

Situativity Approaches for Improving Interdisciplinary Team Processes

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Abstract—Interdisciplinary teaming requires not only multiple levels of expertise but also social competencies gained through interactive contexts. In the classroom, a situativity approach that encourages student engagement can help students learn to value differing perspectives. To foster students' interdisciplinary collaborative skills, an interdisciplinary capstone design class that brings students and faculty from electrical and computer engineering, industrial design, and marketing was developed and twelve fourth-year students participated (four from each discipline). The students were tasked with designing a next generation firefighter helmet that incorporates innovative computing technology. Various interventions such as learning modules and teaming exercises were implemented throughout the class to help students learn how to communicate across disciplines. Direct observation, interviews, questionnaires, and assessment of course assignments indicated both benefits and limitations of the class. Implications and future directions are also discussed.

Keywords: Situated learning, interdisciplinary design teams, interdisciplinary team processes

INTRODUCTION

In order to successfully adapt to accelerating technological innovations that are globally interconnected, engineers of the next decade will need to present strong abilities to think innovatively, which requires synthesis of interdisciplinary expertise [Clough, 4]. The number of interdisciplinary design teams is growing in industry, and having members who are capable of communicating the expertise across disciplines is key to successful interdisciplinary collaboration [Chen, 5]. Further, miscommunications across disciplines have been shown to reduce effectiveness of interdisciplinary teams. For example, communication breakdowns among interdisciplinary medical teams have been identified as a critical source of errors [Alvarez, 1]. Also, in the field of engineering design, many design failures have been attributed to communication deficiencies of interdisciplinary design teams [Schein, 16]. That is, the current curriculum does not sufficiently prepare engineers with the essential collaborative skills to handle interdisciplinary teamwork. Hence, it is important to offer students interdisciplinary courses that can allow them to experience and learn communication and collaboration across disciplines.

REVIEW OF LITERATURE

We adopt a situativity approach for improving interdisciplinary team processes. That is, instead of basing instruction solely on cognitive factors, it is also important to take into account social, historical and personal factors, including classroom contexts and their affordances. Our view is that learning is greatly influenced by social contexts in which students participate [Pintrich, 13; Greeno, 8]. Furthermore, motivational factors directly impact conceptual changes and can be promoted by manipulating classroom contexts [Pintrich, 13]. In this analysis, we draw from theory on goal orientation beliefs, value beliefs, control beliefs, and classroom context—specifically course structure. Multiple studies suggest that modifying these factors can result in deeper cognitive engagement, longer persistence at a task, and greater self-regulation and meta-cognition (see [Pintrich, 13], for descriptions of specific studies). Instructors can encourage intrinsic mastery goals in contrast to extrinsic, performance-oriented goals (e.g., grades) by modifying task, authority, and evaluation structures in classroom contexts [Pintrich, 13]. Students can also be encouraged to adopt high levels of interest and value beliefs (e.g., interdisciplinary teaming skill is important for one's career) through classroom contexts and instructor modeling of certain traits. Finally, students' control beliefs

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can influence students' performance in school. In other words, when students have more opportunities for controlling their own work (e.g., as in project-based learning), they may perform better.

One factor that influences learning is prior knowledge, which poses both challenges and opportunities for conceptual change. For example, students in an interdisciplinary design course bring differing knowledge and experiences of teaming processes, which can contribute to resistance to change but also "provide frameworks that the learner can use to interpret and understand new, potentially conflicting information" [Pintrich, 13, p. 170]. Members of interdisciplinary teams face tougher barriers because people from different disciplines not only have different expertise but also have different expectations. Also, different disciplinary backgrounds influence the way one perceives and solves problems. A recent study found that disciplinary culture challenges students as they communicate across disciplines [Dannels, 7]. As culture defines the way people perceive, appraise, and experience the world as a collective perspective [Hofstede, 9], disciplinary culture can function as a set of norms. That is, people view the world through their own cultural lens [Klein, 12], and that shapes their experience and sometimes causes cross-cultural problems. Following the same reasoning, it can be argued that disciplinary culture also is a cultural lens that affects the interactions of team members. It has been shown that different occupations possess different cultures. For instance, the academic and professional cultures of engineers are identified with preference for linear and quantitative thinking [Safoutin, 15], whereas designers prefer flexibility and innovation [Cross, 6; Julier, 10]. These studies further suggest that a discipline is a culture that shapes people's way of thinking and communicating. Thus, we can anticipate communication difficulties among students with different disciplinary backgrounds, which can impair their teamwork. In this study, to address these deficiencies and enhance interdisciplinary team processes in an engineering design course, we attempted to manipulate classroom contexts (e.g., course structure and class activities).

