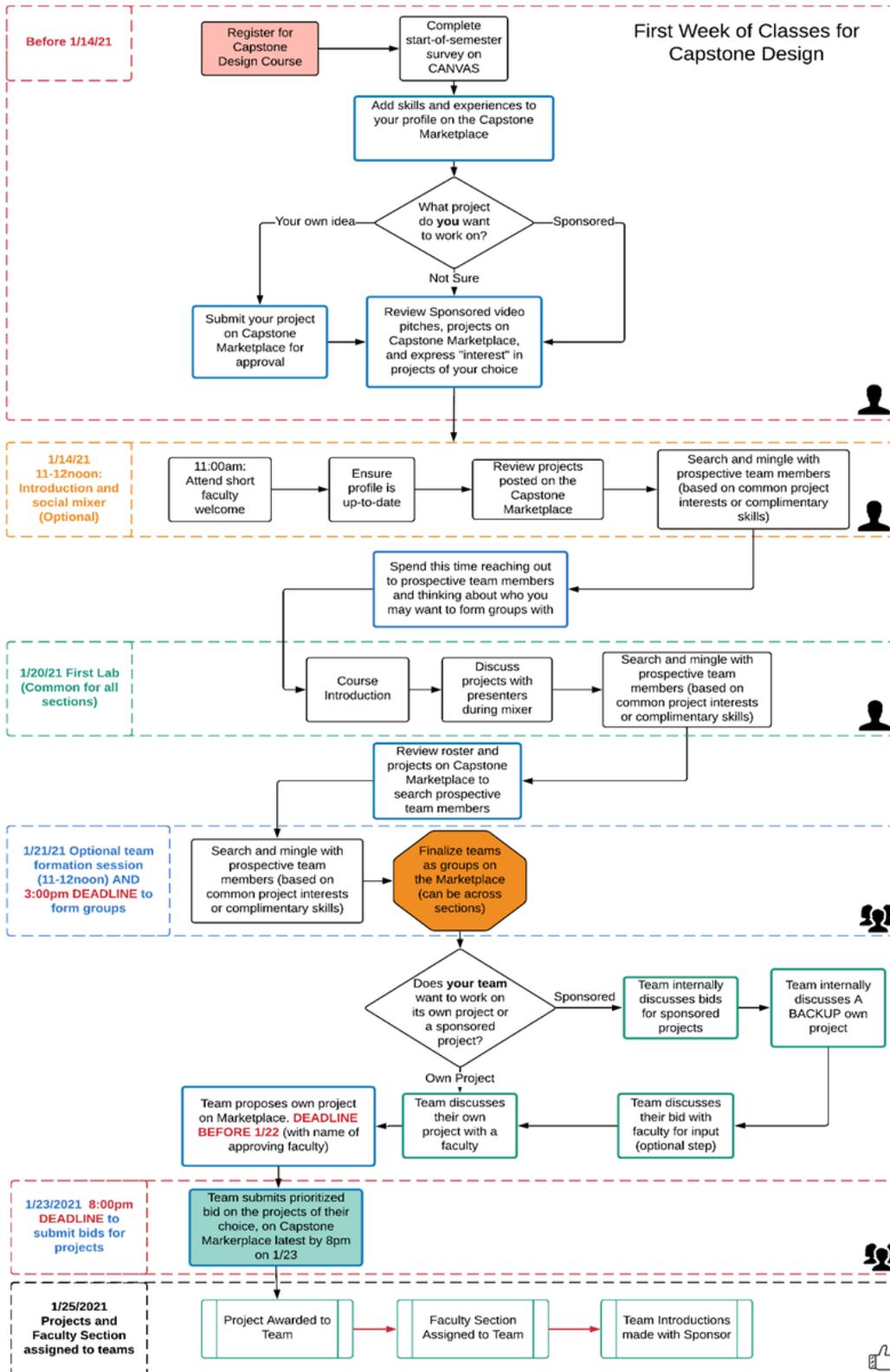
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