Session 2625

Focusing on Teamwork Versus Technical Skills in the Evaluation of an Integrated Design Project

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Engineering 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 a competitive advantage for the company. Teaming, rather than individual effort, is how the business world gets work done and effective teaming builds significant human capital for the company (Beyerlein, 2001). Unfortunately, a typical engineering 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 (2001) 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 industry.

Design projects provide ample opportunity for faculty to engage students in activities that lead to learning teamwork. The open-ended aspect of design problems, the need for cooperation between members and the multiple decision points make such projects an ideal vehicle. Unfortunately, a design team left to develop a solution strategy on their own is not likely to engage in effective teamwork. If teamwork is the desired outcome, then it is important to design all aspects of the project to meet that goal. In this case, the engineering design tasks are simply the avenue by which students practice such behavior. A significant impediment is the lack of a model for students to explicitly learn teaming skills in the context of an engineering problem.

This paper focuses on the teaching and assessment of teaming skills in a vertically integrated team design project (VITDP). We begin by presenting our definition of effective teamwork as supported by the literature and why this differs from group work. Next we describe VITDP, the pedagogy involved in this project and how we design each aspect of the project to meet our goals.

These elements include the grading scheme, problem statement, team construction, and the desired learning outcomes. The purposeful design of the elements in the project are what Biggs (2001) calls constructive alignment of teaching so motivated students cannot escape learning. We present a number of different assessment instruments and an in-depth study of one of them is presented elsewhere (Broadway, 2003). In the results section, we discuss whether VITDP allows students to engage in effective teamwork and how well the project meets its desired outcomes. We conclude with a description of the lessons learned from our experiences and some ideas for future improvement.

Effective Teamwork

A team is a synergistic group that uses an agreed upon process to reach an agreed upon goal. The critical aspects of this definition are consensus and synergy. Our definition is consistent with that of Katzenbach and Smith (1993), whose work was cited by Levi and Slem (1995). In order to reach consensus a team must establish an effective communication plan, a task that is more difficult when team members are not at the same location. Furthermore, the communication between team members must be based on openness, trust, and fairness. As a result, there should be little or no criticism of people on the team. Synergy is achieved by identifying the strengths of each team member and then capitalizing on those strengths. Rather than arbitrarily splitting up tasks or responsibility, the team should determine the required skills to handle the task and delegate accordingly. An important aspect of this approach is that consensus is reached on how the tasks are handled with input from different perspectives.

An engineering design team differs from other teams only by the nature of the goal or problem they must solve. In general, an engineering design problem involves seeking a practical recommendation (or solution) that is constrained by and may need to be optimized relative to issues such as cost, safety, environmental impact, geographical location, intellectual property, aesthetics, public opinion, and time. The engineering design team must decide how to utilize its resources in order to provide a satisfactory solution or recommendation within these types of constraints. As with any other team, the team members must have the appropriate skills to achieve the agreed-upon goals.

When deciding whether to use teams, faculty should consider the complexity of the problem. Cohen (1972) reports that what is suitable work for teams is not calculations which could be done by an individual given enough time, but rather tasks that require brainstorming different options, deciding how to apply what they have learned to a problem, participating in role-playing situations, reviewing another's individual work, working through difficult concepts, or explaining problem areas to one another (St Louis, 2002). Most calculation-intensive engineering courses, particularly lower-level engineering-science type courses, promote working in groups and while this collaborative-learning process leads to a higher retention of concepts, it is not effective for teaching teamwork. In fact, over-dependence on group work may undermine the learning of effective teaming skills in capstone design courses, because the cost of learning new skills (Atherton, 1999) (i.e. changing their ways) may inhibit or discourage the learning of essential teaming skills. The critical factors for a successful project are that the students understand what an effective team is and how it operates and that the problem they are addressing is suitable for, and requires, a team approach.

Structure for the VITDP

VITDP is a vertically integrated design experience that is incorporated into four required chemical engineering courses – Tools for Chemical Engineering, Material & Energy Balances, Mass Transfer, and Process Design I. For the last four years, the Department of Chemical Engineering at The University of Akron has implemented VITDP for the entire undergraduate chemical engineering student population. Rather than segmenting the acquisition of teaming skills via projects in each of the four courses, a common design project is assigned during a five-week period in the fall semester. VITDP counts as a class project for each of the four courses. Our reasoning is that if each course includes a student-centered design project that varies by complexity and difficulty, why not have a single, realistic project and distribute the students by ability (i.e. class level)?

Teams consisting of freshman through seniors come together to work on an open-ended design problem while simultaneously satisfying individual course requirements. A common one-hour recitation time is scheduled each week to ensure that all can attend meetings and to allow pre-project instruction on effective teams. During the project period, each team is required to hold a formal meeting with either an industrial or faculty mentor who provides feedback on the team's progress and teamwork dynamics. Each meeting must have a leader, scribe and facilitator where these roles rotate among members. The mentor may impart some technical advice but their role is primarily as an observer of effective interaction and judge of how well team members are participating during the meeting. Meeting minutes and a progress memo are submitted each week by the teams. Students are asked to submit individual work logs describing their activities as well as reflective journals. A final design report and a 15-20 minute oral presentation are graded by the project instructors.

The Tools for Chemical Engineering course plays a larger role than the other courses in teaching some skills and providing information the teams need for project success. Since these students may be overwhelmed by the terminology, design tasks, and feelings of inadequacy, we purposely 'plant' information with the freshman. For example, one of their lab assignments prior to the start of VITDP is to search the Internet for patents they will use in the project. Another lab assignment asks them to prepare the VITDP process flow diagram using Visio®. Lectures on teamwork and oral presentation skills emphasize what they can do as freshman and how they can prevent being relegated to a non-participatory role. In-class discussions may revolve around more complete explanations of the problem statement and what the VITDP instructors are looking for in the deliverables. The special considerations given to the freshman are an attempt to impart value so teams cannot succeed without listening to their freshman, a form of positive interdependency (Smith, 1996).

Assigning Grades for VITDP

Past experience with VITDP has shaped our grading strategy using the principle of rewarding desirable teamwork behavior while seeking the assessment from the most suitable participant. For example, the mentor is the most suitable individual to record satisfactory participation during team meetings, faculty gauge the technical merits of the final reports as well as the written memos, and peer evaluations assess overall teaming performance. Details for the grading strategy are shown in the appendix and discussed below.

In any grading scheme, the free-rider problem is perhaps the dominant issue for academic teams (Felder, 2001; Joyce, 1999). In our VITDP, students earn 30% of their score from individual contributions and 70% of their score from team efforts. The individual score is based on participation at and preparedness for meetings as well as submission of work logs and journals. The team score is based on communication between the team and the VITDP instructor as well as their ability to work as a team. To minimize the free-rider problem, students must receive a score of at least 18 out of 30 on the individual portion to share in the team points.

The intra-team communication is evaluated mainly by the team mentor. The mentor attends each of the team meetings and through observation evaluates the preparedness and participation of each team member. The mentor uses a scale of 0 –3 for both preparedness and participation. In addition, the mentor evaluates the effectiveness of the meeting leader, scribe, and facilitator. During the meeting the mentor fills out a scoring sheet and then reviews their performance with the team at the end of the meeting. (An example of the scoring sheet is shown in the appendix.) At the beginning of the project students are told that active participation at all meetings is mandatory. Therefore, team members who receive a score of 0 or 1 for any meeting receive no credit for participation at meetings.