OBJECTIVE OF THE STUDY

This paper contributes to the research and practice of interdisciplinary design curriculum by presenting results of a triangulated, mixed methods study of improvement of team processes within the course. Framed in a situated cognition approach and using the project teams as the primary units of analysis, variables of 1) quality of interdisciplinary communication and 2) knowledge integration are analyzed in data from the video-recordings of team meetings at the beginning and at the end of the semester. The results are triangulated with in-depth interviews and assessments of course assignments.

METHODS

Study Design

To allow for an in-depth investigation of the unique setting of this class, this study was conducted as a case study. For the data collection and analysis, both quantitative (questionnaire, assessment of course assignments) and qualitative (direct observation and interview) inquiry was used. A content analysis was conducted on the transcripts of the observations and the interviews. Nonparametric one-way analysis of variance was conducted for the quantitative data with academic discipline as a factor. A content analysis was conducted for observation and interview data.

Participants

Twelve fourth-year students, four from each of the three different academic disciplines (electrical and computer engineering (ECE), industrial design (ID), and marketing (MAR)) participated in the study. There were nine males and three females. The age of the students ranged from 21 to 24. The students were selected by the four instructors, who worked in departments from each discipline, based on a convenient sampling. Before they joined the class, instructors explained the interdisciplinary nature of the class and also briefly informed students about the design task.

Interdisciplinary Capstone Design Class

This study was conducted in a naturalistic setting with an existing project-based interdisciplinary design class held during fall semester 2009. An interdisciplinary design team was assembled for a special topics course in which students were charged with producing a project design proposal. The class met once per week in a classroom physically modeled to simulate the studio style of instruction, in which the space is designed to encourage sketching, ideation and critique. Four instructors who had been working as an interdisciplinary research group facilitated the

class, and they served as models for the students. Various interventions were implemented throughout the class to help students learn how to communicate and collaborate across disciplines. For example, team-building activities were integrated into brainstorming sessions to stimulate teaming processes. Also, the students kept an 'Idea Log' not only to capture design ideas but also to reflect meta-cognitively on teamwork experiences. The instructors took roles of facilitators rather than knowledge providers to maximize flexibility and autonomy of the students (for a description of this course design, see also [McNair, 14]). The design proposals were to be entered into a design competition with a post-semester deadline in February 2010. The participants were expected to form three interdisciplinary teams to develop three components of the design. Unexpectedly, the class decided to stay as one team of twelve. During the semester, they formed into smaller work teams several times. However, the membership of those teams changed many times, so those separate teams were not the subject of this study. This will be further explained in the discussion section.

Questionnaires

Two questionnaires were used to identify different cultural attributes associated with disciplines. First, general characteristics of different disciplines were examined using the Organizational Culture Profile [Cable, 3]. The OCP measures respondents' preference of 40 organizational characteristics such as autonomy or adaptability. The participants were asked to rate how important a given characteristic was for them on a 7-point Likert-type scale (1: most undesirable, 7: most desirable). Second, five uncertainty avoidance items regarding work structure taken from a previous empirical study [Ang, 2] were used to investigate how the three disciplines differed in their tendency of uncertainty avoidances in a teamwork environment. The participants were asked to read the statements (e.g. "I prefer work that is highly structured.") and rate their responses on a 7-point Likert scale (1: strongly disagree, 7: strongly agree).

Direct Observation and Interview

The design team meetings were observed and video-recorded. The authors and two transcribers transcribed the video-recordings verbatim. The authors took field notes during observation, which later was combined with the transcripts. In addition, the students were interviewed about their perceptions of interdisciplinary collaborations and the flexibility of the class structure and environment. The interviews were conducted in disciplinary groups and audio-recorded and transcribed.