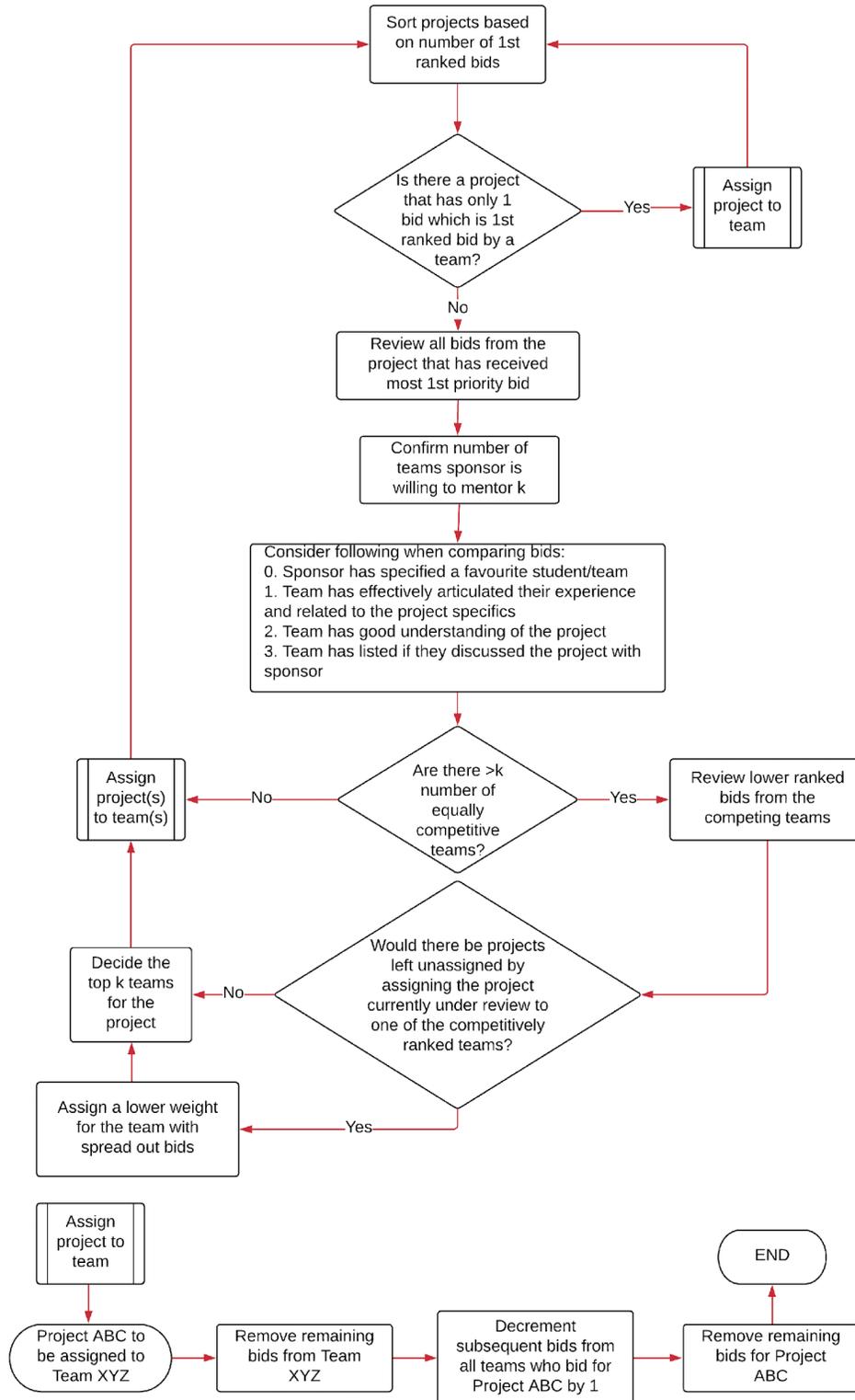
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## **Appendix A**



