Using a Vertically Integrated Team Design Project to Promote Learning and an Engineering Community of Practice

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Recent curriculum reforms in engineering education have focused on implementing the scholarship on pedagogy into the engineering classroom experience. For example, the paradigm shifts toward learner-centered versus teacher-centered delivery modes have been well established in many departments. In addition, department level curriculum reforms have begun to design integration of concepts and skills throughout the curriculum in response to ideas from constructivist theory on how students learn. In this paper we draw on theoretical models from cultural psychology and anthropology about the importance of designing an educational experience for engineering students that helps develop communities of practice and promotes student self-development[1-2]. Baxter Magolda argues that there are links between the epistemological, interpersonal, and intrapersonal aspects of student development that must be recognized if we are to move students forward in their educational and intellectual journey and development. Following the framework of Baxter Magolda,[3] we show how a freshman through senior vertically integrated team design project (VITDP) enhances learners' development on these multiple levels and moves them toward self-authorship.

In addition, we use the work of Lave and Wegner[2] to examine how VITDP helps students move from novices to experts in an engineering community of practice. 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 social interaction and represents a process of becoming, in this case an engineer. Thus, there is a focus on the relationship between identity within the community and cultural knowledge necessary to maintain and expand that identity. Tonso[4] 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".

Kegan[5] argues there is often a mismatch between what schools and society expect of people, and the abilities they currently have to meet those expectations. What is needed is a developmental bridge to help them cross over, a bridge that acknowledges who they are now and fosters the skills needed to move forward. The VITDP is specifically designed to act as such a bridge for students, and is based upon three developmental principles: 1) knowledge is socially constructed, 2) the individual's developmental stage is key in knowledge construction, and 3) this construction occurs through shared expertise. Data from VITDP show that students are able to move from absolute and transitional knowing toward contextual knowing and self-authorship[1,3,6] along an identity trajectory that moves them from novice positions toward expert positions[2]. This shift is facilitated by the structure of vertical integration that takes into account and holds students accountable to the three previously listed developmental principles. It is also facilitated by the use of assignments that foster these same principles, including the use of reflective journaling "as a vehicle for personal and professional development."[9] Assessments from the team project show that structures like vertical integration and assignments like reflective journaling facilitate students' transition toward self-authorship, creating "intentional learners" who are empowered, informed, and responsible lifelong learners.

Following the frameworks of Baxter Magolda and Lave and Wegner, we show how a freshman through senior vertically integrated team design project (VITDP) helps to provide a community of practice for engineering students, enhances learners' development on multiple levels, and moves them toward self-authorship. Drawing on data from participant observation, student work samples, student and faculty journal entries, student surveys, student and industrial mentor interviews, and student and mentor evaluations, we argue that the VITDP results in increased learning, not only about engineering concepts, but also about what it means to be an engineer and participate in an engineering community of practice. This project, while currently part of the chemical engineering program, is currently being explored in other disciplines, such as physics, and could be adapted successfully in other disciplines and areas, thus providing students with a more seamless approach to learning.

Structure for the VITDP

The VITDP is a vertically integrated design experience that is currently presented as four, co-listed single credit required courses that are taken in each year of the program. All students in the chemical engineering program register for the course at the same time during the Fall semester; different course numbers are used for the respective classes (freshman, sophomore, junior, and senior). Several factors contribute to the success of the project but the most important are 1) purposely constructed teams, 2) carefully crafted problem statements, and 3) attentive team mentors. Students and teams must also submit assignments that can be used to assess their progress toward meeting the course learning objectives.

Purposely-constructed teams consisting of freshmen through seniors come together to work on an open-ended design problem. The details of how these teams are assembled have been described previously[7] but will be described briefly here. Each student is first given an initial teamwork rating based primarily on evaluations from previous VITDP experiences. Then several rules are applied to construct the teams and include: 1) 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, 2) Add juniors to each team to obtain heterogeneity in both teamwork and technical skills (i.e. poor through excellent ratings), 3) Add sophomores and freshmen in order to provide leadership and technical balance to the team and to make sure that no team has an isolated female or minority student member; teams with mixed genders should have at least one female junior or senior. One of the first things that the teams must do is develop a team communication plan and resource list. This activity helps the teams to get acquainted with each other and determine their initial strengths and weaknesses.