Procedures

The participants signed informed consent documents during the first week of the semester. During week 5, an interdisciplinary team-building exercise was conducted. The researchers asked students to take a short version of Torrance Test of Creative Thinking [Torrance, 17] individually. They were given 15 minutes for the individual test. After they had completed the test, the students were asked to self-form four interdisciplinary teams having a member from each discipline and asked to discuss and combine their answers for 20 minutes. The team answers were drawn on the whiteboards, and a spokesperson from each team presented the results to the rest of the class. All of the class sessions were observed and video-recorded. In week 8, the Organizational Culture Profile and Uncertainty Avoidance items were given as separate sections of a single paper-based test before class. After being briefly informed about the purpose of the questionnaire, the participants were given 20 minutes to complete the questionnaire and additional time was allowed as needed. The students were interviewed after class in week 13. After they had completed all of the activities related to the study, the participants were debriefed and thanked.

Data Analysis Methods

For a content analysis, video-recordings of team meetings were transcribed and coded. The first round of coding was based on *a priori* codes that were constructed based on a previous study on interdisciplinary student engineering design teams [Kim, 11] as well as codes based on the grounded theory, and then significant OCP items from the quantitative analysis were used to re-code the transcripts. After the transcripts were coded, they were organized and condensed to identify emerging themes. The coding procedures were performed using HyperRESEARCH 2.8.3. For the questionnaires, analysis of variance was conducted and internal reliability of the items was tested. All of the statistical analyses were performed using a statistical software package, SAS JMP 8.0.1.

RESULTS

Team Developmental Stages and Design Processes

During the first six to eight weeks, the team learned about each discipline via three instructor presentations and formed into four sub-teams to conduct research on safety issues for firefighters. The students presented and discussed their research and ideas during the first eight weeks in a “transdisciplinary” mode—meaning that the discussions *encompassed* all disciplinary perspectives. However, the meetings did not draw concretely on any area of disciplinary expertise, and one student termed this abstract phase to be “generic.”

After weeks of research and concept sketching, the team members were frustrated with not yet having a final product goal. In week 10, the whole team decided, as they stated in their end-of-semester narrative, “to divest from the professors” and start making their own decisions. In the teaming process, this point was a marked departure in which they claimed autonomy as a group separate from the professors and began to create their own organizational structures. For example, they finalized the components of the product system and brought questions and ideas to fire fighters at a local firehouse. In order to satisfy the requirements of the course, they stated: “we got the professors to give us a list of items they wanted,” which led to “breaking into our majors and beginning to create our final projects.”

By the end of the semester, they had completed a system description for fire fighter protection that included a vitals-monitoring shirt and mask, SCBA gear, and a helmet. They overcame several challenges, including working in a large, interdisciplinary group, struggling with an ill-defined problem and, when finally determined, a very complex goal of designing a system. Additionally, they were working with different concepts and experiences of teaming processes, as well as differences in other practices determined by organizational cultures. However, although team members communicated positively and openly, they rarely asked each other questions that would have led to interdisciplinary learning. Furthermore, although both the class assignment of idea logs and the classroom space encouraged sketching and ideating, only the most vocal students consistently shared their ideas in the classroom discussions.

Idea Logs

Students were asked to keep an “Idea Log” to record project ideas as well as reflections from the class discussions. The extent to which students utilized idea logs during the semester showed large variation with the number of entries ranging from 14 to 67. Three students (1 ECE, 1 ID, and 1 MAR student) used the idea logs extensively, logging more than 60 entries. The types of entries that appeared the most were functional sketches with descriptions (Figure 1, 3, and 4) and concept maps that reflect on the design processes (Figure 2).

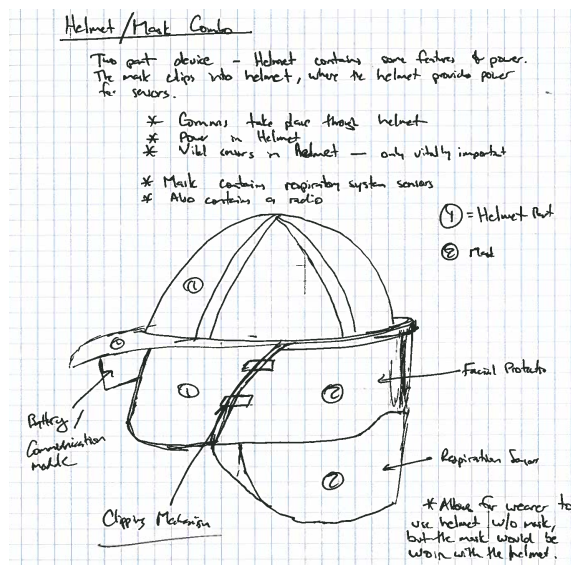


Figure 1.

