AC 2012-3319: THE IMPACT OF CONTEXTUALIZED, HANDS-ON, COLLABORATIVE LEARNING ON WOMEN'S PERSISTENCE IN PROFESSIONAL ENGINEERING: PRELIMINARY FINDINGS FROM A MIXED METHODS STUDY

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The Impact of Contextualized, Hands-On, Collaborative Learning on Women's Persistence in Professional Engineering: Preliminary Findings from a Mixed Methods Study

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Abstract

As many of our female students desire to develop a successful career in industry, of particular interest is how contextualized, hands-on, collaborative learning contributes to their self-confidence and persistence in engineering. While research has indicated that active learning activities and cooperative experiences foster deeper learning and have an impact on persistence in the engineering workforce, there is limited empirical evidence of women's professional persistence and self-confidence as a result of this type of educational experience. Preliminary findings from a validated survey instrument, the General Self-Efficacy Scale (GSE), the Academic Self-Efficacy (ASE), and the Professional Self-Efficacy (PSE) are presented. Key findings of what these women learned and appreciated, insight into the variations across the participants is provided as supported from interview transcripts, and professional career path goals are presented. These findings can aid engineering departments, diversity offices, career service offices, and industry review boards to foster academic experiences to improve women's persistence and success in professional engineering.

Introduction

Undergraduate engineering students who participate in contextualized, hands-on, collaborative learning such as the Society of Automotive Engineer's Collegiate Design Series, CDS, reap many benefits from this type of experience. The Collegiate Design Series is a set of design competitions held throughout the world where both undergraduate and graduate students conceive, design, fabricate, and compete with their built project vehicles. Examples of CDS are: Aero Design, Baja SAE, Clean Snowmobile Challenge, Formula SAE, and Super Mileage. The safety requirements and design standards are structured to challenge the students' knowledge, creativity, and imagination. In addition to providing a meaningful, significant engineering activity, CDS creates the opportunity to begin building a sense of expectation and understanding of the professional engineering workforce – specifically fostering communication skills, promoting teamwork needed to solve complex problems, and increasing engineering self-confidence. Additional skills and benefits students gain are: (a) developing engineering self-confidence, (b) fostering a positive attitude about professional engineering, (c) applying skills and knowledge gained in the classroom to a real-world problem, (d) learning to work with teams in a professional atmosphere, (e) gaining hands-on experience in a real-world situation, (f) learning to develop and compare multiple approaches to solving complex open-ended problems, and (g) increasing their opportunity to be hired post-graduation. The success that the Collegiate Design Series has sustained since its establishment in the 1970's indicates that participation yields high-performing and exceptional students.

Many universities tout co-operative education opportunities to help bridge the gap between a standard engineering curriculum and the engineering workforce, however recent research indicates that there are still significant gaps in the skills required to be a successful professional engineer and what skills are gained through the undergraduate curriculum and co-ops[12]. Several of the skills not addressed by co-ops are –

- applying interpersonal skills in managing people
- gaining leadership skills
- managing the planning and organization of project tasks
- conveying ideas
    - verbally
    - in formal presentations.

Thoughtful integration of the Collegiate Design Series can provide an opportunity for women to develop these skills critical to success in engineering academically and professionally. However, the Collegiate Design Series is historically very heavily male-dominated, and participation is not an avenue traditionally pursued by females. Leadership opportunities presented to female participants are often limited as few of the females feel confident enough to lead such a technically embedded, hands-on team of male peers – who are usually more experienced in the technical and hand-on applications of the Collegiate Design Series and as such are more comfortable to assume and keep leadership roles. Often female participants are relegated to more traditional female roles on the team – writing the technical report or developing the cost report and as such they are often denied the opportunity to foster and improve the critical skills identified above essential for success in an engineering career. According to the National Science Foundation[5] in 2009 only 11 percent of practicing engineers are women, as compared to the 17.8 percent of women graduating with undergraduate engineering degrees. While the number of engineering degrees awarded since 2000 has increased from 59,497 to 69,895 in 2008 very nearly *all* of this increase went to male students, as such the number of females earning undergraduate engineering degrees has dropped two percent; Figure 1 documents this negative trend. There has been an equal percentage increase in the number of women pursuing graduate degrees in engineering, Figure 2 shows this increase. Published reports call for contextualized, hands-on, collaborative learning experiences to have a greater and lasting impact on women's persistence in engineering[3, 4, 7]. In an effort to promote engineering as a viable career for women, in 2005 we developed and implemented an all women's CDS team to provide female students the opportunity experienced by many of their male counterparts.

