A Comparison between Collaborative Learning and Situated Learning Teams in Two Freshman Engineering Design Experiences

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Abstract
Many engineering programs have first-year design experiences that are designed to initiate students into the engineering community and enhance interest in engineering. In this paper we compare how team structure affects the acquisition of effective teaming skills in two different first-year design experiences. One structure consists of a vertically-integrated team of first-year students through seniors completing a 7 week design project in chemical engineering where the teams are constructed to enable situated learning (SL). The multi-level experience is an attempt to create a community of practice in which students can interact academically and socially[1]. The impact on the first-year students in the SL teams was compared to collaborative learning (CL) teams where students in a freshmen-only biomedical engineering course are assigned to 3-4 person groups and complete a level-appropriate design problem. The purpose of the comparison was to determine if the structure of the team yields differences in learned teaming skills as well as how they learned. Analysis of a Team Characteristics Survey and student short answer responses indicates that both experiences generate a positive attitude toward engineering but that SL first-year students engaged in higher levels of metacognition and acquired a more complete perception of effective teams.

Purpose
Educators must fully prepare students in the best practices and attributes of teams. Our graduates will be expected to contribute in a collaborative environment such that their efforts yield success either for a competitive advantage or in civic engagement[2]. Engineering students must acquire these skills in addition to discipline-specific technical expertise. Unfortunately, a typical student experiences a learning environment with high rewards for individual achievement and little or no emphasis on critical skills such as cooperation, trust, communication and leadership. McAnear and Seat[3] correctly point out that teamwork skills are behavioral and teaching effective teaming requires different approaches than for the more cognitive engineering skills. What is needed in undergraduate education is a learning experience that requires teamwork and more closely simulates what students will experience in professional practice. In this paper we compare two experiences to determine how each contributes to the acquisition of effective teaming skills.

In the chemical engineering implementation of a vertically integrated team design project (VITDP), all undergraduates enroll in a one credit hour course called Project Management and Teamwork (I – IV) depending on academic level during the fall semester; total enrollment in this class is between 130 and 150 students. Ten member heterogeneous teams, consisting of freshmen through seniors, are formed following a set of rules that insures that each team has a minimum level of teamwork and technical expertise; team formation is based on performance data from prior VITDP activities. These SL teams work on an open-ended design problem over a five to

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seven week period during the semester. Teams are asked to complete an engineering project based on technical, economic, environmental, and safety considerations. (The Fall 2003 project statement is given in the appendix.) The SL teams meet once a week with a professional mentor whose primary role is to observe team meetings and provide feedback on how to improve team communication and project planning.

The chemical engineering department is moderate in size with 10 faculty and approximately 160 undergraduate and 40 full-time graduate students. Almost 90% of our students are involved with alternating coop education semesters that causes a gap in both maturity and experience between juniors and seniors. Seniors will have completed 3 semesters of work experience while juniors will not have started their coop work experiences. A typical distribution of students by level is 32 seniors, 32 juniors, 38 sophomores, and 50 freshmen. During the fall of 2003, we had 16 teams for a total of 137 chemical engineering majors, six K-12 educators, 4 engineering faculty mentors and 12 industrial team mentors.

The biomedical engineering department consists of 6 faculty members with a typical first-year class of 20-25 students. In the biomedical engineering implementation of the course Introduction to Engineering Design, first-year biomedical engineering students enroll in a 2 credit problem-based learning course. Informal groups are assembled for 2 in-class projects early in the semester. Three to four students are randomly assigned to a team for the last 4 weeks of the semester to design, construct and test a simulated biomedical device. During the spring of 2004 they were asked to construct an artificial limb capable of picking up several ping-pong balls. Every team meets with the course instructor for one hour each week for additional advice and direction. Thus, these CL teams are provided with more direct instruction during their project period. The course content includes lectures on a seven step design process but little specific content on the design of artificial limbs.