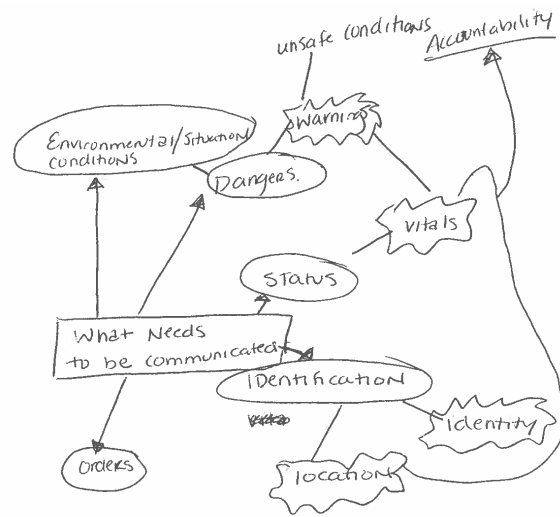


Figure 2.

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Wearable Ambient Light

- System consists of flexible light bars attached to the body to provide various kinds of light to work in
- Uses clusters of white LEDs → low power but bright

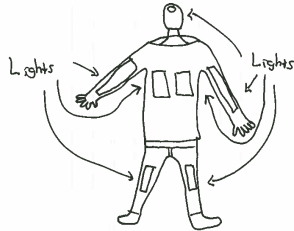


Figure 3.

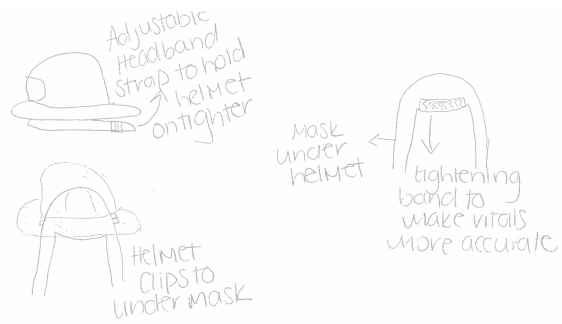


Figure 4.

An ECE student who made a total of sixty-seven entries had numerous concepts that he did not share with other members in class discussions. This suggested that ideas of students who were not vocal were not communicated well with other team members.

Questionnaires

For the Organizational Culture Profile, the Kruskal-Wallis test (nonparametric one-way analysis of variance) revealed significant differences of one item at .05 level and six items approaching the conventional significance at .10 levels. To ensure the internal reliability of the OCP, one item (Working long hours) was dropped ($\alpha = .76$ after the item removal). In order to identify cultural attributes that are associated with different disciplines, variance was tested. When the Shapiro-Wilk test was performed, the data were not normal. Thus, the Kruskal-Wallis test was performed with discipline (ECE, ID, and MAR) as a factor. The OCP asked students to rate how important a given characteristic was for an organization in their field. From the OCP, a total of seven items (being innovative, opportunities for professional growth, autonomy, being competitive, achievement orientation, praise for good performance, being calm) showed significant differences among different disciplines. In other words, students with different disciplinary backgrounds responded differently to these items. For example, marketing students considered Achievement orientation to be a more important characteristic for an organization they would work for, in contrast to electrical and computer engineering or industrial design students. ($\chi^2(4, N = 12) = 6.62, p < .04$). The OCP results are summarized in Table 1.