Technical memos are the principal mode of communication between the team and the VITDP instructors and are evaluated by a faculty member. The memos and subsequent evaluations are delivered via email. The teams are told in advance what is expected in the memo. The technical memos are evaluated based on style, organization, presentation, and completeness. A small amount of the memo score is reserved for elements that exceed expectations. This is intended to motivate the team via high expectations. The memo scoring rubrics are shared with the teams. The completed memo evaluations should be returned to the teams prior to submission of the next memo but this point is perhaps the most difficult for the instructors to satisfy. VITDP faculty emphasize the importance of making improvements in the technical memos from one week to the next. At the end of the project, teams receive one point for each memo submitted and up to five points if the scores on the memos improved over the course of the project.

Each team member is asked to submit a weekly work log and journal. The work log is used to record the type of activities and the number of hours spent on each activity. The journal entries are responses to the project activities. Project evaluators review the work logs and journals and provide comments to some students about their effort level and issues that arise about the project. The content in the work logs or journals was not evaluated and so students earn individual points by simply submitting them on time. The content in the work logs and journals, as well as the other peer assessment information, is used solely to identify any individual deemed to be non-participatory. That individual will receive a VITDP project grade of zero even if they submit some items.

Finally, the teams must present a final recommendation in both written and oral form. The oral presentation is evaluated based on the quality of the presentation materials, the presentation mechanics, and the technical confidence the presentation engenders in the recommendations. The written recommendation is evaluated based on style, organization, completeness, and technical confidence. Note from the above description, very few points are ascribed to the technical merits of the process design. The focus of the project is on teamwork and the grading scheme reflects that emphasis. Nevertheless, it has been our experience that students have difficulty grasping the true importance to their grade of process and teamwork versus the technical correctness of the design.

Pedagogy for the VITDP

With the project structure in mind, we turn to the literature to evaluate the efficacy of our multi-level design team strategy. For freshman 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 (Yokomoto, 1999). The multi-level experience is an attempt to create situated learning, a primarily social form of learning (Lave, 1991). Freshman and lower skilled students share information gathered from their efforts on less technical tasks and so their role is more in peripheral participation versus a leadership role. 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 it's effectiveness stems from the circulation of knowledge among the team. If successful, this cooperative learning environment quickly generates positive interdependence since each team member needs to learn from the others for both individual and team success.

As students progress through the program they will have repeated practice at developing the so-called career skills of teamwork and communication. According to Reynold's (1965) model of developing competency, consistent and reliable performance of a skill occurs after a number of attempts since competency rises just after an attempt but wanes between attempts or experiences. According to Reynolds, students will master teaming and communication skills only after repeated exposure to projects that include these elements. Others have reported this as well (Seat, 1999). An important distinction between VITDP and more typical in-class projects is the exposure to all elements of design and teamwork including those beyond their immediate competency. Students 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) to construct knowledge while simultaneously applying new knowledge gained from increasingly higher-level engineering classes. In essence, VITDP combines Reynold's model with constructivism theory as the mechanism for learning teamwork.

Design of the Project Statement

The challenges in creating the VITDP problem statement so that students learn teaming skills are in:

1. creating a set of deliverables that allow the teams to stay on track,

2. providing tasks that the less experienced members of the team can reasonably contribute to,
3. crafting a problem which allows students to emphasize the process of using a team format to meet the project goals,
4. allowing each level of student the opportunity to learn something they perceive as valuable, and
5. accomplishing all of the above while keeping the time required manageable for the students.

The specific topic for the project has turned out to be less important than one might suppose provided it meets the above criteria. An example of this year's problem statement is given in the appendix.

The problem statement includes a spectrum of design tasks that require the teams to find and interpret a range of information about the subject area in addition to performing traditional chemical engineering design tasks. The categories that apply most often include: technology reviews (especially utilizing the patent literature), market forecasts, price analysis, safety analysis, and a general analysis of HSE (health, safety, and environment) implications of the product or process under consideration. It is also important to have some of these 'softer' deliverables due throughout the project period to keep the underclassmen engaged while the engineering task follows its usual course of escalating in detail and complexity.

The project must allow students to emphasize the process of using a team format to meet the goals of the project. The level of difficulty of the project should be easily understood by the seniors and many juniors although the specific details will need to be investigated. Underclassmen will obviously be somewhat confused on how to go about solving the problem. A problem statement that significantly challenges the upper-level students in terms of technical skills or knowledge is not effective since having the needed skill set to reach the project goal is an established element in successful teams. Rather than learning new technical skills, we want them to put some time into planning the project timeline, organizing the activities, partnering and learning from each other, preparing for meetings, preparing memos, reports, and the presentation. From prior experience we know that making the problem challenging can force the upper level students to leave the underclassmen behind in order to focus on the final technical design. We often ask the teams to provide a recommendation to an imaginary supervisor where the recommendation relies not only on the final technical process design and associated economics but also on the detailed information gathered by the less-experienced team members. This is a second aspect of VITDP that creates positive interdependency, i.e. members perceive that they cannot succeed unless everyone succeeds, which is critical for cooperative learning. See the Cooperative Learning Center at the University of Minnesota (www.clcrc.com) for more information on this point.

The project statement should allow each level of student the opportunity to learn something they perceive as valuable. In this case the problem statement cannot be too basic or elementary. It is not sufficient to simply identify learning outcomes that faculty feel are important. Students will be more motivated to put the time and energy into the project if they perceive value in the activities.

Finally, the problem must be doable in terms of the expected time needed to perform the tasks. Time management was the number one negative aspect of earlier attempts at the VITDP. We have a limited window in terms of keeping mentors available with minimal disruption to their schedules, minimizing the negative impact on the students' other academic responsibilities, and keeping the students' enthusiasm for the project high.

Construction of the Teams

Following the advice of many educators who specialize in collaborative learning, the teams are arranged using specific criteria. Arranging the teams allows us to draw on knowledge gained from previous VITDP projects concerning technical abilities, interpersonal skills, behaviors, and attitudes for every student except the freshman. Given that collaboration, communication, and cooperation are key elements for success, our prior knowledge of individual behavior provides the potential to foster positive social interactions within each team. Based primarily on evaluations from previous VITDP experiences, each student is given an initial teamwork rating of 1) poor, defined as likely to drop out of participation, 2) fair, defined as willing to participate but work habits deemed unreliable to complete critical assignments, 3) good, defined as willing to collaborate with others and can complete tasks, or 4) excellent, defined as exceptional teamwork skills. In addition, each instructor is asked to submit an opinion based on the student's class performance to date.

The principles for arranging the teams are as follows:

- The number of teams is dictated by the size of the senior class.
- Teams that meet with industrial mentors must be able to meet at 5 PM. The number of teams with industrial mentors is dictated, therefore, by the class with the least number of students choosing this option. Usually half of the teams have an industrial mentor.
- Assign two seniors to every team such that one is capable of performing the highly technical tasks (i.e. process simulation, design calculations) while the other is capable of project organization and people skills. This combines two critical skills needed for project completion: technical and teamwork skills.
- Juniors are added to each team to obtain heterogeneity in both teamwork and technical skills (i.e. poor through excellent ratings).
- Sophomores are added to balance the teamwork ratings as well as gender and underrepresented groups (see next item).
- In order to minimize poor social interaction, no team has an isolated female or minority student member. Felder (2001) recommended this approach particularly for lower level students. In addition, we hope that informal networks develop for both women and minorities.
- Teams with mixed genders have at least one female junior or senior. This prevents women from being relegated to unimportant tasks in potentially gender-biased teams.
- At least one team consists of all women and one team of all men. This allows us the possibility to study gender differences in teamwork projects.
- As much as possible, freshman from the same section of Tools are assigned to the same team to allow for informal discussion and collaboration in completing their tasks.
- Using a short list of probable tasks developed from the problem statement, we check that each team has the needed personnel to complete the essential aspects of the project.

