Engineering Change for Women in Engineering: The Role of Curricular and Instructional Change

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Introduction

Women currently make up 56% of all undergraduates but remain underrepresented in almost all science, technology, engineering and math (STEM) programs. This trend certainly holds true in engineering at the University of Akron, where women constitute only 18% of the engineering student population. In addition, while women's representation in the workforce has increased, their representation in the science and engineering workforce has remained stagnant or declined (Clewell & Campbell, 2002). Given these numbers, it seems imperative that university engineering programs focus efforts on the recruitment and retention of women. Tonso (1996) argues that "engineering education must change before inclusion of women is realized" (p. 217), and that this change must represent substantive changes not only to the curriculum, but also to the very culture of engineering education.

One response to this problem is to develop and implement curricular and instructional strategies that move to restructure the cultural norms in engineering education in ways that are more inclusive of and effective with girls and women. We argue that an innovative new program in Chemical Engineering at the University of Akron, the Vertically Integrated Team Design Project (VITDP), provides the tools to enact this cultural shift. Our data suggest that women who participated in VITDP experienced increased opportunities for participation and leadership, thus helping them to hone their engineering skills and boost their self confidence regarding their engineering abilities. In addition, many of these young women articulated how the project helped them feel connected—to their own experiences, to others, and to the material —and how they learned more as a result. We believe the increased opportunities and self-confidence women experienced are the result of cultural shifts in how chemical engineering education takes place at The University of Akron, influencing not only how women, and men, learn chemical engineering, but also what they learn about the meanings of engineering practice and culture.

Gender Equity in Science and Engineering Education

Gender equity is most often defined as equality for all genders and sexes (Arambula-Greenfield & Feldman, 1997; Lynch, 2000). More specifically, gender equity means parity in quality and quantity for males and females (Rodriguez, 1998). A definition of gender equity, in reference to science education, might be equality of gender representation in those who do science as scientists. However, in light of the standards movement's documents such as Science for All Americans (Association for the Advancement of Science, 1989) and the National Science Education Standards (National Research Council, 1997), gender equity might also be achieved if the same numbers of male and female students have the opportunity to do science. In other words, equity is achieved when all students have the knowledge, tools, and dispositions to do science (Kahle, 1996). Mason and Kahle (1998) argue that: "Women should be recognized as being as capable as men" (p. 37), and define gender equality as "attaining full and fair participation in educational programs in science" (p. 28). Consequently, equity is equal opportunities for both boys and girls to succeed in science (Levin & Matthews, 1997). However, equity in science learning reflects broader responsibility, embodied by the social justice model: the obligation to prepare all students to participate in a postindustrial society with an equal chance at attaining the accompanying social goods—rights, liberties and access to power (Lynch, 2000, p. 16).

In order for the science learning to be equitable, it is necessary to have "full and active participation in a contextually equitable classroom" (Krockover and Shepardson, 1995, p. 224). Lee (2003) posits: "from an anthropological perspective, science teaching should enable students to make smooth transitions in border crossing between their everyday cultures and the culture of Western science" (p. 473). Hence, "equity comes to depend on not treating people the same ways but in ways that are sensitive to differences" (Gaskell, et al., 1998, p. 865). Some of the current discourse on gender equity in science education focuses on empowering students to transform science in a direction that "denaturalizes conceptions of one singular, whole, and 'acceptable'" (Miller, 1998, p. 320) science to something that is more representative of the fluid and multiple meanings, experiences, and identities that students bring with them to their science education. Tonso (1996) argues for a shift in the cultural norms of engineering education in order to truly move toward a more inclusive and responsive practice. VITDP attempts to create such a cultural shift, and this paper presents some of our early findings about how well the program is doing in this regard.

Curricular Structure for VITDP

The VITDP is a vertically integrated design experience that is currently presented as four, single credit required courses that are taken in each year of the engineering program. All students in the chemical engineering program register for a co-listed 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 are considered in this educational experience but the most important are 1) purposely constructed teams, 2) carefully crafted problem statements, and 3) attentive team mentors. Students and teams submit assignments that can be used to assess their progress toward meeting the course learning objectives.