Theoretical Framework

For first-year students in particular, it has been reported that the level of student integration into the college environment affects their ability to persist in the pursuit of a degree[5]. Collaborative learning, often referred to as small group learning, is an established and successful technique to enhance student interactions while learning. Collaborative learning teams are typically put together without following a set of guidelines and roles on the team (leader, facilitator, scribe, etc.) may be assigned arbitrarily. In general, CL is a process in which students rather than the instructor guide the activities to be completed to meet a specific goal. Cooper (2004)[1] reports "CL creates an environment "that involves students in doing things and thinking about the things they are doing",[1] and reaches students who otherwise might not be engaged." The key characteristics of CL are socially constructed learning via direct discussions between students, critically assessing knowledge learned from others while defending and evaluating individual positions or decisions.

Situated learning is a specific variation of collaborative learning in that it has the same characteristics but is embedded within a discipline specific culture and, in our case, the teams are constructed following a set of guidelines.[6] Situated learning examines how cultural knowledge is constructed and maintained within a group over time, and specifically how people move from novices to experts within the group. It posits that learning takes place within the processes of

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social interaction and represents a process of becoming, in this case an engineer. For example, the role of each team member on an SL team and how the team functions is determined by the members of the team based on their past experience and knowledge base. Thus, there is more of a focus on the relationship between identity within the community and cultural knowledge necessary to maintain and expand that identity. Tonso argues that: "Because engineering has persisted through time as an endeavor with historical, cultural, and social meanings, it resembles the communities of practice where Lave and Wenger grounded situated learning theory" (p. 145)[7]. The chemical engineering multi-level experience is an attempt to create an environment or community of practice in which students can interact academically and socially[1]. The less experienced students share information gathered from their efforts on less technical tasks and so their role is supportive rather than directive. The upper-level students should gain a deeper understanding of the subject material through their attempts to explain the material to the lower-level students. Case studies have shown that this is a legitimate form of learning and its effectiveness stems from the circulation of knowledge among the team. If successful, this situated learning environment generates positive interdependence since each team member needs to learn from the others for both individual and team success.

In our study we assume each individual will construct new knowledge and understanding of effective teams based on what they already know and believe[8]. In other words, "the learner pulls from previous experiences, applies this knowledge to new experiences … juxtaposes old and new experiences, and then constructs or reconstructs a personal understanding.[9] An important distinction between the multi-level SL project and the more typical one-class-level CL project is the exposure to all elements of design and teamwork including those beyond the first-year student's immediate competency. SL teams (chemical engineers) see the overall, 'big-picture' by participating in the project each year, but they will comprehend more and more aspects with repeated exposure. Constructivism suggests that students will use their memories from prior projects (both positive and negative experiences) and their social interactions with other team members to construct knowledge while simultaneously applying new knowledge gained from increasingly higher-level engineering classes. Since all students have participated in a vertically integrated project since their first year, this constructed knowledge is potentially available to the newest team members in what has now become a community of practice.

Data Sources or Evidence

Data for this project come from the 2003-2004 and 2004-2005 academic years and include participant observations of the VITDP course and student team meetings, documents generated by faculty and students during the course, student journal responses, student attitude surveys, a Project Evaluation survey, interviews with students, and short answer questions given out in class for students to answer. The variety of data collected provides greater capability for triangulation and thus greater credibility in the interpretation of data. In this paper we focus on the use of journal responses, short answer responses, and a Team Characteristics Survey. Participants completing the Team Characteristics Survey include 26 (8 female) for the SL team and 16 (7 female) for the CL team.

Results

Teamwork Survey Results

Both CL and SL first-year students completed a Team Characteristics Survey. The Team Characteristics Questionnaire is a modified version of the Work Group Characteristics Measure developed by Campion, Medsker, & Higgs.[10] The Work Group Characteristics Measure has 54 items and 19 different subscales. Many of these items and subscales were used to develop the Team Characteristics Questionnaire, however some items and subscales were modified or deleted to be more relevant to the specific design project. For example, some subscales were developed and added that are very specific to the project (e.g., Engineering Design Process, Oral Communication, Individual Contribution, Project Management/Leadership, Reactions, Writing Skills, & Thinking about my Thinking). The newly developed Team Characteristics Questionnaire has 59 items and 16 different subscales as shown in the appendix. Participants responded to each item on a 5-point Likert scale with 1 being equivalent to strongly agree and 5 being equivalent to strongly disagree.