- Teams with the 'potentially' weakest seniors are assigned to the most effective mentors. If necessary, the mentor can impart some leadership to the team.

While the above may seem to be a fairly complicated strategy for team assembly, the extra level of complexity is important to minimize difficulties that can arise when teaming freshman through seniors.

Desired Teaming Outcomes

VITDP has four objectives to prepare each student for a career in chemical engineering. The four objectives are listed below in the order of their importance:

1. Work effectively in teams. Teamwork includes demonstrated support for others in the team by actively encouraging participation of others. Places a priority on the team (versus the individual) meeting its goals and allowing each team member the opportunity to both fulfill their responsibilities and learn.
2. Communicate in a technical setting. This includes speaking, listening to others, writing memos and reports, and giving oral presentations.
3. Design a process for chemical production and prepare a rationale recommendation. The technical aspect of the project should be correct. This includes the process simulation, design decisions, economic analysis, and other technical details.
4. Build a network within chemical engineering. One way to strengthen the undergraduate program is to foster a sense of community between all students. Upper level students should practice managing the team while lower level students should practice that aspect of the project in which they are currently taking courses as well as assimilate new concepts.

Past VITDP projects indicate that we are making progress in reaching our goals and a full longitudinal study to verify this is planned. In this paper, we concentrate on the following specific learning outcomes for which we quantify what students know or can do:

- Students should be able to identify the attributes of a good team.
- Teams should demonstrate the characteristics of effective teamwork
- Students should enhance their meeting skills.
- Team members should learn from each other.
- Freshman should learn more about chemical engineering
- Sophomores should enhance their ability to locate pertinent technical information.
- Seniors should enhance their ability to lead a team.
- The project should build friendly connections between students.

The project evaluation survey (see appendix) gave us feedback on key issues for VITDP such as 1) did the project enhance specific abilities, 2) did the project enhance teamwork, and 3) what are the positive and negative aspects of the project structure. The responses are shown as % positive (strongly agree plus agree) and % negative (strongly disagree plus disagree) from either all students or only specified classes in the following three figures. In general, we received mostly positive results that indicate progress towards meeting each of our desired learning outcomes. This preliminary information allows us to have confidence in the benefits of our unique approach to teaching teamwork and to identify elements that need improvement. This last point is further developed in the conclusions section.