The problem statement must be written to encourage each student to learn important engineering and other professional skills. The deliverables must therefore allow the teams to reach their milestones in the time allotted and include items that the less experienced members of the team can work on effectively. The senior members of the team should be able to easily understand the scope of the project. If written carefully, the project and its deliverables will emphasize the process of using a team format to meet project goals and allow each level of student the opportunity to learn something they perceive as valuable. For example, the fall 2002 project asked each team to design a process capable of producing 200 MM lbs/year of methyl methacrylate (MMA) by retrofitting an existing plant or using new MMA process technology. The deliverables from the project were a review of the patent literature, an estimate of the credit(s) to be used in the economic analysis, a market forecast for MMA demand, an assessment of the process safety, health, and environmental implications of the new technology, and a report on the potential public relations and financial impact of the 'green' nature of the proposed technology. This problem involved extensive information searches along with a conventional chemical engineering process design as well as critical decision points on economic, environmental and safety issues. The technical aspects were well within the grasp of senior and advanced junior students but these upper-level students relied on sophomores and freshmen to supply needed information for the critical decisions.

The project statement or VITDP structure does not assign project activities by academic level, these are left for the team to discuss and decide. All students are given a lecture on project management where instructors describe the benefits of matching project tasks with the interests and skills of the team members. We find that seniors and juniors typically spend 3-4 hours each week working on the project. They most often serve as meeting leaders and spend a majority of their time explaining concepts and context specific details to the lower level students. These details are important for effective and time-efficient information searches most often performed by freshman and sophomores. Many teams distribute the project action items so an upper-level and lower-level student work on related materials. For example, if feedstock materials costs must be estimated, a freshman student will be asked to look up pricing for the major commodity chemical feed stocks while a senior will locate prices for specialized catalysts or adsorbents. The senior will often explain where to look for pricing information and how to interpret the different price structures since they have performed pricing searches in previous VITDP projects. Freshmen and sophomore students typically spend 2-3 hours each week on the project but their contribution levels vary quite a bit. Very active freshman often 'hang out' with the more experienced students so they familiarize themselves with more aspects of the project and feel comfortable volunteering for tasks. These freshmen often serve as meeting leaders during the end of the project term with very positive response from their peers. Examples of project statements from the last two years are given in the appendix.

During the project period, each team is required to hold five one-hour meetings with either an industrial or faculty mentor who provides feedback on the team's progress and teamwork dynamics. 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. The mentor's job is to help the team function in a highly effective manner. At the beginning of the project, the teams that are likely to have problems completing the tasks because of teamwork issues are assigned the most attentive mentors.

Meeting minutes and progress memos are submitted by the teams. Students are asked to submit individual work logs describing their weekly activities as well as reflective journals. A final design report, a poster presentation, and/or a 15-20 minute oral presentation are graded by the project instructors.

Research Methodology and Theoretical Framework

This research is based on qualitative methods rooted in the naturalist tradition. This methodological perspective recognizes that there are: multiple, constructed, and holistic approaches to reality; that there is an interactive and inseparable relationship between the knower and the known; that it is possible to have working hypotheses which are time and context specific; and that all research is value-bound.[10] With naturalistic inquiry, it is impossible to utilize the same measures of trustworthiness as in experimental research using quantitative data. Complementary concepts for internal and external validity, reliability, and objectivity must be established to promote the trustworthiness of the study. Credibility, applicability, consistency, and confirmability are the concepts typically employed in qualitative research to provide trustworthiness in the results. Credibility (internal validity) is attained by prolonged and persistent observation and engagement in the research site, along with triangulation of data from multiple sources, methods, and theoretical perspectives. Applicability (external validity) refers to how well the researcher describes the context of the study so that readers can gauge the applicability of the study to their own sites. Consistency (reliability) depends upon the extent to which an audit trail of the research process and its link to the research product is provided, demonstrating that the data and results cohere and that competing hypotheses can be ruled out. Confirmability (objectivity) results from the organization and accessibility of research records, as well as on how well the researcher situates himself or herself within the study.[10] This paper utilizes these measures of trustworthiness.