Table 1. Organizational Culture Profile Results

Organizational Characteristics	Kruskal-Wallis Test Results	Median Importance Ratings
Being innovative	$\chi^2(4, N = 12) = 5.50, p = .06 *$	ID > ECE > MAR
Opportunities for professional growth	$\chi^2(4, N = 12) = 4.81, p = .09 *$	ID > MAR > ECE
Autonomy	$\chi^2(4, N = 12) = 5.28, p = .07 *$	ECE > MAR > ID
Being competitive	$\chi^2(4, N = 12) = 5.03, p = .08 *$	MAR > ECE > ID
Achievement orientation	$\chi^2(4, N = 12) = 6.62, p < .04 **$	MAR > ID > ECE
Praise for good performance	$\chi^2(4, N = 12) = 4.89, p = .09 *$	ID > MAR > ECE
Being calm	$\chi^2(4, N = 12) = 5.28, p = .07 *$	ID > ECE > MAR

Note. * $p < .10$, ** $p < .05$

The Kruskal-Wallis test did not reveal significant differences in Uncertainty Avoidance items among the three disciplines. However, the descriptive statistics indicated that this class had higher than neutral overall uncertainty avoidance ($M = 4.70, SD = 0.91$). When engineering (ECE) and non-engineering (ID and MAR) students were

compared, engineering students showed higher Uncertainty Avoidance than non-engineering students (Figure 5). Internal reliability of the items was established ($\alpha = .86$).

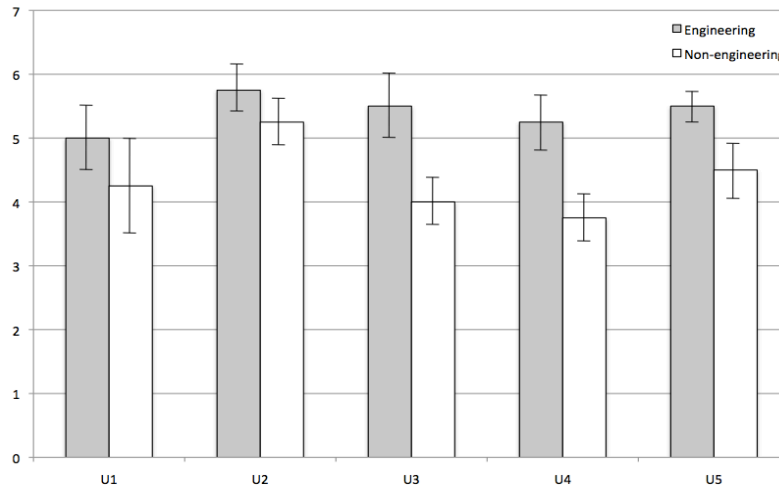


Figure 5. Mean of Uncertainty Avoidance Items

Themes from Observation Transcripts

Based on the observation notes, five critical weeks (weeks 6, 7, 10, 11, and 12) were selected for a full content analysis. During these weeks, the students showed the highest level of team interactions and important decisions were made regarding team formation as well as project progress. As a result, several themes emerged. First, there was contrast between engineering students and design students. There were several occasions where either an ECE student or an ID student interrupted each other. This was not observed between any of the other students. Second, role assignments and separations based on disciplines were observed. For instance, an ID student who acted as the team leader said,

“So, we are rendering fully polished awesome [expletive] scuba and mask, and obviously, there are people in the room that we have in mind working on that. And schematic diagrams that show how all our electrical components are working, and all of our tech stuff- there are obviously people in the room we have in mind for that.”

After this ID student spoke, the rest of the team did not object, which indicated that it was implicitly agreed among them that they were dividing the team based on the disciplines. Third, there was no evidence of performance appraisal among team members. The students did not give feedback regarding their performances in the class. During the meetings selected, they performed a brainstorming session, concept presentation, and a discussion of the components of the helmet. However, no one was observed commenting on the quality of ideas, drawings, or presentations.

Interviews

From the interviews, there was an evident separation between design students and non-design students in terms of familiarity with the design process. ID students were comfortable with the process of defining problem areas and designing solutions. An ID student said that they had an “unfair advantage” compared to the other majors in the class. Another ID student said, “This was not a project for everybody here.” Also, because the class was geared towards industrial design majors with ID goals, processes and deliverables, the ID students felt they did not learn anything from other disciplines. On the other hand, non-design students, both ECE and MAR, said that this was very different from their team project experiences. For ECE students, collaborating with others to tackle a problem is even an honor code violation in some coursework. MAR students agreed that in marketing classes, people “communicate in the same wavelength, as opposed to three different ones” in this class.