**Figure A1. Capstone First Week Flowchart: Flowchart provided to students for first week team formation and project selection.**



**Figure A2. Capstone Bid Selection process: Flowchart used by faculty to assign project to teams based on their bids**

Dashboard Roster ▾ Groups Projects Bids Register for Expo

### Skills

[+ Edit Skills](#)

Detailed Search ▾

My Skills [↻](#) [☰](#) ▴

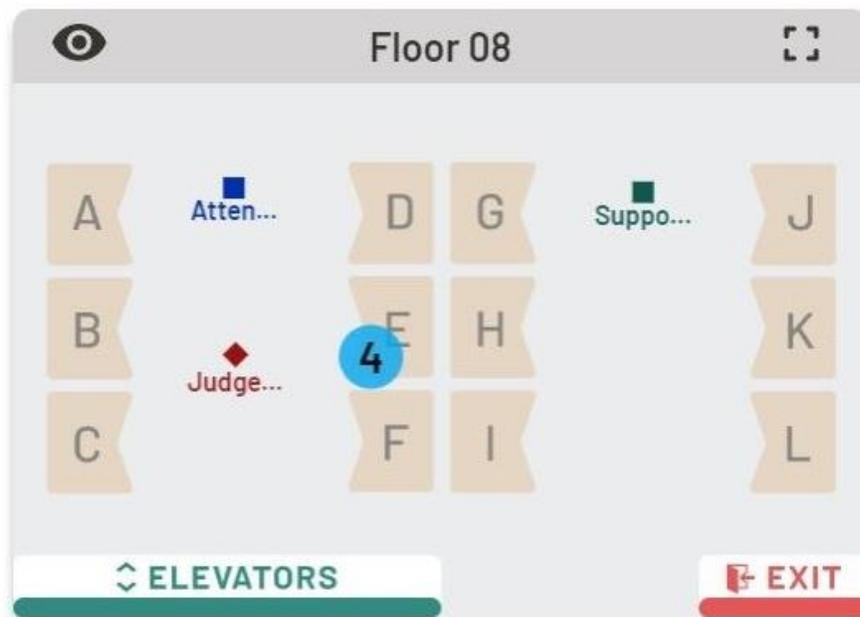
Skill Name	Proficiency Rating(Double-Click to Edit)
FEA/CAE	3

1 - 1 of 1 items

Skills of all students in course [↻](#) [☰](#)

Skill	Number of Students ↓	Number of Groups	Workflow Actions
CAD	168	4	<a href="#">Add to Profile</a>
MATLAB	95	0	<a href="#">Add to Profile</a>
Technical Writing	87	0	<a href="#">Add to Profile</a>
Machining	62	0	<a href="#">Add to Profile</a>
Power/Hand Tools	59	0	<a href="#">Add to Profile</a>

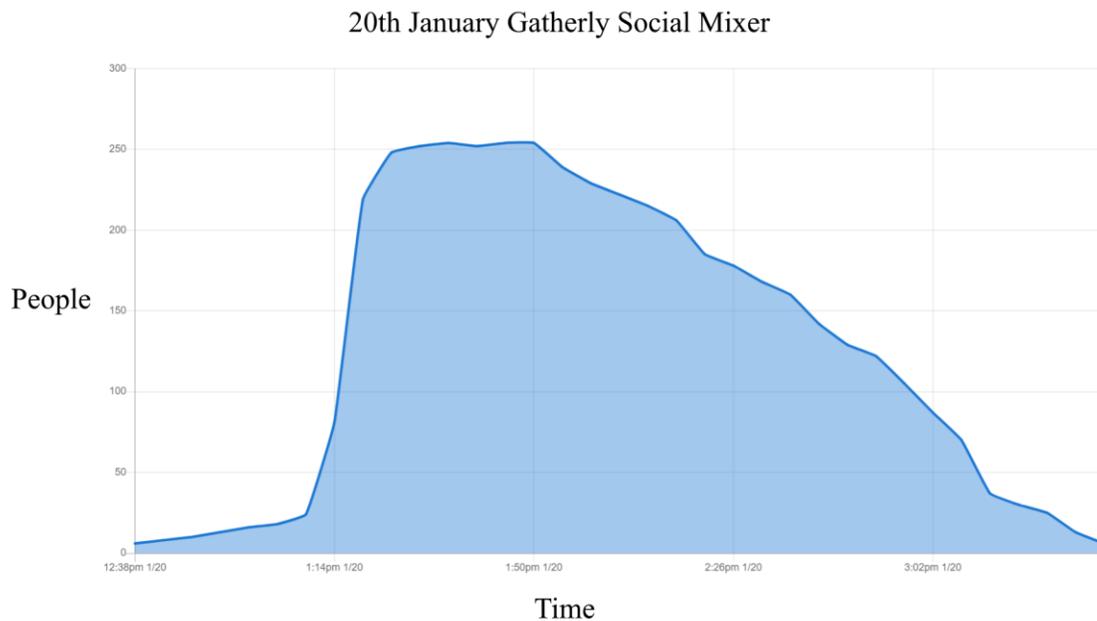
**Figure A3. Capstone marketplace skills tab: Another example of a feature of the capstone marketplace is displayed for students to assess skill ratings and topics**



**Figure A4: Screenshot showing color-based identification for judges, attendees, and support staff in Gatherly.io**

Floor #	Topic/Theme
01	Accessibility/Rehabilitation
02	Biomedical Procedures
03	COVID-19/Diagnostics/Testing
04	Healthcare
05	Automation
06	Energy/Education/Space
07	Industrial Tooling/Sustainability
08	Consumer Products
09	Data/Business Modeling
10	Supply chain/Inventory
11	Special

**Figure A5: Project floor categories used in Gatherly.io.**



**Figure A6: Gatherly.io social mixer attendee count against time**

## Appendix B

Q1 Welcome to the research study!