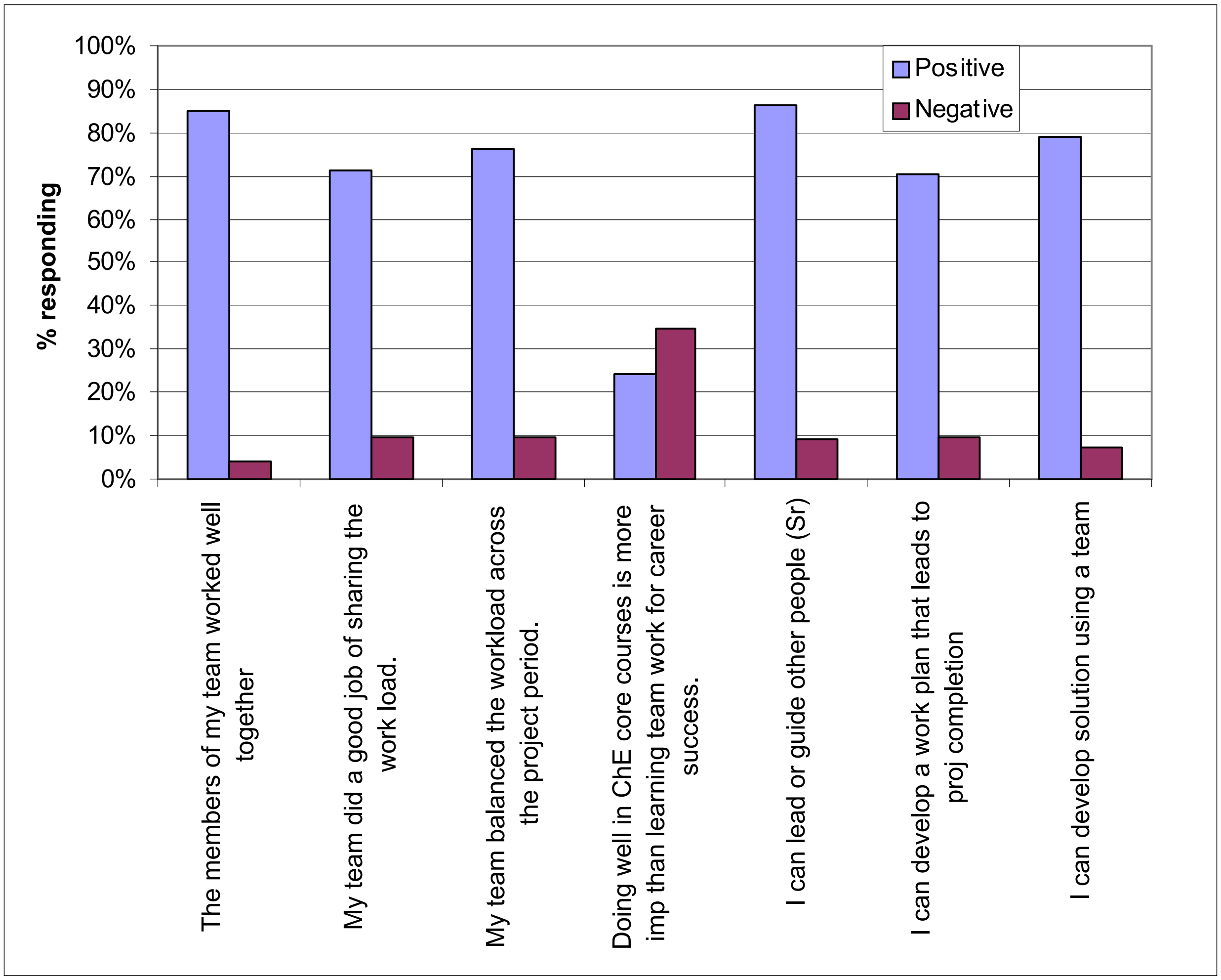

Figure 1. Student Assessment on Teaming Concepts

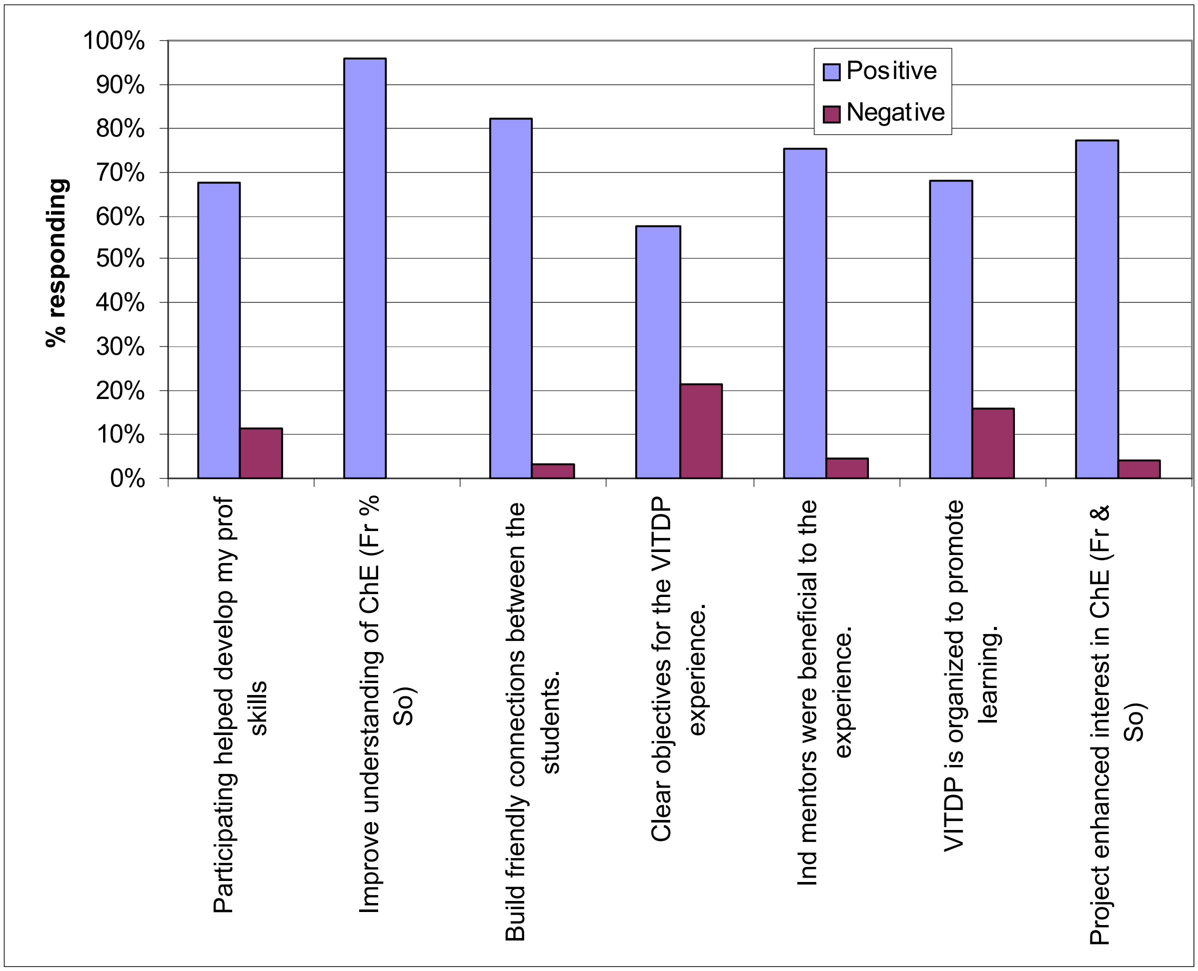

Figure 2. Student's Assessment of Concepts Related to VITDP

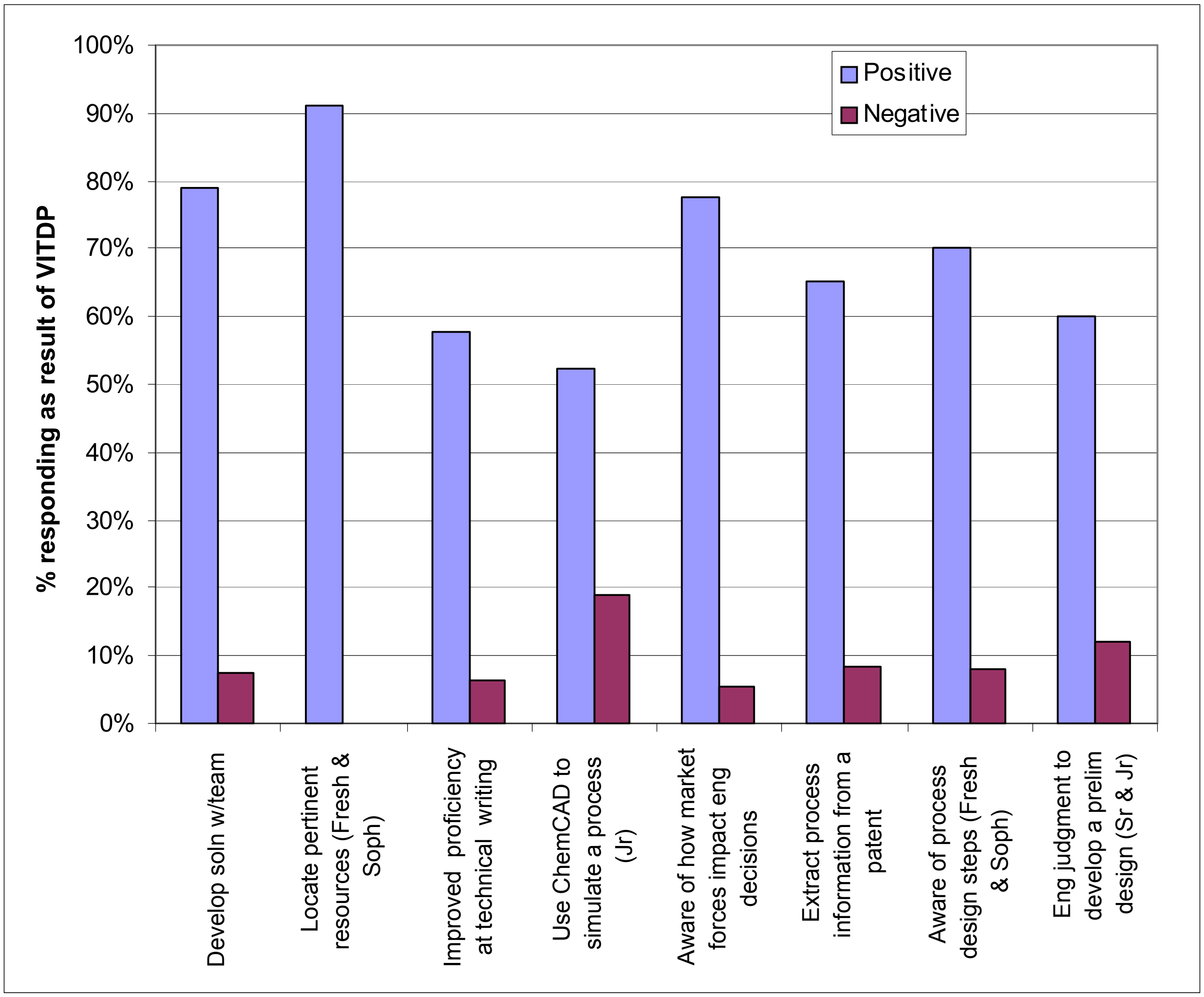

Figure 3. Student's Assessment of Skills Enhanced by VITDP

Results

Current research results show that teams fail 50-70% of the time (Beyerlein, 2001), an unacceptable rate for our VITDP experiment but perhaps an indication of how difficult it is for student teams to exhibit effective teaming skills. In evaluating the benefits of VITDP, we first ask whether there is any evidence that the students exhibited the characteristics of successful teams. To perform this evaluation, we consider the peer evaluations from each team for the 11 characteristics listed in Table 1 and compare this to the grade each team received on the project. Note that the maximum project score is 70 since 30% of the VITDP grade is for individual efforts.

Table 1. Average Teamwork Ratings for All Teams from Student Peer Evaluations

Characteristics of the Team	Average Team Rating (0-10)	Number of Teams Rating Themselves Below 7.0
1. Members committed to completing the project	8.7	0
2. Individuals willingly took on tasks	8.5	0
3. Decisions made after discussion	8.3	0
4. Most tasks completed thru individual efforts	7.9	3
5. Information readily shared within the team	8.7	0
6. Members did their fair share of the work	7.6	3
7. Team worked well together.	8.7	0
8. Team trusted each other to complete assigned tasks	8.3	1
9. Team formed a **we** attitude about project completion	8.4	0
10. Little or no criticism of individuals	8.6	0
11. Individuals did not withdraw from team effort	7.3	6

In the table above, the rating scale was defined as: 0 = never present in my team, 5 = sometimes demonstrated by team, 8 = often demonstrated by team, and 10 = always demonstrated by team.