When using a survey such as this, it is important to demonstrate that the subscales are reliable. To explore reliability, the coefficient alpha or internal consistency of each subscale was calculated. In general, reliability of .70 or above is considered acceptable. Coefficient alpha of each subscale is reported next to the title of each subscale in the survey listed in the appendix. As a result of this analysis, items 5 and 12 were removed in subsequent results to drastically improve reliability. All but four of the subscales reached the cut off level of .70 (feedback/rewards, team work preferences, social support, and interdependence). Campion et al. found similar results for these scales with the exception of the Preferences scale for which a reliability of .9 was reported.[10] The lower reliability of the four scales is most likely due to the limited number of items used in each subscale. One way to increase the reliability of these scales would be to write more items.

Table 1. Team Characteristics Survey Comparison between Two First-Year Design Group Projects

Subscale Element	Mean ChE	Mean BME	σ^2 ChE	σ^2 BME	p-value
Importance	1.63	1.38	.29	.18	.12
Participation	2.01	1.60	.28	.30	.02
Spirit	1.95	1.51	.34	.28	.02
Sharing the Work	2.23	1.70	.60	.35	.03
Cooperation within Team	1.64	1.47	.18	.28	.27
Individual Contribution	1.79	1.50	.19	.28	.06
Engineering and Design	2.21	1.79	.27	.14	.01
Attitude about teaming	1.74	1.38	.41	.28	.07
Thinking about Thinking	3.87	2.41	.62	1.28	.00

A comparison of the aggregate results for both team structures is reported in Table 1 along with the corresponding p-values; the survey is included in the appendix. Collaborative learning teams (i.e. BME) report a higher degree of participation within the team and feel their teams are working as a team better than the SL teams as measured by the differences from the characteristic teaming factors. CL first-year students felt they acquired more engineering design skills (a specific emphasis in their project), had a better attitude about teaming, team spirit and higher levels of participation and workload sharing (statistical significance $p<0.05$).

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Interestingly, the SL first-year students felt their teams had shown a similar level of cooperation during the project period even though the SL teams were larger (10 versus 4 members) and had much less opportunity for direct interactions. In general, both the SL and CL students gave positive responses to the project experience. Both types of teams agreed that the course project was important to enhance their engineering and professional skills.

Definition of an Effective Team

Students' perception of the definition of effective teams was compared pre-and post project using content analysis. All of the participating students were asked to *List the characteristics of an effective team* during the first week of the semester and again one week after the end of the team project. Responses were classified into ten elements encompassing two broad classifications, elements referring to an operational definition of an effective team and elements referring to processes used by effective teams. The ten factor definition of effective teamwork was based on the business and management academic literature.[11] As shown in figure 1, there were no significant differences in the perception of effective teamwork between the two first-year groups prior to the start of the project.