Methods of Data Collection and Analysis

Data for this project come from the 2003-2004 and 2004-2005 academic year 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 reliability in the interpretation of data. Systematic methods for analyzing the qualitative data were utilized, including content analysis and grounded theory. Themes were identified in the data and then expanded into codelists that went through multiple revisions and developed into codebooks. The goal was to produce effective and reliable qualitative descriptions and make systematic comparisons of the data. In this paper we focus on the interpretation of the journal responses and the attitude survey.

Students participating in VITDP were asked to provide journal responses each week to questions that asked for self reflection about the course and their own learning. The responses were collected electronically and some feedback was provided to students to encourage deeper reflection. Bleich posited that journals should first encourage untutored, spontaneous feeling responses (affective responses) and then seek to expose the derivation of the feelings (associative responses). The purposes of the reflective journals were to “engage students in the construction of understanding and then creation of personal meaning and to focus on the implications, applications of science to one’s life”, and “to engage … students emotionally and personally”. [12]

Students are asked to fill out an attitude survey that includes sections which ask them to rate their own abilities. Students are asked to rank their skills on a scale of 1 -5, with 5 being the highest. The remainder of the survey asks them to indicate how much they agree with a particular statement (i.e., "Participation on this team design project improved my ability to use process simulators and other modeling software") on a scale of 1 -5, with 5 being "Strongly Agree". For the VITDP project, students were asked to fill out a Project Evaluation Survey at the end of the semester; this survey was found to be both reliable and valid.

The Shift to Self-Authorship

Students have been schooled for many years to accept teachers as authorities and to memorize knowledge. They believe that there are "correct" answers and that teachers know them. Traditional engineering courses reinforce this, with teachers as holders of knowledge and students as receptacles for learning. Helping students recognize that there are multiple ways problems can be solved and that knowledge is uncertain, socially situated, and self-constructed is a difficult process, characterized by dissonance and discomfort. More often than not, students do not reach the level of self-authorship during their college years, in part because they are not provided with opportunities to do so[1,3,5]. Baxter Magolda[1] argues movement toward self-authorship demands that "teachers model the process of constructing knowledge in their disciplines, teach that process to students, and give students opportunities to practice and become proficient at it".

This journey toward self-authorship needs to begin by connecting to students' own experiences, using these to promote critical thinking and to help them translate learning skills into learning experiences. A report by the National Science Foundation[8], *Shaping the future: New expectations for undergraduate education in Science, Mathematics, Engineering, and Technology*, recommends that college faculty: start with the student's experience, but have high expectations within a supportive climate; and build a sense of inquiry, a sense of wonder and the excitement of discovery, plus communication and teamwork, critical thinking, and life-long learning skills into learning experiences.

VITDP is a pedagogical and curricular tool used to help students practice and become proficient at constructing knowledge for themselves. It begins by recognizing where students are in their cognitive, interpersonal, and intrapersonal development, but also demands that they engage in new ways, with the material (epistemological), with others (interpersonal), and with themselves (intrapersonal). Kegan[5] describes this movement toward self-authorship as a holding environment, a transitional culture that accepts students where they are, but invites them to grow. The goal is to engage students in activities that: build on their experiences, knowledge and beliefs; promote the sharing of ideas with others; and give them opportunities for self-reflection and metacognition. VITDP promotes communication with self, through practices like reflective journaling, and with others, through a team based approach to learning. These experiences help students build teamwork and critical thinking skills and move toward self-authorship.

Narrating the Shift: Student Perceptions about Learning and Knowledge

In their reflective journals, many students narrated a shift in their thinking about how learning occurs, recognizing it requires more than just being in a classroom. Some students, like the three below, spoke about the importance of others in the knowledge construction process, recognizing the importance of the interpersonal dimension.