In general, students felt that their team often demonstrated many of the characteristics of good teamwork. They felt they were very good at sharing information, working together, and completing the project. If we define satisfactory as greater than 7.0, then some teams had difficulties with having a fair distribution of work, trusting each other to complete tasks, and individuals withdrawing from the team effort. Correspondingly, from the instructor's evaluation of teamwork, 10 out of the 13 teams scored greater than 70% on the teamwork portion of their final project score.

We ranked each team in terms of their self-assessment of teamwork skills (i.e. ranked order using the average of questions 1 –11 shown in Table 1). Figure 4 is a comparison of the team's score on the project as graded by the VITDP instructors versus this ranking of teamwork skills for the last two VITDP projects. As expected, those who are better at teaming outperform their peers in terms of grades received. Our results from the student assessments and instructor evaluations provide evidence that most students are actively engaged in teamwork and good teamwork characteristics correspond to high evaluations, that is, the outcomes match the assessment.

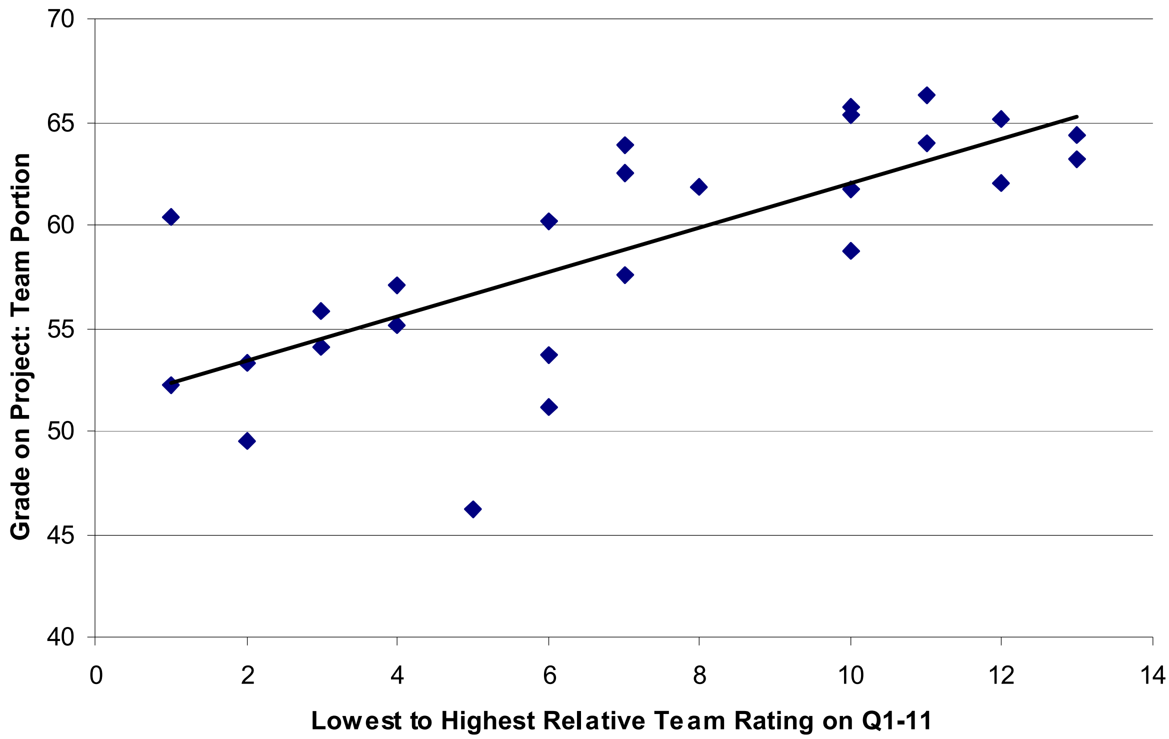

Figure 4. Comparison of Project Performance and Self-Reported Teaming Characteristics

Another important aspect in VITDP is how much it is worth to the overall grade in the class. It is well documented that grades are a significant external motivator for students at all levels and we see this result in VITDP. Each instructor distributed between 5% and 15% of the course grade to the project. We find a large disparity in the effort extended to the project for the junior class that allotted only 5% of the course grade to the project. Only the juniors gave a higher positive (33% agreed) versus negative (14% disagreed) response to the statement that doing well in chemical engineering core courses was more important than teamwork for career success. One third of the juniors who finished the course either did not participate in the project at all or participated at such a low level they were not entitled to receive team points. This result is compared to 15% for the sophomores, 7% for the seniors, and 0% for the freshman. The actions of the juniors mimic that seen in other cooperative experiments, namely, students behave in a manner they believe yields optimum personal benefits (even if they are wrong.). With almost half of the teams reporting less than satisfactory evaluations on individuals not withdrawing from the team, we must consider how best to use course grading to enhance true VITDP participation.

Another characteristic of successful teams as pointed out by Warner (1996) is the degree to which they partner or help each other with the project. In this case we define partnering as the average of questions 4-7 from the nine-question checklist (see appendix). Preliminary results from a team checklist survey show that teams who receive higher grades on the VITDP project also give themselves high ratings for partnering as seen in Figure 5. Some teams did not submit the checklist creating fewer points in Figure 5. One exception to the trend seen in Figure 5 is the last ranked team who consistently rated themselves the lowest in all categories of

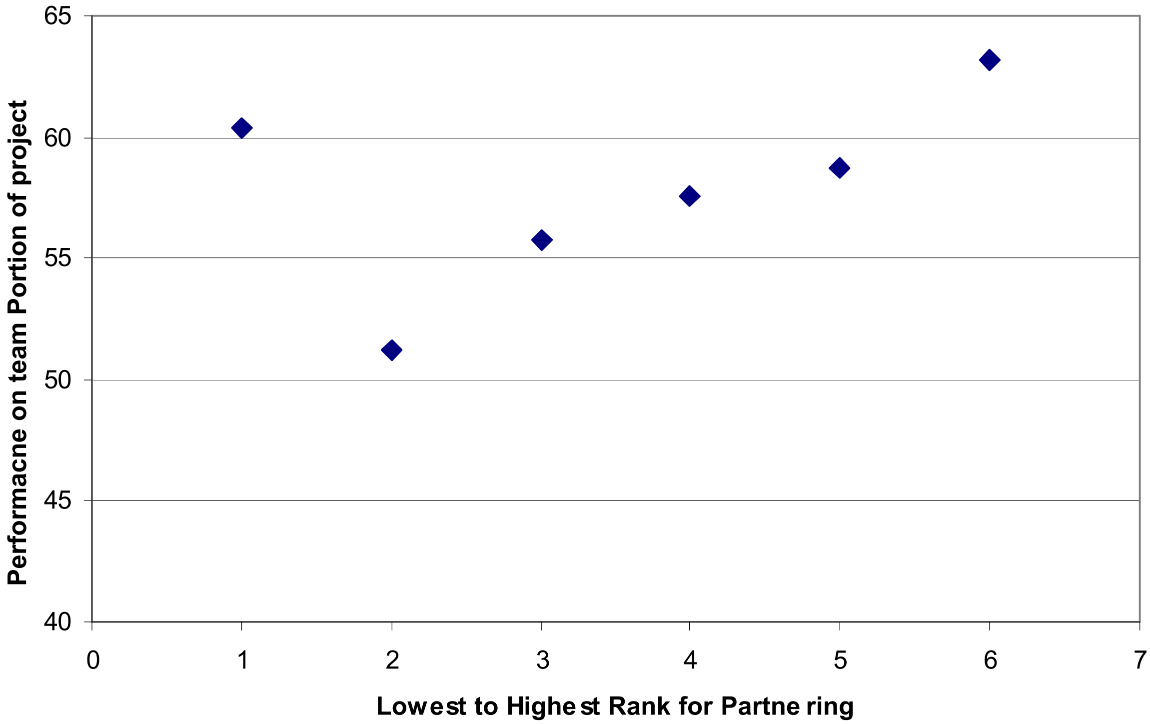

Figure 5. Comparison of Team Project Score and Relative Degree of Partnering.

teamwork both on the checklist and peer evaluation survey. Interestingly, this team gave themselves average ratings when asked if they enjoyed working with others on their team and this positive aspect in socialization may explain the higher than expected project score. The trend in Figure 5 indicates that answers to questions 4-7 are an early indicator of likely team success or failure.