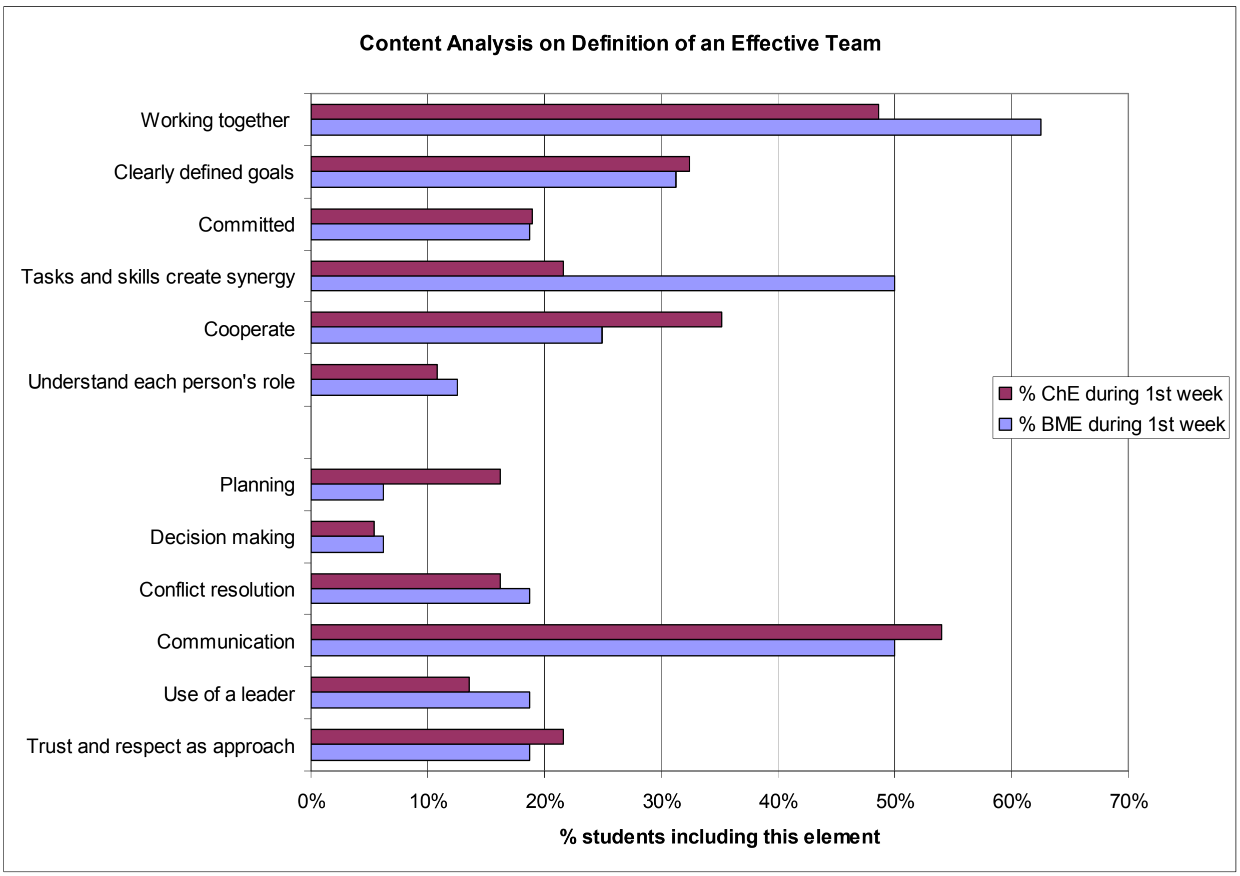

Figure 1. Pre-project definition of an effective team.

An overview of the percent change for each factor for both team structures is shown in figure 2. After their 8 week experience, statements from the SL chemical engineering students showed a marked increase in their perception of the definition of an effective team but only marginal changes in the processes used by effective teams. Statements from the CL biomedical

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engineering students described more factors associated with the processes of an effective team but had only a significant increase in one factor, decision making. This increase may be attributable to the weekly meetings with the course instructors where CL students received advice on what to consider next. For other factors the CL students as a whole had fewer descriptors after their four week experience. This preliminary analysis appears to indicate enhanced perception of teamwork on the part of the SL students. This may be attributable to the higher complexity in the specific project as well as the different structure for the chemical engineering teams.