> *The part of teamwork that I never realized is that it is more focused on teaching others and learning from others on your team. This is extremely important for teams since each member has different levels of knowledge and various forms of technical or relevant experience. If teamwork was simply working together, rather than helping one another by discussing issues, teaching concepts, and understanding each member's ideas, the project would never get completed on time or a few people would end up doing all the work. By allowing everyone to bring forth their own ideas, the project continues to develop and take shape rather than being one-sided, which would be the case if only a few members contributed.* (MA-II:4)
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> *This was the best meeting I have ever participated in because we were all working together towards a common goal of learning about the process. We were all throwing out ideas and safety concerns faster than we could have written them down, and had a great discussion about a run away reaction due to auto-acceleration in the process. After the meeting, our team was happy and excited about what we had all accomplished together. We all sat down and wrote out the memo and started to write out the material balance and size the equipment for the preliminary design. I really enjoyed working with everyone because someone always had something to contribute to this process and our final goal. As opposed to working either individually or even in pairs we have a tendency to get tunnel vision of getting our task done and moving on. The whole team was brainstorming and asking questions. In my opinion, that meeting was so insightful that you could visualize the years of hard work, dedication, and talents of the team members as we all came together.* (RT-II:4)
>
> *I also believe that by working in teams with different types of personalities that you can benefit your communication skills and how to work together through a common goal.* (RT-I:2)

Rita and Matt, the students quoted above, speak about how important others were in helping them learn. "Different types of personalities" and "brainstorming" and "understanding each member's ideas" helped students learn as individuals, but also made the team more successful. Learning did not occur in a vacuum or from a book, but through the dialogue and interaction with others. Barbara Thayer Bacon says that: "As scientists, or philosophers, we must negotiate with each other in order to come to an agreement of "what is"….Individuals can and do make individual contributions to knowledge, but they do not do so as isolated individuals because they are community members".[11] "Relationships are central to the learning process because knowing others promotes sharing perspectives and sharing perspectives promotes adding to one's knowledge"[1].

Students also related how the interpersonal dimension of learning had an impact on the intrapersonal dimension. The final quote above shows how Rita perceived the interaction of her peers helped her with her own communication skills. Below, Rita speaks again about how the experience of working with others also helped her "feel more confident" about her own ideas, an important component in Baxter Magolda's schema.

I really enjoy working with different people on this project to help gain insight as to how they communicate and approach different ideas. This is an important experience to help myself feel more confident about my own ideas and communicate these ideas effectively to a wide variety of people as well as listen to their ideas and the way they communicate to me and each other. (RT-II:7)

Here, Rita narrates how working with others reinforced her own sense of self and her own ideas about the engineering project. Kegan[5] notes that it is difficult for students to create and maintain this sense of "self-as author, maker, critiquer, and *re*maker of its experience" (p. 133) because they have little experience doing so. Baxter Magolda[1,3] argues that self-authorship is only possible when students have "an ability to construct knowledge in a contextual world, an ability to construct an internal identity separate from external influences, and an ability to engage in relationships without losing one's internal identity" (p. 12).

Other students reflect on how their ideas changed over the course of the project, and detail their movement from absolute to more contextual knowing.

I feel like I had this set image of how a team should be operating and that I could guess as to all of the different problems and frustrations we would go through. Every situation is different, and always will be. (JS-II:5)

This student began with a "set image of how a team should be operating," but came to recognize that "every situation is different." Her understanding of a team changed because of the experience she had with VITDP, but what changed even more was her understanding of knowledge as contextual and uncertain.

However, other students were not as successful in this shift, still holding on to more absolute ways of knowing.

I understand that it is supposed to give us good practice and prepare us for real life project management and what not, but I think it has become incredibly difficult to "fake" these documents. I feel like we have less direction this year than last. It seems that our team, as well as the other teams, is kind of lost when it comes down to exactly what we are supposed to do. (JS-II:2)

Jocelyn describes how she felt the work they had to do was "fake," and how she felt "kind of lost" when it came to understanding what the team was "supposed" to do. In other journals, she describes how she feels the professors are not giving the teams what they need to accomplish their goals, have information that would help teams solve the problems, and have a set expectation about how the project should be completed.