Team Construction

Purposely-constructed teams using the same criteria to ensure heterogeneity have been implemented for the last 5 years. The details of how these teams are assembled have been described previously (Qammar, 2003) 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 heterogeneous teams which 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. Mixed-gender teams typically have a senior-woman who has received excellent ratings. Finally, we purposely construct an all-women team since the above stated rules and the larger numbers of male students always yields a corresponding all-male team.

As noted by Tonso (1996), the use of teams does not necessarily mean more inclusivity for women, and "the customary strategy of assigning at least one woman to each team resulted in isolating women students from each other and significantly disadvantaged lone women students" (p. 217). VITDP teams are specifically constructed to always include at least two women in order to avoid these pitfalls and increase the potential for the participation and learning of women. The same rationale is used for the inclusion of freshmen students on the team, and all teams have at least two freshmen on them. The purposeful construction of teams for the project is one example of how faculty members work to insure positive outcomes from the VITDP experience. In addition, the course is team-taught by three different faculty members from the Department of Chemical Engineering, two males and one female. The three share teaching time in the whole group class setting and demonstrate the process of a team-based approach in their teaching. The teaching team, along with members of the research team, met weekly to discuss the course and planning. This framework is far different than that described by Tonso where the male teacher took control, marginalizing his female counterparts. Students saw all those involved with the teaching as integral to the course, learning important lessons about how team-based approaches can work in an engineering education setting.

Problem Statement Construction

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 will rely on sophomores and freshmen to supply needed information for the critical decisions.

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.

Role of Mentors
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. We do not consider the gender of the mentors when assigning them to a team.

Methods of Data Collection and Analysis
Data for this project come from the 2003-2004 and 2004-2005 academic years and include participant observations of the VITDP course and student team meetings, documents generated by faculty and students during the course, student journal responses, student attitude surveys, a Project Evaluation survey, interviews with students, and short answer questions given out in class for students to answer. The variety of data collected provides greater capability for triangulation and thus greater credibility in the interpretation of data. Systematic methods for analyzing the qualitative data were utilized, including semantic domain analysis based on Spradley's systematic procedures (1979, 1980) and Van Maanen's use of vignettes (1988). Careful, repeated readings of the data by multiple faculty members involved in the project provide credibility and consistency to the research. The goal was to produce effective and reliable qualitative descriptions and make systematic comparisons of the data. In this paper we focus on the use of journal responses since they provide the richest source of data; the other data were used to make sure our interpretation of the journal responses is reliable.

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 (1975) posited that journals should first encourage untutored, spontaneous feeling responses (affective responses) and then seek to expose the derivation of the feelings (associative responses) (p. 17). 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" (p. 11), and "to engage … students emotionally and personally" (p. 11).

Interviews of some VITDP students occurred at the end of the semester or early in the following semester. Interviews were transcribed, coded, and then analyzed. We attempted to interview a range of students, from freshman to senior, male and female, those who enjoyed the project and those who did not. We feel this range provided us with access to multiple perspectives and ideas about VITDP and what participants experienced in it.

Women's Learning and the Role of VITDP
The work of Belenky, Clinchy, Goldberger and Tarule (1986) raises questions about the role of gender in how we come to know and learn. Their research demonstrates that many women come to know things in different ways than men, and that, generally, women are more likely to acquire

knowledge through connection with the self and others. Belenky and her colleagues also found that even women who were adept at abstract reasoning, like those who would be attracted to STEM disciplines, still preferred to use personal experience as a starting point for understanding. De Courten-Myers' (1999) work in the area of brain research also reports that learning is often contextual for women, and that they tend to integrate facts and understanding into a broader context, while men are more likely to consider and examine facts and ideas in isolation. Given what we know about the ways in which girls and women learn and react to teaching/learning situations, it appears that traditional teaching methods may not be as effective with this population. This may be just as true for male students, as for female students (Baxter Magolda, 1999). Much of the recent research on effective strategies for teaching focuses on the positive benefits of cooperative learning, small-group instruction, inquiry-based approaches, and activity-based methods, all of which work particularly well with girls and women (Clewell, Anderson & Thorpe, 1992; Fox, 1996). VITDP draws on many of these same strategies in unique ways to provide all students with opportunities to move from absolute to contextual knowing (Baxter Magolda, 1999), with particular benefits to women in the program.