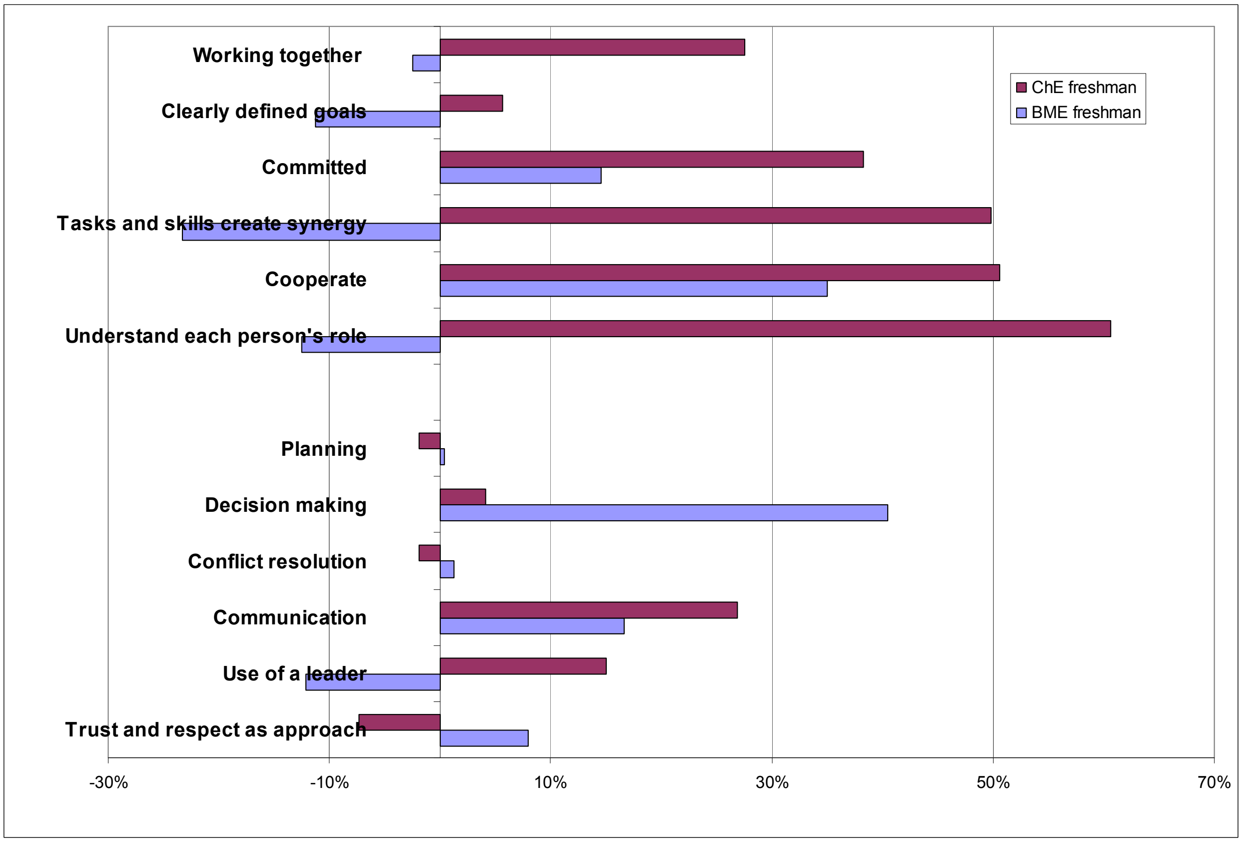

Figure 2. Percent change in how first-year students define effective teamwork after completing their respective project.

How First-Year Students Learned

The final objective of our study was to compare differences in how the SL and CL students learn. We performed a content analysis of the reflective journals submitted during the latter weeks of the semester and after the completion of the team projects. We categorized the responses based on five elements from the NRC report, How People Learn[8] including 1) Learner's beliefs about their ability to learn, 2) Learning can be strengthened through collaboration, 3) Awareness and self-monitoring of learning, 4) Knowledge is structured around major concepts and principles and 5) Learning is shaped by the context in which it appears. In evaluating their journal responses we looked for instances in which the students made a clear indication of one of these five elements.

We found a striking difference in students' responses to how they learned from their team experience. The SL students appeared to be engaged at higher levels in each of the five factors, as listed below:

- Learner's beliefs about their ability to learn: 41% SL versus 15% CL
- Learning can be strengthened through collaboration: 64% SL versus 23% CL
- Awareness and self-monitoring of learning: 95% SL versus 77% CL
- Knowledge is structured around major concepts/principles: 100% SL versus 46% CL
- Learning is shaped by the context in which it appears: 53% SL versus 0% CL

It was very apparent that while the CL students were aware that they were doing something, the SL students were more aware that they were learning and of how that learning impacted their engineering career. It is likely that the SL first-year students have created a better understanding of the major concepts that create the structure for learning engineering because of their interaction with the upperclassmen and mentors.