Take it one step at a time. I have a hard time seeing the big picture when there is such a small bit of information given. I hope they give us more information along the way. (TC-II:3)

Interestingly enough all team members have expressed at one point or another that they do not understand what we are doing and what [the professor] wants. (TC-II:5)

Theresa describes similar frustrations in the above quotes. She wants more information from the professors, and indicates that team members assume the professors want something in particular, that they are not disclosing.

Theresa and Jocelyn describe the need to still see the instructor as holder of knowledge, that needs to be passed on to students who are willing recipients. Below, another student, Ed, again represents the shift from seeing knowledge as certain and given to uncertain and constructed.

> *The learning experience in the VITDP is an odd one. It is more an experience of self-revelation and personal discovery. I learn things through VITDP from experience. I also learn by answering my own questions. In the traditional classroom, I am instructed and asked very specific questions to which there are very specific answers. The learning is more structured and I believe that a greater quantity of info can be learned in this way. However, there is something to be had in the VITDP experience. You learn how to be resourceful and how to work in a high performance tem. Before the VITDP, my idea of a team was a group of people that solved a problem together. Now I believe that a team work better when they meet periodically to discuss the problem, but break up the work into individual tasks. Perhaps the result of the VITDP is a better quality of learning, but the lack of guidance during the VITDP (as compared to classroom) can make for a more stressful and overwhelming experience.* (EH-III:4)

Ed recognizes the stress and frustration resulting from being challenged to construct knowledge for oneself, but also recognizes the benefits, "self-revelation and personal discovery," that can result. In the interview excerpts below, students also speak about "real world applications," which they differentiate from classroom learning.

> *Then academically, seeing real world applications are a real process. And companies make this product this way. There may be some things over my head now, but maybe when I'm a senior it won't be.* (G Int. III)

> *For chemical engineering we did the VITDP project. We had kids from each class working together. It was interesting and somewhat useful. You don't have a professor telling you what to do. You get to do everything on your own.* (G1-S4:Int.)

These students saw themselves gaining valuable knowledge, skills, and dispositions from participation in VITDP that helped them learn from themselves, from each other, from the project, from the professors, and from the various other resources they utilized. This experience brought freshmen through seniors together with industrial mentors, helping to create a community of practice where all could participate and learn.

Situating Themselves as Engineers: Moving from Novice to Expert

Based on the student attitude survey administered at the end of the semester, 82% of the students agreed with the statement: "As a result of this experience, I learned things about engineering that I would not learn in the classroom." For underclass students this percentage was over 95%.Over 60% of all students said the project enhanced their ability to develop a work plan that leads to project completion and that they are now better able to formulate a strategy or process to solve problems. Students began to see themselves as more capable of taking on the tasks of engineers; they moved along the identity trajectory described by Lave and Wegner[2], moving each year toward increased skill level and expert status. While none of these students will become experts in any given year, it is clear they see a shift in themselves and their abilities, as well as in their conceptualizations of themselves as engineers.

Lave and Wenger[2] argue that in order for learners to gain the knowledge and skills necessary to become experts they must engage in a process of "legitimate peripheral participation" where they move from novices to experts by participating more and more in a community of practice. This positioning of learners, or novices to the community, on the periphery provides an opening and an opportunity for them to gain access to (re)sources for learning through growing involvement and participation.

> *As a senior, I feel that my role as a leader is somewhat different from the role that I took as a sophomore or freshman. My role now is to ensure that the underclassmen are getting involved and taking ownership of some of the project. Bluntly, a good team leader does not do all of the work alone, but ensures that everyone takes part in the project. At times, I feel that the upperclassmen may act as a mentor-figure to the underclassmen.* (JS-IV: 1)
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> *The benefits of this class are that they teach skills which are necessary to be a competent engineer in modern industry. In industry, you must get along with your coworkers, and many times your success will depend on how you communicate information with coworkers…Overall as much as people will complain, the knowledge gained by working with such a group is pretty valuable especially in the freshman and sophomore years. I think it is also important to create the interactions between freshman and senior members of the teams. I think, in the end, creating these "mentoring-type" interactions may help retention rates in our department. I know that I enjoyed sharing my experiences in chemical engineering and any advice with the freshman and sophomores, and I would like to think that they will appreciate the advice that we can offer them.* (JS-IV: 15)

Jennifer's comments reflect an awareness of how important it is to help bring first and second year students into the practice and community of engineering, and she recognizes her role as an upper-class student in doing this. In order for legitimate peripheral participation to result in learning, novices need to have real experiences in the community, and be considered as legitimate participants. Jennifer's journals reflect her acceptance as a senior of more novice first and second year students, and her willingness to help mentor them into the community of practice. She also recognizes how her role in the community shifted over the years, as she gained knowledge and experience.