One of our learning outcomes is to have students learn the attributes of an effective team. From the published literature we compile the following attributes for teamwork:

- Create synergies to get the most out of the resources available.
- Committed to achieving goals, have a strong sense of personal commitment that distinguishes high performance teams from other teams.
- Teams have a balance between technical expertise, social skills, and leadership.
- Focuses on the processes that drive the results, not just the answers.
- Discipline within the team creates the conditions for team performance.
- Having an organized work plan is important to project completion.
- Cooperation within the team leads to project success.
- Decisions made after discussion.
- Team trusted each other to complete assigned tasks.
- Little or no criticism of individuals.
- Information readily shared within the team.

A list of key words descriptive of good team characteristics was created from the above to perform a simple qualitative analysis of the final reflective journal where each student was asked to list the attributes of a team. The type of response varied with some restricting their answer to those attributes exhibited by their team. The number of times each word was listed by students is given below:

1. cooperation 34
2. commitment 25
3. focus on a common goal 25
4. communication 21
5. trusted 16
6. get along 11
7. leadership 11
8. use skills of the group 11
9. organized 10
10. work hard 7
11. work plan exists 2

In addition, there were 2 responses with no answer to the question. There were 8 responders that incorrectly stated – since in an effective team responsibility is shared according to expertise - a good team has well defined roles and corresponding tasks for each team member. Thus, approximately 10% of the responders did not meet the outcome of correctly identifying the attributes of a successful team while 90% of our students were successful in this regard.

Team satisfaction is also important for success. Approximately 84% of the students enjoyed working with their team while only 4% did not and 12% were neutral. VITDP places a larger responsibility on the upper class students and we found that 10% of these students did not enjoy working with their teams.

Conclusions and Lessons Learned

Over the last four years that the VITDP has been the mechanism to help students learn teamwork, we have identified some critical lessons learned. Briefly, these are that the students must have a clear understanding of the project goals, participate in the assessment of themselves and their team, and be aware of effective teaming skills. The faculty must select teams carefully and provide feedback to the students in a timely manner.

The problem statement and the objectives of the project must be carefully put together. Most of the lessons learned about the problem statement are described above. The project description and the learning objectives must be clearly communicated. Since the first offering of the VITDP, information about the project (including the problem statement, the timeline for submitted materials, information on teamwork, the project objectives, etc.) has been posted on the web so that students have ready access. More recently, scoring rubrics for each of the written assignments are also distributed so that students know what is expected. One method for assessing the teams' understanding of the problem and the objectives is to collect a work plan from each team within the first two weeks of the project *and to evaluate it carefully*. The work plan should spell-out the milestones, tasks, and resources quite clearly. The work plan should also cover how problems will be resolved. As the project moves forward, the team can then make reports that refer to and modify their initial work plan. In future offerings of the VITDP, therefore, we will spend more time helping teams develop effective work plans.

Students should also take responsibility for assessing their progress. We have observed improvement in the overall project performance that can be attributed to the use of work logs and journals (Broadway, 2003). Asking students to reflect on their efforts and how these efforts relate to the overall team goals encourages them to "have something to write about" at the end of the week. In future offerings of the VITDP we will encourage team processing by asking teams to discuss how well they are achieving their goals and maintaining effective working relationships. They need to describe what member actions are helpful and unhelpful and make decisions about what behaviors to continue or change. Continuous improvement of the process of learning results from a careful analysis of how members work together and determining how team effectiveness can be enhanced. More discussion of this point can be found at the www.clcrc.com web site and in works by McAnear and Seat (2001), London (1997), Sundstrom et al. (1990), and Dominick et al. (1997).

Because we are emphasizing and evaluating the students' improvement in teamwork skills, we must continue to improve our teaching of those skills. Students must be made aware of what is meant by effective teamwork and how it differs from group work. For the first time this fall, we gave two interactive presentations on effective teamwork prior to the start of the VITDP. These presentations seemed to help the students in getting through the start-up stages of teaming. Miles and Mangold's (2002) results suggest that effective training and development efforts may enhance team member satisfaction by showing students how to resolve conflicts and keep an open line of communication. We plan to spend more time on covering pre-project team skills training and to invite outside speakers from industry to help present the material. For example, more emphasis will be placed on good communication and project organization. Time will be allotted to give teams an opportunity to identify their strengths and weaknesses.

The VITDP faculty must provide better communication to both students and mentors. Feedback to the students should occur as rapidly as possible. We have addressed this need by increasing the number of faculty evaluators from two to four. Clear instructions for the mentors that describe their role and what we expect from them are critical. Further improvements can be made by streamlining the assessment tools and developing strategies for rapidly evaluating written assignments. Alternatively, with more time to carry out the project, the assignments can be spread out. Likewise, additional mentor training on teamwork evaluation, what to look for, and how to provide useful feedback would be helpful.

Many of the issues that we face can be addressed by increasing the project timeline and being more consistent in the amount of credit for the project in each course. With more time we can elaborate on the teamwork skills, spend more time on meaningful feedback to the students, and make sure that students understand the VITDP goals. Next year the VITDP will be offered as a separate one credit hour course for all chemical engineering majors. Each student will receive a letter grade from this course and, therefore, the partial credit system we are using now will be eliminated.

Acknowledgements

We would like to thank Professor Tom Angelo for discussions concerning course design, assessment of student achievement and useful suggestions. We are indebted to the faculty in the Department of Chemical Engineering for their dedicated support and implementation of the VITDP. We are also grateful for the input and assistance by our industrial colleagues, particularly the outstanding service they provide as team mentors. Finally, we must acknowledge that without the hard work and thoughtful critique of our efforts by our students over the past several years, none of this would have been possible.

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Biographical Information

Rex Ramsier earned his Ph.D. in physics from the University of Pittsburgh in 1994 and after two years in industry joined the faculty at The University of Akron. He is currently an Associate Professor with joint appointments in several departments. He is active in promoting student success, and has received the campus-wide outstanding teacher award as well as many other teaching related honors. His research interests include functionalized materials and surface coatings, nanofibers and nanolithography, and surface science.

Francis Broadway received a Ph.D. in elementary education, which he earned in 1997 from the University of South Carolina. He holds an undergraduate degree in chemistry and worked as a middle and secondary school instructor before attaining his Ph.D. He is very active in pre- and in-service teacher education programs, and participates in many professional education societies. Prof. Broadway also plays a major role in cross-college collaborations involving the colleges of Education, Engineering, and Arts & Sciences. His research interests involve cognitive learning and assessment of student performance.

H. Michael Cheung training is in chemical engineering. He earned his B.S. in 1979, his M.S. in 1982, and his Ph.D. in 1985, all at Case Western Reserve University in Cleveland, Ohio and is a registered professional engineer (Ohio). He joined the chemical engineering faculty at The University of Akron in the fall of 1984 as an assistant professor, was tenured and promoted to associate professor in 1989, and became full professor in 1998. His research areas include supercritical fluids processing, nanostructured materials synthesis, ultrasound driven processes, and laser measurement methods.