Situated Learning and VITDP

This study is also informed by Lave and Wegner's (1991) theory of situated learning, an anthropological theory focused on out-of-school learning sites and experiences based on traditional apprenticeship models. Prior research by Tonso (1996) moved this theoretical perspective from learning which takes place outside a school context to one specifically focused on examining engineering education within the school context. Situated learning theory focuses on how cultural knowledge is constructed and maintained within a group over time, and specifically how people move from novices to experts within the group. Situated learning theory posits that learning takes place within the processes of social interaction and is grounded in communities of practice.

VITDP helps to create a community of practice where engineering students have access to cultural knowledge and where novice practitioners are able to contribute to the activities of the community because they are working alongside their peers and those with skill levels close to their own. A major focus of this perspective is on the process of becoming, in this case an engineer, and hence on the relationship between identity within the community and cultural knowledge necessary to maintain and expand that identity. Lave and Wegner's work focused on how identity continuously changed as novices moved along an identity trajectory from novice to expert, where different skill levels and acquisition of knowledge distinguished a participant's identity and guided how he/she accomplished tasks within the community. Thus, Lave and Wegner developed a process model to explain how knowledge, identity, and task organization interacted to move participants from novices to experts within any given community of practice. Tonso (1996) argues that: "Because engineering has persisted through time as an endeavor with historical, cultural, and social meanings, it resembles the communities of practice where Lave and Wenger grounded situated learning theory" (p. 145). We use this theory as well to explore how men and women responded to the process of VITDP and whether this process helped them develop along the identity trajectory from novice to expert.

The Importance of Connection in Team-Based Learning
In addition to a team-based approach to teaching, students learned from participating in a team-based approach to learning. For example, many of the student journal entries addressed this issue, highlighting several different aspects of teams that contributed to their own learning. These included: learning from others; working together for a common goal; learning as occurring outside of books and classrooms; and learning by doing. As many students reflected on and wrote about their experiences with VITDP, it became clear they were becoming more confident as learners and saw themselves as part of the teaching and learning process. This was especially true for the responses of women.

> *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-F-04F-II:1)

> *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. Being a freshman, I was not sure how I would be able to contribute to the project, but after discussing the work plan, I realized that Tools class would help us understand and give us background information*. (JSh-F-04F-I:2)

These students both articulated the importance of the team in building their confidence and helping them recognize the contributions they could make. In their first journal entries they wrote about their fears regarding engineering knowledge, but by the end of the project, they were able to see themselves as capable learners and stronger engineering students. According to Belenky and her colleagues (1986), a male model of instruction provides confirmation of the self as a learner at the end of the process. "Confirmation as a thinker and membership in a community of thinkers come as the climax of Perry's story of intellectual development in the college years" (pp. 193-194). However, the women in their study needed validation as learners from the beginning. They needed "confirmation that they could be trusted to know and to learn" (p. 195). Emma and Jocelyn, quoted above reflected the same sentiments; for them, VITDP provided early confirmation of the self as knower, thus enabling them to participate as valued and knowing members of the team and the engineering community of scholars.

Another mechanism by which students came to see themselves as knowers and as legitimate participants in the project, was a teaching style that relied on sharing the process with students. "So long as teachers hide the imperfect processes of their thinking, allowing their students to glimpse only the polished products, students will remain convinced that only Einstein—or a professor—could think up a theory" (Belenky et al., 1986, p. 215). Teachers in VITDP worked very hard to share their learning processes with students, relating how they were learning with the students and how going through the process was as important as the final product. One example of this occurred in the course during a discussion about how to engage in reflective journaling. Researcher fieldnotes demonstrate how one of the teachers used his own examples of reflective journaling in an overhead with the class. He noted how this was new, and somewhat foreign, to him as well, and how difficult it was to do for someone who was not used to it. He talked about working with another colleague to develop his journal writing and how he had to work through what it meant to be reflective versus <just describing my actions or thoughts> (FN:1:2). One student sitting next to one of the project researchers seemed truly amazed that a professor spoke as if he did not have all the answers. She leaned over and said to the young woman next to her: "Wow, so they don't have all the answers all the time either." Her friend replied: "what's even more amazing is that they'd let us know that!" These students, both women, exemplified the stance of students who have come to see teachers as holders of knowledge and information, omnipotent in their command of thinking and content. They were amazed, and as the next statement demonstrates, pleased to have a teacher who demonstrated vulnerability and openness about his own learning. "I'm impressed. Maybe this [VITDP] won't be so bad."