Everyone agreed that the structure of the class did not meet their expectations. They felt the goal of the project was open for too long, and the instructors were not clear about the expectations. Also, it was suggested the team size (one team of twelve) was too large to move the project forward. An ECE student said that he liked the autonomous nature of being able to direct the project although more structure would have been more desirable. It was agreed that

the goal of the project was not focused on products, and some students felt that they “wasted a lot of time” discussing “meaningless” concepts. Due to lack of structure along with ID focused goals, students felt that they did not benefit from the interdisciplinary setting as much as they had hoped. MAR students suggested having learning modules that teach skill sets of other disciplines so that the class experience would be truly interdisciplinary.

DISCUSSIONS

Quality of Interdisciplinary Communication and Integration

The students presented effective team communication patterns with little conflict among members. They worked with each other without visible conflicts, and active discussions about the project were evident throughout the semester. However, little evidence of knowledge integration or interdisciplinary learning was found. The students discussed the concepts and design ideas based on their research conducted outside of the class, but only rarely asked questions about concrete details that might require disciplinary grounded knowledge from a team member with the relevant academic background.

Also, varying degrees of dominance in the communication was observed. There were two students who were acting as leaders of the team although the class never designated any ‘team leader.’ They tended to lead the class discussions and voiced more opinions. During the observation, more quiet students did not show signs of frustration with having more vocal and opinionated members. However, triangulation with idea logs suggested that many design ideas of more quiet students were never shared with the rest of the class. For example, an ECE student showed the highest number of idea log entries with numerous (67) design concepts (e.g., wearable ambient light) that were never discussed in class. Therefore, it could be argued that team communications were driven by opinions of members who were more outspoken and dominant.

Uncertainty Avoidance vs. Autonomy

It has been shown that students were not comfortable with the loose structure of the class in the first eight weeks, but after they took charge and started acting as an autonomous team from week 9, they were better prepared and more productive. With little evaluation structure or pre-determined goal structure, the students delayed decision-making. Since the students had high overall Uncertainty Avoidance tendency, the lack of structure from the instructors could have caused them to be uncomfortable. Also, this kind of discomfort can be expected in a conceptual change classroom in which “disequilibrium” is induced by modifying the task, authority and evaluation structures that students typically perform within in their other courses. Having an open-ended and ill-defined project goal and the low level of structure was distant from students’ initial expectations of the class. After struggling in the first two months, they overcame those deficiencies by taking control of organizational structure and the processes. During this later phase, the level of uncertainty they felt was reduced because the students were the ones making critical decisions moving the project forward, which led to higher satisfaction and productivity. This step required many of the students to shift their control beliefs from accepting roles as passive learners to taking initiative as active participants. However, their autonomy did not surface until after the first half of the semester had passed. This time frame allowed initial steps toward interdisciplinary learning, but the product (a final project proposal) was not thoroughly completed.

IMPLICATIONS AND FUTURE DIRECTIONS

Successful teaching methods for interdisciplinary collaboration are yet to be established in the research literature. Our situativity approach places importance on not only cognitive factors, but also social, historical and personal factors, including classroom contexts and their affordances. The course described in this article incorporated strategies that altered typical course norms by situating students from three distinct disciplines in a classroom context that emphasized student autonomy and promoted creativity using a studio environment. To build on the progress achieved in this course design, a few recommendations are offered.

First, an interdisciplinary design class needs to achieve a balance between clear structure and student self-management. Student feedback suggested that the amount of flexibility in this class was excessive for the class to be successful. It is still important to allow students to be flexible and autonomous so that they can practice making their own decisions in collaborative settings. It is recommended that clear goals be established so that everyone can reach consensus on expectations in terms of goals, including a timeline of quality checkpoints for the project especially in the early stages. This will increase student satisfaction.

Second, concrete project goals that require expertise from all disciplines need to be set. The design project this class utilized was structured based on the requirements of a design contest with industrial design-centered review criteria. The requirements did not specify the level of technological details nor asked for a marketing plan, which led to ECE and MAR students feeling that their expertise were not needed for the project. Thus, a project assessment rubric that specifically requires components that pertain to each disciplinary expertise is recommended. This will encourage multidisciplinary collaboration that can lead to interdisciplinary work.

Third, smaller interdisciplinary work teams will need to be formed to enable more interactions and encourage higher quality of team communication. Having smaller teams with more structured ways of presenting individuals in team communication will help the students who are not outspoken communicate and share their ideas with other members. Combined with presentations situated within the larger group, smaller team structures will enhance the team interactions, which will lead to better team performances.

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