Attitude Toward Experience

The last element we considered in our comparison was the attitude of the students toward the experience. Cronbach concluded that attitude toward a subject may be most significant in how they approach that subject in the future.[12] We asked all first-year students to complete an Engineering Attitude Survey during the first week of the semester. Chemical engineers completed this survey during their first semester of the freshman year while the biomedical engineers had completed one semester of classes including an introduction to biomedical engineering course. As shown in figure 3, the biomedical engineering students started out their second semester with a moderate interest level that increased over the course of the second semester. The chemical engineering students had a very high interest in the discipline at the beginning of their first semester but that interest declined to a level similar to that of the second semester biomedical engineers. No students reported a low interest in engineering.

The SL students were engaged in a project that did create a significant level of stress while the CL students were engaged in a project that could be characterized as fun. We can extract two conclusions from this data: 1) the SL environment does not create a significant decrease in the attitude of the first-year students even when the project is highly stressful and 2) a hands-on project that is not stressful can improve the attitude of the first-year student toward engineering. We will incorporate this analysis into future offerings of the SL projects by including laboratory based projects and removing elements that create significant stress levels (i.e., long final reports).

Conclusions

Two different modes of teaching engineering skills through teaming exercises have been discussed, collaborative learning and situated learning. Successful acquisition of teaming skills within the engineering (or other) classroom requires educators to differentiate between small group work (i.e. collaborative learning) and effective teamwork. While the benefits of collaborative learning are well established, engineering programs and engineering service learning projects, that seek to teach professionally relevant teaming skills must determine if collaborative learning teams are sufficient. While both modes will create a positive attitude toward a discipline (engineering), the students in the situated learning environment appear to gain a higher level of understanding of the content (teamwork skills) and of their own learning.

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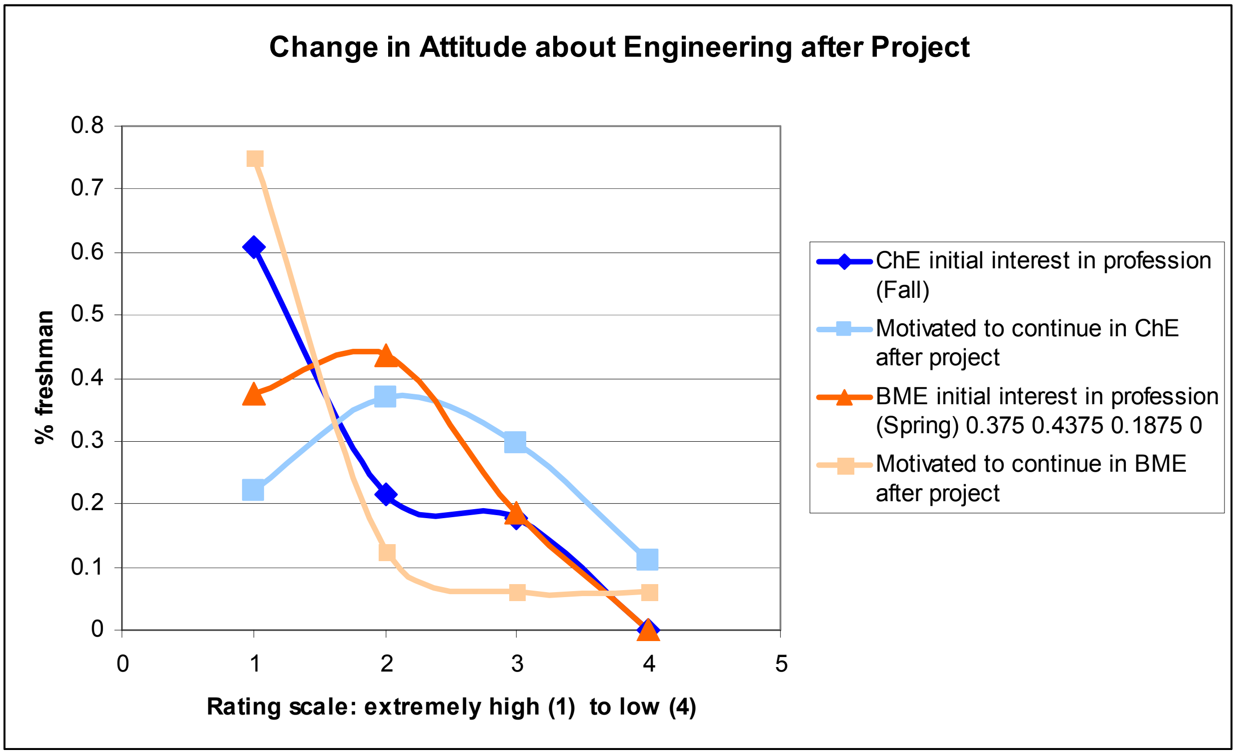