Linked to the idea of validating the self as a knower is the idea of collaboration and the importance of learning from others as well as the self. Below, several students reflect on how the VITDP process allowed them the opportunity to engage with others in a collaborative effort that helped them construct knowledge together.

> *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-F-04J-II:4)
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> *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-M-04S-II:4)

These students, a female and a male, respectively, narrate how VITDP helped them work with others to learn new things, individually and as a team. Members worked together to nurture each other, to teach and learn from one another. Such work helped them construct new knowledge as they engaged in a meaningful, participatory environment. Seymour and Hewitt (1997) argue that: "some aspects of the learning environment in which women feel most comfortable—particularly cooperative, interactive and experiential learning contexts—are also congenial to many young men, and encourage the development of skills and attitudes which have increasing value in occupational and social contexts beyond academe" (p. 314).

For such connected teaching to be effective however, it is imperative that a sense of comfort and trust be established in the group, especially for women, who often deal with “stereotype threat” (Steele, 1998). Stereotype threat exists when a negative stereotype is present in the society (for example, that girls are not as good at science as boys), and when a person sees him/herself as part of the group to which the stereotype can be applied. In this situation, the person understands that he/she could be judged or treated differently because of the stereotype, or that something he/she does could confirm the stereotype, whether intended or not. In order for VITDP to work effectively, all members needed to feel comfortable voicing opinions, asking questions, and trusting themselves and their team members, as depicted in the following quote.

> *Along with trust and letting other people contribute I think it’s highly important to feel comfortable with everyone on the team. Maybe it’s just because I’m such a people person, but I think it’s important to have some sort of connection with your team. Even if that connection is just to succeed in the project.* (JS-F-04S-I:1)

While Justina, quoted above, wrote in her first journal entry about the importance of connection in teamwork, her comments below indicate that her initial experiences on the team did not confirm this ideal.

> *My team didn’t really seem to fit together. I was totally excluded from their conversation and when they asked for my input I gave it, then it was eventually ignored. I was completely disappointed by the outcome of yesterday.* (JS-F-04S-I:2)

> *This week, I suggested getting together so the underclassmen could get some help from the upper classmen as to what exactly is going on. So- yea, they definitely liked the idea, but they planned the meeting time around everyone’s schedule except mine and another one of our team members. I know it isn’t likely that we are all going to be available all the time, but I think it’s kind of aggravating considering it was MY IDEA…and I got excluded.* (JS-F-04S-II:5)

Justina felt excluded, and when asked by a team observer why she thought that was, she replied: “Who knows? I’m just a sophomore, I’m just a dumb blonde, I’m just a girl. Take your pick. But I’ll prove them wrong.” She recognized the many stereotypes these categories held and the power they had to define her. She also perceived them to be getting in the way of her team coming together in a positive way.

However, most students, especially the women, did feel that VITDP provided a venue for such connection, and thus for greater learning to occur. Three typical comments from women participants are:

> *As long as everyone considers others’ ideas, there should be no tension in the group. A successful team needs everyone to contribute and contribute to the best of their potential. With communication and a good work ethic, the project should be successful and everyone should have fun.* (JSh-F-04F-I:1)

> *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-F-04J-I:2)

Through the VITDP I can learn how to work with other individuals on a project that I have no expertise on. I can learn how groups work and operate among and through the tasks given, and among and through the social aspects of group integration. (TC-F-04F-I:2)

These women all expressed the same hope about connection that Justina had at the beginning of the semester. However, by the end, their journals all reflected that their teams had connected in the ways they had initially hoped. They detailed how they all learned more from the experience, and how this learning might not have taken place if their teams had not gotten along so well.

Connection is a major theme in the education of women, and one highlighted by the experiences of women in VITDP: connection to self, connection to others, and connection to learning. When these connected elements are in place, all students, and especially women, are more likely to move forward in their cognitive development. "We believe that connected knowing comes more easily to many women than does separate knowing" (Belenky et al., 1986, p. 229). The development of curricula like VITDP that promote multiple forms of connection for and with students has the potential to help women "be comfortable participants in the world of science and engineering" by working "to eliminate the barriers erected by society to women's equal participation in SMET fields and to rebuild the scientific enterprise as an environment where women and girls can flourish" (Clewell & Campbell, 2002, p. 278).