The purpose of this study is to better understand student perceptions associated with the delivery of engineering design courses in the new, hybrid/online format. We hope to use this information to improve future engineering design courses. You may be in this study because you have participated or are currently participating in an engineering design course.

Your responses will be kept completely confidential. We will comply with any applicable laws and regulations regarding confidentiality. To make sure that this research is being carried out in the proper way, the Georgia Tech IRB may review study records. The Office of Human Research Protections may also look at study records. You must not be in an EU country at the time of your participation. The main risk associated with the completion of this study is identification of the participant personal information which could link your identify to your opinion about this course. However, we believe this risk is minimal because the anonymous survey link is setup to not collect user-identifiable data.

The study should take you around **15 minutes** to complete. Your participation in this research is voluntary. Your participation or lack thereof will not impact your grades. You have the right to withdraw at any point during the study.

The Principal Investigator of this study is Amit Jariwala and can be contacted at amit.jariwala@gatech.edu.

By clicking the button below, you acknowledge:

Your participation in the study is voluntary. You are 18 years of age. You are aware that you may choose to terminate your participation at any time for any reason.

- I consent, begin the study
- I do not consent, I do not wish to participate

*Skip To: End of Survey If Q1 = I do not consent, I do not wish to participate*

**End of Block: Informed Consent**

---

**Start of Block: Team and Project Background**

Q2 Select the Capstone Design course number that you were enrolled in:

▼ <Section> ... Other

Q3 What category best describes your project (Please select maximum 2 options)

- External sponsored
- Faculty sponsored
- Societal/community development
- Personal Project

**End of Block: Team and Project Background**

---

**Start of Block: Team Formation Background**

Q4 How would you describe your emotional state during the start of the semester with regards to the following topics?

	Anxious/Worried/Stressed	Calm	Excited/Eager
Overall state of mind	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Finding out what my project would be	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Finding out who my teammates would be	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Amount of personal autonomy over the choices of team and project.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q5 What tools or methods were utilized in forming your team?

- Capstone Design Marketplace Website (Projects.GaTech.edu)
- Pre-capstone design course
- Your social network
- Faculty assigned
- Piazza, CANVAS, etc.
- Other (please specify) \_\_\_\_\_

Q6 How was your team eventually formed? (Check all that apply - this is a required Question)

- You found a new team member
- Someone invited you to their team
- You requested to join a team
- None of the other options (was assigned a team)

**End of Block: Team Formation Background**

---

**Start of Block: Only if teams are not assigned by faculty**

Q7 What strategies did you prioritize the most during team formation? Rank order the options below by dragging them up or down

- \_\_\_\_\_ Choose to be on a team with my **friends/acquaintances**
- \_\_\_\_\_ **Avoided** being on a team with certain people
- \_\_\_\_\_ Pick my **favorite project** and then assemble a team for the project
- \_\_\_\_\_ Choose to be with team members who had **similar project interests**
- \_\_\_\_\_ Choose to be with team members who had **complementary skills** than mine
- \_\_\_\_\_ Choose to be with team members who had **experiences** relevant to the projects of my interest
- \_\_\_\_\_ Other strategies

Q8 How effective was your team formation strategy in helping you form a satisfactory team?

- Extremely effective
- Very effective
- Moderately effective
- Slightly effective
- Not effective at all

Q9 How useful were the following to form your team and bid for a project(s)?

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not at all useful
Skills	<input type="radio"/>				
Past Experience	<input type="radio"/>				
Project Interests	<input type="radio"/>				
Which students are interested in the same project that interested you?	<input type="radio"/>				
Bids submitted by other teams (know the competitive landscape)	<input type="radio"/>				

*Display This Question: If Q5 = Capstone Design Marketplace Website*

Q10 How useful was the projects.gatech.edu site to help you form your team?

- Extremely useful
- Very useful
- Moderately useful
- Slightly useful
- Not at all useful

Q11 How easy/intuitive was it to use was the projects' marketplace site for team formation?

- Extremely easy
  - Somewhat easy
  - Neither easy nor difficult
  - Somewhat difficult
  - Extremely difficult
- 

Q12 Is there any additional information about projects, faculty, or students that would be useful to you in forming groups?

---

End of Block: Only if teams are not assigned by faculty

---

Start of Block: If Marketplace is not chosen

Q13 How easy/intuitive was it to use your team formation strategy for team formation?