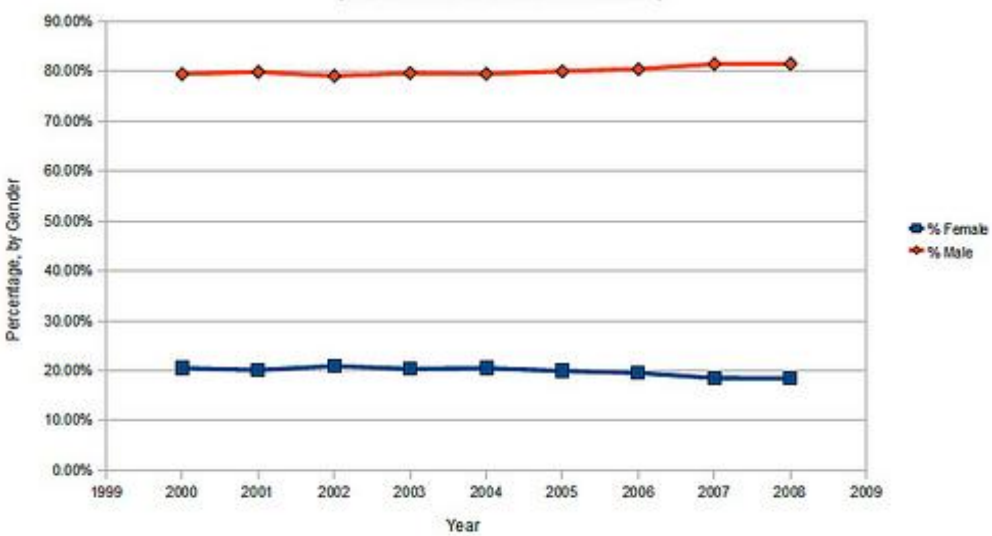

Figure 1: Percentage of bachelor's degrees awarded in engineering, by gender (2000-2008)[5]

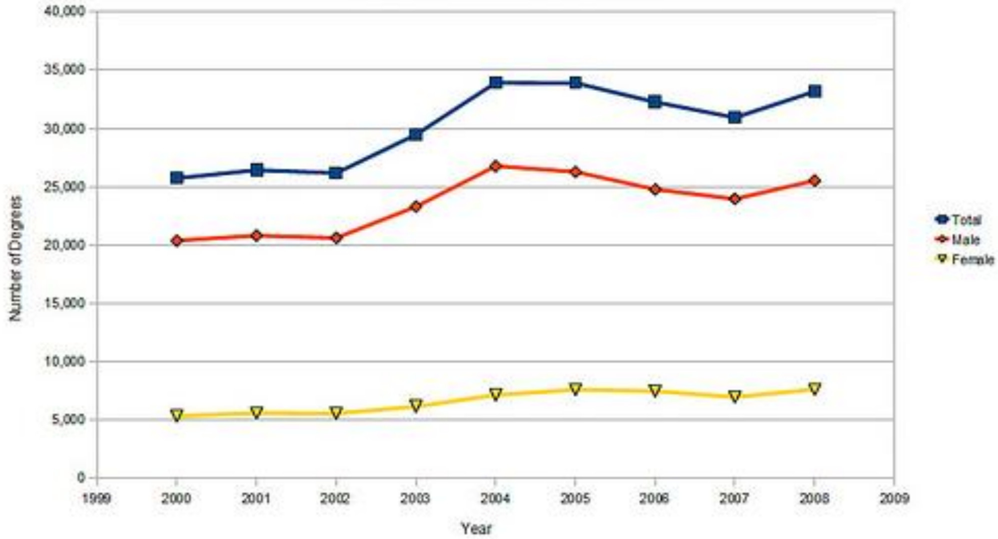

Figure 2: Number of master's degrees awarded in engineering, by gender (2000-2008)[5]

Although studies have looked into the overall positive impact of hands-on, collaborative learning, (increased earning, improved understanding, and broadened, international, cultural awareness)[6, 8, 12, 17] the impact of participation in the CDS on women's engineering self-efficacy and persistence in engineering is understudied. Possibly contributing to the limited research are two factors: (1) limited number of females participating in the CDS, and (2) perceptions of hands-on activities as vocational instead of properly academic and their subsequent relegation. In spite of the repeated calls for contextualized, hands-on, collaborative learning experiences[4, 7, 11, 13, 14, 16] less than 3% of the engineering students from the US have participated in CDS[2]. It stands to reason the percentage of women participants is significantly lower.

There has been a steady call to increase the number of practicing women engineers, but in spite of increased federal funding and increased outreach programs the number of women who persist in engineering as a profession is quite low especially when compared to the number of women graduating with undergraduate engineering degrees[5]. An often quoted primary reason for women leaving the field of engineering is family choices and therefore the exodus cannot be stemmed. However a recent NSF report offers a more precise explanation for women leaving the field. The report cites that while some women do leave for family more leave (30%) because of the organizational climate and a lack of interest to persist in engineering[4]. It is time to begin better preparing our women graduates for professional engineering and providing the much needed skills and self-confidence required to persist and to succeed; the CDS offers such an opportunity.