Being a life-long learner is what I hope to see happening as my group emerges from the project with a better understanding of not only the project and group dynamics, but also of each other. (TC-F-04-F-I:2)

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 [sic] ....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-M-04S-III:4)

The words of these students demonstrate the power of connection in the teaching and learning process, the power present in an educational experience like VITDP. "There is something to be had in the VITDP experience" and it is this something that will help students develop into lifelong, connected learners.

Structures to Help Students Move Toward Legitimate Peripheral Participation

VITDP has several structures in place to help students move along the identity trajectory necessary to move from novice to expert. One of these structures is the use of industrial mentors in the weekly team meetings. These mentors serve as guides and facilitators for students in the program, providing helpful feedback and "real world" experience. Several of these industrial mentors are women, providing women on different teams with positive role models. In responding to the prompt below, Emma, a sophomore student, spoke about how important her industrial mentor was to the team, and to her. She learned a lot from her mentor, making her feel more like an engineer herself.

> Prompt: One goal for PMT/VITDP is to prepare students for engineering careers. Describe some specific examples of what you are learning about engineering practice. How are you learning this (or how did you learn this) and from whom? *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)

Team construction using gender as a factor also plays a role in the learning experience. Insuring that no team had solely underclass females contributed to more positive VITDP experiences for those students. Each year, there is one team comprised of only women creating the opportunity for a unique community and peripheral participation. Emma was on the all woman team this year, and had this to say about it.

> *I know that some of the girls and I had talked about how we were afraid to be on the all girls team. Well, not afraid, but kind of dreading it. I felt the same way at the beginning of the semester. Too much in life strong females get labeled as "bitches" or "bossy" and I think this is why many of the girls on my team, as well as myself, felt reserved about being on the "female team." However, we all said that this was a really good experience, and nothing like we had expected. Everyone got along so well, and we worked so well as a team. Everyone from freshman to senior helped this project come together and be successful*. (EA-F-05S-II:15)

Sarah, a senior on the all-women team who expressed similar reluctance at being assigned to the all-women team at the start, had this comment at the end of the project "I was really glad you assigned me to *this* team. I truly enjoyed it!" The other senior on the all-women team had been assigned to a mixed-gender team in previous years and had extremely low participation scores. When asked to reflect on individual commitment she writes,

> *Since I am a senior I feel that the whole team is expecting so much from me. They look up to me when it comes to explaining things or answering questions. I feel that I can not let them down, so I have to be committed 100% to this project. ... I have to have an eye on everything that is going on the team. It is time consuming but I love it.* (MZ-F-05S-II:7)

In the statement above, Emma articulated common perceptions of women who adopt "masculine" traits of strength and assertiveness, recognizing she did not want to be perceived in this way. However, participating on the team with all women allowed her to recognize the positives of collaboration and helping each other, traits often associated with women and weakness. Emma's initial reluctance and fear associated with being on this team dissipated over the course of the semester, allowing her to move toward more concrete understandings of herself as a legitimate participant in engineering. Her journal response below indicates how much she thinks she has grown as an engineer, moving closer to expert status with each year she participated in the project.

Overall, I feel that a lot of students don't like this project because it is so time consuming for only one credit. However, I see how important and helpful this project is. I can see how just from last year to this year I have grown from it and look forward to finishing up this one, and seeing how I grow through next year. (EA-F-05S-II:13)

Conclusions

In this paper we present a qualitative study of the learning opportunities presented by a unique vertically integrated team experience, particularly for female students. Connection is a major theme in the education of women: connection to self, connection to others, and connection to learning. We believe the statements from our students show that VITDP does reinforce the feeling of connection for women in general although it may also hold equally true for men as well. Our women students describe learning from others, an enhanced confidence in their abilities and connections to an engineering community of practice. Thus, VITDP provides structures for students to move from novices to experts, structures that also serve to improve the learning experiences of women in the program. As faculty in the program continue to learn and grow from these results, the project changes and grows as well, improving from one year to the next. Our hope is that these results can help us move forward in our practice of engineering education, and provide a positive formula for others looking to enact curricular and instructional changes that will help all students become better prepared for their futures as engineers.

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