- Extremely easy
  - Somewhat easy
  - Neither easy nor difficult
  - Somewhat difficult
  - Extremely difficult
- 

Q14 How effective was this strategy for your team formation?

- Extremely effective
  - Very effective
  - Moderately effective
  - Slightly effective
  - Not effective at all
- 

Q15 In what ways was the team formation tool/strategy able to assist with your team formation?

---

End of Block: If Marketplace is not chosen

---

Start of Block: "Meeting" Prospective Team Members

Q16 How important was it for you to “meet” (physically or virtually) with your prospective team member before committing to the team?

- Extremely important
  - Very important
  - Moderately important
  - Slightly important
  - Not at all important
- 

Q17 How did you “meet” or interact with your prospective team members prior to forming your team?

- Email
  - Online chat (like GroupMe, WhatsApp, etc.)
  - Video conference (like Zoom, BlueJeans, etc.)
  - In-class introductions during studio/lab meetings
  - Social Mixer session on gatherly.io
  - Other (please elaborate) \_\_\_\_\_
- 

**End of Block: "Meeting" Prospective Team Members**

---

**Start of Block: If selected Gatherly**

Q18 How **useful** do you think the virtual interactive conferencing tool (Gatherly.io) was to help you find team members and formulate your team?

- Extremely useful
  - Very useful
  - Moderately useful
  - Slightly useful
  - Not at all useful
- 

Q19 What **features** of the social mixer (on Gatherly Platform) did you actually use in finding prospective team members?

- Identifying others by **skills** (Avatar color)
  - Identifying others by **Major** (Name prefix)
  - Identifying others by their **project interests** (floor)
  - Finding others by name and sending private chat messages
-

Q20 To what degree do you agree with this statement: The interactive at-your-own paced virtual meeting with the entire class, sponsors and faculty helped increase confidence and reduce anxiety/stress.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Q21 Assuming all other online tools were available; do you believe that you would have been able to find your team members **without** the use of social mixer on Gatherly Platform?

- Yes
- No

End of Block: If selected Gatherly

Start of Block: Reflection on Team Formation

Q22 How satisfied were/are you with your **team** during the...

	Extremely satisfied	Somewhat satisfied	Neither satisfied nor dissatisfied	Somewhat dissatisfied	Extremely dissatisfied
Start of the Project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
End of the Project / Now	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q23 How satisfied were/are you with your **assigned project** during the...

	Extremely satisfied	Somewhat satisfied	Neither satisfied nor dissatisfied	Somewhat dissatisfied	Extremely dissatisfied
Start of the Project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
End of the Project / Now	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q24 Please mark the response that most closely reflects your opinion for the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The process for <b>forming teams</b> was <b>equitable</b> for all students.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The process for <b>assigning projects</b> to teams was <b>equitable</b> for all students.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

*Display This Question: If Q5 = Capstone Design Marketplace Website*

Q25 Please mark the response that most closely reflects your opinion for the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The process for allowing <i>students to form teams</i> should be used in design courses in the <b>future</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The process of <i>assigning projects to teams</i> should be used in design courses in the <b>future</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q26 Do you have any suggestions for improving the team formation and project assignment process if used again?

\_\_\_\_\_

Q27 With what you know now, what factors would you consider while forming your team for the course? Rank the choices in the order of **importance**

- \_\_\_\_\_ Prospective Member Skills
- \_\_\_\_\_ Prospective Member Experiences
- \_\_\_\_\_ Common Project interests
- \_\_\_\_\_ Previous Acquaintances/Friendships
- \_\_\_\_\_ GPA
- \_\_\_\_\_ Other (please specify)

Q28 Explain your rationale for above response:

\_\_\_\_\_

## End of Block: Reflection on Team Formation

---

### Start of Block: Expo

Q29 On average, how engaged or interactive were the judges and attendees with your team during the expo?

- A great deal
  - A lot
  - A moderate amount
  - A little
  - None at all
- 

Q30 Please rate the following questions based on the **effectiveness** of the virtual interactive expo. The Capstone Design Expo was effective to...

	Extremely effective	Very effective	Moderately effective	Slightly effective	Not effective at all
Practice and improve your communication skills	<input type="radio"/>				
Enhance and grow your professional network	<input type="radio"/>				

---

Q31 Please mark the response that most closely reflects your opinion for the following statement: Participation in the expo...

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Increased team's confidence in pursuing projects beyond the course	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provided inspiration or new application ideas for the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Helped improve the final project report/deliverables	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is recommended for future students	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q32 Do you have any suggestions for improving our Expo in the future?

---

End of Block: Expo