This idea of juniors and seniors serving as mentors for underclass students is also voiced by Joshua, who speaks below about his role as a mentor, which he "knew, but didn't know."

> *I also came to the realization this week that the underclassmen in my group really look to me for guidance and support, with this project and with their academic careers. It was something I knew, but didn't know, if that makes any sense.* (JJ-IV: 11)

Students like Jennifer and Joshua are moving toward fuller participation[2] in this engineering community of practice, and recognize their role in helping newer students feel confident as novices in the community. Such mentorship is crucial to help more novices feel valued as legitimate participants.

Novice students often feel as if they have nothing to offer the group and no role to play in the community. Without help from more expert participants, their learning will suffer, since they are not recognized as legitimate participants. Lave and Wegner argue that for newcomers, participation in a community of practice provides a way of learning that involves "both absorbing and being absorbed in - the "culture of practice.""[2] Below, novice students speak about their initial feelings and frustrations, but also about how upper-class students helped them move toward feeling more valued and confident.

> *Last Thursday, my team gathered together in a computer room to do research and complete the work plan. I was nervous entering the room, but I found out that my team was very approachable. I was confused about the whole project. I didn't know the point of it or what we were going to be doing. The upper classman explained it to the freshmen, which made me feel more confident about the project.* (JSh-I: 2)
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> *In going back through my journals…I have also realized that I don't think I had enough confidence in myself as an important part of my team. Before, I felt like I would be stupid and wouldn't know how to do anything. Now, though, I feel like I was mistaken and that I do have valuable qualities to add to my team.* (EA-II:1)

Through their participation in VITDP, these students are able to gain experience in a community of practice that helped them absorb knowledge about engineering, and also helped absorb them as valued and valuable members.

Journal entries are only one form of data providing evidence of how VITDP functions as a community of practice for legitimate peripheral participation. Data from end of the year student evaluations also demonstrate this claim. A strong majority of first year students report feeling respected and responsible in the project, and 100% of them felt comfortable asking questions of their upperclass counterparts. This is exactly the type of result we would like to see, highlighting the importance of vertical integration to the project. First year students also reported an increase in their technical confidence, and well over 80% of them said they felt very comfortable with team discussions and taking on responsibility at the conclusion of the semester. Over 90% of first year students report they believed other members of their team depended on them for information or materials, and over 70% of seniors report they relied on other students to complete their project tasks. This collaborative interdependence helps upper level students mentor their peers with less experience, but provides more novice students with opportunities for legitimate participation. Another heartening statistic is that 96% of all first year students report that as a result of participation in VITDP, they learned things about engineering they would not have learned in a classroom. Below, a student puts these data in perspective, speaking about how the project helps students "become" engineers.

> *I feel that this project is very helpful in giving me an idea of what a real engineering career will be like. I know this because our mentor, [a female], was just talking last meeting about how this project is very much like the "real world." She was speaking of how she is a big advocate of the project because it is so helpful in letting students get experience with teamwork and working together towards a project goal. Another thing I am learning about engineering careers that I feel is important is presentation portion of the class. I feel that the presentation portion of this project is very good experience. Our mentor has also mentioned how she has to give presentations to clients on a weekly basis. I believe that this "real life" like presentation is very helpful in teaching me how to relax during technical presentation.* (EA-F-05S-II:13)

VITDP provides students with opportunities to learn from each other, as well as to learn from industrial mentors. They are able to move from peripheral to fuller participation through experiences that position them as legitimate participants in this community of practice.