Figure 3. Attitude towards engineering both pre- and post- project period.

The situated learning environment that results when students from different academic levels work together allows the first-year student to develop a sense of the "big picture". In fact, overuse of group work may undermine the learning of effective teaming skills because the cost of learning new skills (i.e. changing their ways) may inhibit or discourage the acquisition of essential teaming skills.[13]

Acknowledgements

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Appendix

VITDP Project Statement for Fall 2003

Your team is in charge of the preliminary process design for a new polyols manufacturing plant to be built as an expansion of our Portsmouth, Ohio facility. Our corporation also is considering investing very heavily in polyols, well beyond the scope of the current project, and is looking for new ideas to improve the economics and safety of future polyol processes. We plan to build a conventional polyols process in Ohio along the Ohio River at our Portsmouth facility to meet

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demand in the Ohio Valley. Your team is to present a preliminary design using conventional polyols processing technology. We may need to license from BASF in particular their Pluracol product line technology. Along with creating a preliminary design, your team is to identify key safety issues for follow up during detailed design. Detailed design will likely be handled by outside contractors, but we need internal expertise from the preliminary design to effectively manage that effort.

I want to emphasize the need for careful consideration of safety issues. This technology is new to our corporation and we want to be absolutely certain that we've identified all of the significant safety concerns for protection of our personnel, our investment, and, most importantly, the safety of those in the nearby community. In addition we're, of course, also interested in making sure that we comply with applicable federal, state, and local regulations. For the preliminary design phase we can focus on our obligations under federal statutes. It is essential that we develop plans and background materials for all of the formal safety reviews that will come as part of the detailed design even though we will not be doing those formal reviews as part of this phase of the project. Some of the items that come to mind are potential compliance issues with CFR 1910 sections 38 & 119, RCRA (Resource Conservation and Recovery Act), CAA (Clean Air Act), SARA, and CWA (Clean Water Act). Also, a historical issue you may want to look into is the catastrophic loss of a BASF polyols plant, I believe in 1975 in Geismar, LA.

Key design targets for the new plant:

- Total operating time: 8000 hr/year and allowed wash/cleanout time: 160 hr/year
- Total production capacity: 120 to 125 million lb/year
- Four main products of varying EO/PO content
  - "A" 60% of capacity (~72 MM lb/y); ~10 hr net cycle time
  - "B" 20% of capacity (~25 MM lb/y); ~10 hr net cycle time
  - "C" 10% of capacity (~13 MM lb/y); ~11 hr net cycle time
  - "D" 10% of capacity (~13 MM lb/y);~14.5 hr net cycle time

Long term we hope to leapfrog present technology and move to an inherently safe process for polyols manufacture. We believe that doing so will position our company to absorb most of the projected polyols market growth ourselves and possibly to displace weaker suppliers. Your team is to propose opportunities for process research and development efforts for an inherently safe polyols process.

Our timeline is to have this phase of the project completed by the first week in November. Please forward to me at your earliest convenience, but not later than COB next Friday, 9/26, your draft project charter and workplan. Please anticipate submitting weekly progress reports and workplan updates.