Edward Evans earned his Ph.D. in 1998 from Case Western Reserve University and has been teaching Chemical Reaction Engineering and Materials Science for the last five years in the Department of Chemical Engineering at The University of Akron. He has included material from the National Effective Teaching Institute Workshop (6/17/99-6/19/99) in many of these courses. Dr. Evans is currently funded under an NSF Bridges for Engineering Education (BEE) grant and a Department Level Curriculum Reform (DLCR) grant to implement novel approaches to engineering education. Dr. Evans participates in a multidisciplinary research group that studies vapor deposition of nanostructured materials.

Helen Qammar is an Associate Professor in the Department of Chemical Engineering. She earned her PhD in chemical engineering at the University of Virginia in 1986 and worked as a research fellow at Resources for the Future prior to joining the University of Akron. She is actively involved on campus in the scholarship of teaching and learning including chairing the college ABET committee. Research interests include the application of nonlinear dynamics to process identification and control.

Appendix

i. Problem Statement from Fall 2002
ii. Team Checklist Survey
iii. Final Project Evaluation Survey
iv. Peer Evaluation Survey
v. Project Grading Scheme
vi. Meeting Mentor Evaluation Form

VITDP Problem Statement

Date:	Thursday, September 26, 2002
To:	Process Engineering & Design Group
From:	R.U. Sure, Director of Process Engineering & Design
Re:	MMA repositioning
Cc:	I.C. Starrs, New Technologies Director

Ukron presently is operating a medium scale methyl methacrylate (MMA) monomer production facility at our Bayview, TX complex on the Gulf coast southwest of Houston. This unit is nearing the end of its' useful life and will soon require either replacement or major refurbishment of most of the plant. Further the process is a very large producer of highly acidic wastewater. The plant's wastewater treatment facility is also in need of major refurbishment and improvement. Your team is to be part of an effort to provide background technical and economic information to support an upcoming management decision on whether to proceed with refurbishment of the current facilities, exit the MMA market, or attempt to expand Ukron's MMA market presence with a larger MMA plant utilizing newer technology. This new technology is available for licensing from Ineos Acrylics. Other team's are working on the first two options, your team is to focus on the third option, that of utilizing new technology for MMA production at the Bayview complex and increasing capacity from our current 120 MM lb/y to 200 MM lb/y.

New Technologies is considering licensing a new route to MMA being commercialized by Ineos Acrylics, UK Ltd. Ineos acquired the rights to this technology when they purchased ICI's acrylics business. Their process carbomethoxylates ethylene to form methyl propionate (MP) using a homogeneous palladium catalyst. MP is then reacted with formaldehyde in the gas phase, giving MMA and water. Both reactions are highly selective. The reactions are:

$CH_2{=}CH_2 + CO + CH_3OH$ ® $CH_3\text{-}CH_2\text{-}COO\text{-}CH_3$
(MP)

$CH_3\text{-}CH_2\text{-}COO\text{-}CH_3 + CH_2O$ ® $CH_3\text{-}C(COO\text{-}CH_3){=}CH_2 + H_20$
(MMA)

Following the reactions, MMA needs to be purified to meet normal commercial specifications, typically 99.5% purity which is what our current plant produces. Ineos' technology is covered by World Patents 99/21820, 99/52628, and 99/02480 to ICI.

Our current plant produces 120 MM lb/yr of MMA via the conventional MMA production process using sulfuric acid as a catalyst. The sulfuric acid is neutralized with ammonia, producing ammonium sulfate which we presently are selling at a loss of $0.02/lb. HCN is also used in the process and an advantage of the proposed new technology is that it would require neither sulfuric acid nor HCN. While we have never had a serious release in the 40+ years the plant has operated, HCN is a highly toxic chemical that presents numerous handling, safety, and public relations difficulties. The term 'cyanide' resonates quite negatively with the local media even given our 40+ year near perfect track record handling it.

The new MMA process would eliminate the sulfuric acid catalyst waste making the wastewater much easier to treat since no neutralization would be required. We believe that the existing final MMA purification column and all of the MMA product storage and loading facilities can be reused since they were refurbished and upgraded in a debottlenecking project 10 years ago. These facilities were upgraded to be capable of handling 200 MM lb/yr of MMA during that project. Therefore you should consider an expansion of Ukron's MMA capacity from 120 MM lb/y to 200 MM lb/y.

In addition to the engineering design tasks, please be sure to address the following:

- review the patent literature and determine what other options, if any, exist to produce MMA and assess whether these merit the assignment of another design team to evaluate them (justify your assessment)
- estimate the credit(s) to be used in the economic analysis of the ICI process for avoiding the current $0.02/lb loss on ammonium sulfate and any other costs which would be reduced using the ICI technology
- provide a market forecast for MMA demand identifying the main uses & consumers of MMA and projecting selling price if possible
- assess the process safety, health, and environmental implications of the new technology
- report on the potential public relations and financial impact of the 'green' nature of the proposed technology
- assess whether the MMA final purification column and associated storage & loading facilities may in fact be reused

By the week of 7 October, I need a memo from you outlining your team's planned approach. The plan must make effective use of all members of the design team and encompass all necessary tasks as you anticipate them at this time. In reporting the work plan, please describe the activities and estimate the time needed to fulfill that activity for each week. Note when items will be due each week. Your direct supervisor will sign off on the work plan.

By the week of 14 October I need a memo with information concerning market size and existing producers of MMA as well as a brief summary of pertinent background material. I'll need follow up memos on the economic potential of your options and other process information you may have discovered or developed by the week of 21 October and 28 October. The week of 28 October memo should include **preliminary** process flowsheets for the base case your team plans to recommend. I'll need a brief report with your recommendations by early November. The specific date for that report will be finalized in the next couple of weeks. Your early November report should consist of a summary of the advantages and disadvantages of the new process, a recommendation concerning the new process, and proposed flowsheets with preliminary economics. Also, I'll need your team to make a short presentation of your recommendations in a meeting to follow your early November report.

Assuming we decide to proceed, and following signing of a memorandum of understanding with Ineos, Ukron will prepare a pre-project plant design for submission of a capital project proposal to the Board of Directors. Your reports must be complete enough to allow an easy transition for this next design team so Ukron can meet the expected timeframe for project completion. With luck the project will make it onto the Board's agenda for their March meeting and they will approve the capital project for detailed design using 2003 funding. That would permit a late-2005 plant startup.

Acknowledgement: The idea for this problem comes from the chemical engineering department at Penn State University.

Name ___________________________

Team CHECKLIST

adapted from Johnson and Johnson, Cooperation in the Classroom (1990).

Team Number ___________

Everyone volunteered ideas and information.

Always				Never
1	2	3	4	5

We asked all members for their ideas and information.

Always				Never
1	2	3	4	5

We frequently summarized our ideas and information.

Always				Never
1	2	3	4	5

We asked each other for help when it was needed.

Always				Never
1	2	3	4	5

Everyone helped by accomplishing their task.

Always				Never
1	2	3	4	5

We made certain everyone understood how to do the work we needed to do.

Always				Never
1	2	3	4	5

Everyone helped keep the team focused and on task.

Always				Never
1	2	3	4	5

We included everyone in our work.

Always				Never
1	2	3	4	5

In general we functioned well together in accomplishing our goal.

Always				Never
1	2	3	4	5

Of the behaviors listed above, our group was best at

Of the behaviors listed above, next time we will be better at

Project Evaluation Survey

One way for the chemical engineering department to continue to improve our vertically integrated team project is to monitor the performance and accomplishments of the students. For each of the items below, please rate your ability. You should be as objective as possible. All responses will be held confidential. Place an "x" in the cell corresponding to your response.