Conclusions

When asked what they want to see in their future engineering employees, mentors for this program and others working in the industry say they are looking for workers who can think for themselves and who also know how to work in team situations and contribute effectively. Tonso argues: "What students must learn to become engineers extends well beyond the academic knowledge that is the central focus of most engineering curricula."[4] Helping students move toward self-authorship and legitimate peripheral participation provides them with a mechanism to become the kind of engineer industry demands today. While students (and teachers) experience frustration when confronted with these new demands and ways of learning, it does appear from this evidence that students are learning. Baxter Magolda argues that: "Teaching students how to self-author their own beliefs is a matter of creating conditions to promote their development"[1]. VITDP is working to create those conditions, recognizing that we must continually reflect on and refine the process. For us, the conditions include vertical integration where more novice students work alongside more experienced upperclass students in a project that simulates a "real world" practice, and where all participants are valued in the community.

Appendix

Fall 2003 Polyols Plant Safety and New Venture

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 demand in the Ohio Valley. This will be the first polyols plant Ukron has built. Your team is to rough up a preliminary design using conventional polyols processing technology. We may need to license from BASF. Their Pluracol product line is produced using technology very similar to what we'll likely want to use. 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.

Key design targets for the new plant:

- Total operating time: 8000 hr/year
- 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.

Fall 2004 Investigation of a Hydrogel Drug Delivery Product

Ukron has held recent discussions with PharmX, a national pharmaceutical company, interested in forming a partnership. The new entity would combine our expertise in hydrogel polymers with patented compounds from PharmX for the controlled drug delivery market. PharmX is particularly interested in hydrogel drug delivery via transmucosal (buccal) membranes. We need to know whether some of our hydrogel products may be candidates as well as other issues related to market potential including profitability, regulatory concerns, and risks and opportunities. Management is waiting for a preliminary study before continuing the negotiations with PharmX.

Your team should be prepared to deliver an oral report to project management and corporate planning on the elements listed below. In addition, your team will be scheduled to make a poster presentation to PharmX on the effectiveness of our hydrogels. They will discuss with your team the technical concepts from your experimental study. Further details on the schedule for the oral and poster presentations will be forthcoming in the next memo.

Experimental Feasibility Study

PharmX has specified a set of specifications for the possible hydrogel and two of our products have been selected as test candidates. Your team should plan a series of experiments to determine if these hydrogels meet the objective of drug release for at least 24 hour duration. In lieu of the actual drug compound, a suitable dye has been selected for your testing. Once your experimental plan has been approved, you will need to perform the following studies for each hydrogel:

1. Swelling study to determine swollen weight and time to swell
2. Loading study to determine amount loaded and loading efficiency
3. Release study to determine total release time, rate of release, and drug dose per time.

Background Study

This is a new area for Ukron and it is imperative that your team provide sufficient background information to assist Corporate Planning in their decision to continue negotiating with PharmX. It is important that you clearly and succinctly report on the following issues keeping in mind the objectives for Corporate Planning.

1. Summary of the advantages and limitations of controlled drug delivery systems, the role of hydrogels, and any issues related specifically to drug delivery via transmucosal membranes. As part of this investigation, consider whether the intended drug delivery mechanism has any issues related to dosing effectiveness and patient compliance.
2. Market analysis including pricing, potential competitors currently in the hydrogel drug delivery business, market forecast.
3. Drug delivery may introduce a number of new regulatory concerns for Ukron. Summarize the most significant regulatory implications particularly those related to possible changes in our manufacturing protocols (see cGMP current good manufacturing practices) and issues related to FDA approval. Management is particularly interested in whether the merger will entail acceptable costs and risk.

Plausibility Study

Negotiations with PharmX may include a number of other issues. Corporate Planning has asked that your team provide them with additional information on the following questions: 1. Does the current literature suggest the type or category of drug compound that would be a suitable candidate for this specific application, i.e. transmucosal drug delivery using a hydrogel? 2. For this specific application, is the scientific knowledge base well established or would the newly merger corporate entity be primarily involved with research and development before products can be delivered to the marketplace.

Since this is an unusual project for Ukron, your team should start by describing the project milestones and initiate a project plan using these milestones. Detailed activity planning is expected to be ongoing throughout the project period. Details on the schedule and procedure for weekly reports to management will be sent to your team soon.

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