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Team Characteristics Questionnaire for Chemical Engineering Students.

Rating scale 1=Strongly agree, 2=Agree, 3=Neutral, 4=Disagree, 5=Strongly Agree

Importance (.74)

1. The work performed by my team is important for learning about project management skills.
2. This team project allowed me to improve my teamwork skills.
3. As a result of this experience, I learned things about engineering that I would not learn in the classroom.
4. Working in a team has contributed to my professional development
5. For career success, doing well in core ChE courses is more important than learning project management and teamwork

Participation (.77)

6. On my team I had a real say in how the team carries out its work.
7. Most members of my team got a chance to participate in decision making
8. My team was designed to let everyone participate in decision making

Interdependence (.66)

9. I could not accomplish my tasks without information or materials from other members of my team.
10. Other members of my team depended on me for information or materials to perform their tasks.
11. Within my team, jobs performed by team members were related to one another.
12. Our project could not have been completed without the unique expertise of each team member.

Feedback/Rewards (.49)

13. My team mentor provided useful feedback during the team meetings.
14. My grade will be strongly influenced by how well the team worked together.
15. Doing well as a team is just as important as doing well as an individual.
16. My grade will be strongly influenced by how well I perform as an individual.

Size

17. The number of people in my team was too small for the work to be accomplished.

Team Work Preferences (.63)

18. If given the choice, I would prefer to work alone rather than to be a part of a team.
19. I find that working as a member of a team increases my ability to perform effectively
20. I generally prefer to work as part of a team

Social Support (.60)

21. Being on my team has given me the opportunity to provide support to other team members
22. My team increases my opportunities for positive social interaction
23. Members of my team help each other out with work when needed.

Spirit (.79)

24. Members of my team had confidence that the team would perform effectively
25. My team was capable of taking on nearly any task and completing it.
26. My team displayed a great deal of enthusiasm or team spirit.

Sharing the Work (.83)

27. Everyone on my team did his or her fair share of the work.

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28. No one on my team depended on other team members to do the work for them
29. Nearly all the members on my team contributed equally to the work

Communication/Cooperation Within the Team (.77)

30. Members of my team shared information with other team members about their work in an effective and productive way.
31. My team had so much conflict it was hard to work together.
32. Members of my team cooperated to get the work done.
33. Team members were respectful of one another throughout the project.
34. I felt comfortable approaching a member of the team with a suggestion or a question.

Individual Contribution (.77)

35. I was well-prepared for each meeting
36. I invested enough time and energy to learn new skills
37. I completed tasks on time.
38. I provided constructive feedback and ideas to others in my group.

Oral Communication (.78)

39. I am more comfortable participating in technical discussions during team meetings after participating in this project.
40. The project enhanced my ability to develop an effective oral presentation.
41. I feel more comfortable articulating my opinion among a group.

Engineering Design Process (.80)

42. This project has enhanced my ability to locate pertinent resources and information
43. Because of this project, I have a greater understanding of how safety issues impact engineering designs
44. As a result of this project, I am confident that I could design an inherently safer process.
45. As a result of this project, I am confident that I could lead a safety review of a chemical process.
46. As a result of my efforts in this project, I could identify the most pertinent environmental regulations for a chemical process.
47. This project enhanced my abilities to determine the cost effectiveness of a process design.

Writing Skills (.80)

48. This project improved my proficiency at technical writing (i.e. memos, email and reports)
49. This experience has improved my ability to summarize information in a written format.

Project Management/Leadership (.77)

50. The project enhanced my ability to lead or guide other people
51. I am now better able to formulate a strategy or process to solve problems
52. This project enhanced my ability to facilitate a meeting.
53. This project enhanced my ability to develop a work plan that leads to project completion

Reactions (.82)

54. I enjoyed working on my team and would like to work on other teams in the future
55. This project helps to build friendly connections between the students.
56. Learning was more fun as a team.

Thinking about Thinking (.96)

57. The journals helped me to better understand myself.
58. I feel like I learned a lot by journaling.
59. Journaling has made me more aware of my strengths and weakness as a team member.

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