Team Number						
Knowledge or Skill	**Strong Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Not Able to rate**
The project enhanced my ability to develop engineering solutions as part of a team effort						
The project enhanced my ability to locate pertinent resources and information						
The project enhanced my ability to lead or guide other people						
I am more comfortable participating in technical discussions during team meetings						
I can develop an effective oral presentation						
The project enhanced my ability to give an effective oral presentation						
I can apply newly acquired knowledge to develop solutions						
This project improved my proficiency at technical writing (i.e. memos, email and reports)						
I am able to formulate a strategy to solve problems						
The project enhanced my ability to use ChemCAD to simulate a process						
I can develop a recommendation based on economic considerations						
The project enhanced my awareness of how market forces impact engineering decisions						
I am aware of how regulatory issues may impact engineering solutions						
This project enhanced my ability to run a meeting.						
I can summarize all significant discussions into meeting minutes						
This project enhanced my ability to extract process information from a patent						
This project enhanced my awareness of all of the steps in the design of a process.						
This project helped me learn good oral presentation skills						

This project enhanced my engineering judgment to develop a preliminary design						
This project enhanced my ability to develop a work plan that leads to project completion						

Teamwork Skills	**Strong Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Not Able to rate**
Teamwork is an important component of engineering practice						
The members of my team worked well together						
I enjoyed working on my team and would like to work on other teams in the future						
Participating in the team has helped my learning of chemical engineering						
Participating in the team has helped to develop my professional skills						
Getting to know everyone is important to team success						
My team did a good job of sharing the work load.						
My team balanced the workload across the project period.						
Having an organized work plan is important to project completion						
Dong well in ChE core courses is more important than learning team work for career success.						
Cooperation within the team leads to project success.						

Questions about the Project	**Strong Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Not Able to rate**
This project enhanced my understanding of chemical engineering.						
This project helps to build friendly connections between the students.						
Email was effective at communicating information within my team.						
The instructors clearly outlined the objectives for the VITDP experience.						
The instructors provided useful feedback.						
My team mentor provided useful feedback during the team meetings.						
Having industrial mentors was beneficial to the project experience.						
The VITDP project is organized to promote learning.						
The worklogs and journals helped me think about teamwork skills.						
The project grading scheme promoted good teamwork.						
This project enhanced my interest in chemical engineering.						

Questions about Yourself	Always	Usually	Some	Rarely	Never
I learned from other members of my team.					
My design team motivated me to participate.					
I was well-prepared for each meeting					
I invested enough time and energy to learn new skills.					
My level of participation on the project was high.					
I completed tasks on time.					
I provided constructive feedback and ideas to others in my group					
I enjoyed working with my team					
I am confident our team has done well in the project.					
Project grades will reward my contributions to the team.					
Overall, I gave my best possible effort to learning					

Peer Evaluation Survey

Please evaluation how well your group worked as a team. For each of the attributes below give a rating from 0 to 10 where 0 = never present in my team, 5 = sometimes demonstrated by team, 8 = often demonstrated by team, and 10 = always demonstrated by

Characteristics of the Team	Score (0-10)
1. Members committed to completing the project	
2. Individuals willingly took on tasks	
3. Decisions made after discussion	
4. Most tasks completed thru individual efforts	
5. Information readily shared within the team	
6. Members did their fair share of the work	
7. Team worked well together.	
8. Team trusted each other to complete assigned tasks	
9. Team formed a **we** attitude about project completion	
10. Little or no criticism of individuals	
11. Individuals did not withdraw from team effort	

Please rate how well each team member performed using the following scale: 0=poor, 1=fair, 2=average, 3=above average, 4=exceptional, blank=unable to rate

	Student 1	**Student 2**	**Student 3**	**Stduent 4**	**etc**	**Student 10**	**Student 11**
1. Provided direction to the team							
2. Willingly took on tasks							
3. Contributed to the group effort							
4. Cooperated with the team							
5. Showed initiative in making decisions							
6. Provided good ideas to move project towards completion							
7. Helped others understand concepts							
8. Helped others complete tasks							
9. Performance while chair or scribe of a meeting							
10. Worked hard on tasks given other commitments							
11. Quality of their efforts given their background							

12. Obtained information needed by the group							
13. Contribution to the written memos							
14. Contribution to the final written report							
15. Contribution to the oral presentation							
16. Contribution to the economic analysis							
17. Contribution to the process design calculations							

Project Grading Scheme

Individual Points	Pts		How we will grade
Attend all meetings (attend all = 2, missed any = 0)	2	Must total 10	Attend all = 2, miss any =0
Submitted worklogs	3		1 free miss, submitted all = 3, miss any = 0
Submitted journals	5		each journal subvmission = 1 point
Reviewed another team's presentation	1	Must total 20	Review sheet filled in =1, otherwise = 0
Participated during meetings	8		mentor sheets: score of 2 or 3 receive 2 pts per meeting
Completed assigned tasks	8		mentor sheets: scores of 2 or 3 receive 2 pts per meeting
Prepared for meeetings	3		mentor sheets: received 2 or 3 at each meeting = 3, miss any =0
	30		

Team Points			How we will grade
Submitted meeting minutes and memos	5	Fixed	0.5 pts for each memo and meeting minutes submitted
Design report well written	4	Report total is 20	Graded based on grammer, spelling, style
Included each required section of the report	2		all sections included = 2 pts, any section missing = 0 pts
Completed all 6 design tasks and project objectives	12		2 points for each task completed
Final recommendation based on sound tech. results	2		All or nothing: Final Report Score
Oral presentation: visual aids	8	Oral total is 20	From fac scores: 7-10 = 8 pts, 5-6 = 5 pts, 3-4 = 2 pts, else 0 pts
Oral presentation: presentation style and mechanics	6		From fac scores: 7-10 = 6 pts, 5-6 = 4pts, 3-4 = 1 pts, else 0 pts
Oral presentation: technical relevance & confidence	6		From fac scores: 7-10 = 6 pts, 5-6 = 4pts, 3-4 = 1 pts, else0 pts
Showed evidence of progress thru memos	5	Teamwork total is 25%	Increased memo scores and then maintained memos scores
Social Interdependency: no one excluded	10		Freshman and soph worklogs contain meaningful experiences
Teamwork based on peer assessment	10		Peer evaluations: average of Q1 - 10

Vertically Integrated Design Team Meeting Evaluation Form

rev 3.1 (9-26-02)

Team Number:				
Faculty Mentor:	Qammar	check one:		
Date:		present	absent with notice	absent w/o notice
special role (leader, scribe, or facilitator)				
	Sue			
	Brad			
	Mary			
	Jeff			
	Mike			
	Ian			
	Jasen			
	Brad			
	Jon			
	Jim			

Ratings

0 = extremely poor or missing
1 = poor or sub-par effort
2 = good, expected effort or result
3 = excellent, more than expected

		Rating	
Leader evaluation			
	kept meeting on task		
	maintained structured working atmosphere		
	all tasks and action items assigned		

F

Scribe evaluation			
	took notes on meeting proceedings		rate during meeting
	organized notes into accurate minutes		rate once minutes received
	distributed minutes in a timely fashion		rate once minutes received

Facilitator evaluation		
	kept meeting on time	
	encouraged/facilitated participation	

please email these 'scores' to cheung@uakron.edu

use the same 0-3 rating system

Members		**Jeff**	**Mike**	**Ian**	**Mary**	**Jasen**	**Sue**	**Jon**	**Brad**	**Jim**
	assigned tasks completed prior to meeting									
	brief report prepared prior to meeting									
	succinctly and clearly presented task results									
	participated in project/task/other discussions									
	participated in division of task labor									