The purpose of this research is to explore the impact of participation in the CDS on women's self-confidence in an engineering profession and to discover how they persisted in engineering since graduation. The specific research questions framing this investigation are:

1. What are the specific professional engineering skills gained as a result of participating in the Collegiate Design Series?
2. What experiences (positive and negative) from their participation in CDS contributed to their persistence in engineering professionally.

We implemented a survey instrument: the General Self-Efficacy Scale (GSE). The scale was created in 1979 to assess a general sense of perceived self-efficacy with the intent to predict coping with daily hassles as well as adaptation after experiencing a myriad of stressful events. Self-efficacy is defined here as "facilitating goal-setting, effort investment, persistence in face of barriers, and recovery from setbacks[9]". Survey item emphasis was placed an assessing knowledge and skills related to: (1) communication skills, (2) teamwork, (3) mentoring, (4) leadership skills, (5) negotiation skills, and (6) interest and persistence in engineering. In addition to completing the surveys all research participants also participated an in-depth interview about their experience in the CDS. In this paper, we present key findings of what these women learned and valued, insight into the variations across the participants, and professional career path goals. The research is structured so it can be replicated across institutions. Findings can aid engineering departments, diversity offices, career service offices, and industry review boards.

Methodology

Team members were solicited through email requests to participate in this research. To establish an engineering profile of the past team members, each completed a three part, 4-point Likert survey evaluating their own ability, interest, and persistence in engineering both academically and professionally. Using the GSE as a guide, we developed the Academic Self-Efficacy Scale and the Professional Self-Efficacy Scale. The Likert survey responses were used to generate the semi-structured interview protocol to more fully investigate the impact of their participation on their perception of engineering.

Two areas of particular interest are: 1) what professional skills were gained as a result of participating, and 2) the impact of CDS on persistence to pursue engineering professionally. All participants were interviewed to gain a deeper understanding of their survey responses. Close examination of their surveys and interviews may provide a key to motivating more young women to persist in engineering as a career.

The construct of perceived Self-Efficacy reflects an optimistic self-belief[15]. This is the belief that one can perform a novel or difficult tasks, or cope with adversity -- in various domains of human functioning. Bandura defines perceived self-efficacy as "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives"[1]. Self-efficacy beliefs determine how people feel, think, motivate themselves and behave. Perceived self-efficacy enables one to approach difficult tasks as challenges to be mastered rather than as threats to be avoided. It can be regarded as a positive resistance resource factor. Ten items are designed to tap this construct. Each item refers to successful coping and implies an internal-stable attribution of success. Perceived self-efficacy is an operative construct, i.e., it is related to subsequent behavior and, therefore, is relevant for clinical practice and behavior change. The GSE, ASE, and PSE all utilized a 4-point Likert scale, 1 = not true at all, 2 = hardly true, 3 = moderately true, and 4 = exactly true. Reliability of the General Self-Efficacy Scale, based on data from 23 nations, ranged from .73 to .90 (Chronbach's alpha coefficients) and criterion-related validity has been documented in several correlation studies. This study took place at a private university; participants completed the computer-based surveys and the online interviews after graduation. The survey instruments and administration were approved by the Institutional Review Board (IRB) of the Office of Sponsored Research.

Participant Demographics

In this section, participant demographics are presented. Nine team captains and sub group leads participated in this study. Table 1 shows the participant demographics in terms of engineering degree, job title, company worked for, years at current job, ethnicity, and gender. As can be seen, a majority of the participants earned a B.S. in aerospace engineering (89%). While this is unusual given that a majority of the participants in CDS are mechanical engineers, it is expected given that Embry-Riddle Aeronautical University has such a strong history with aerospace engineering and over 85% of our engineering students are enrolled in aerospace engineering. The remainder (11%) earned a B.S. in mechanical engineering. As for job held, 33% were flight test engineer, manufacturing and design engineer were each 22%, and systems engineer and vehicle engineer were 11% each. All participants work for an aerospace company. Furthermore, 44% have worked in their current position for at least one year, 33% have been in their current job for at least two years, 11% for at least three years and 11% for at least five years. All participants were female. As for ethnicity, the majority were Caucasian (78%) and 22% minority students (includes Hispanic and Asian).

Table 1: Participant demographics in terms of degree, job title, company, ethnicity, and gender

Question	Participant Response	Percentage
What is your B.S. degree?	Aerospace Engineering Mechanical Engineering	89% 11%
What is your job title?	Flight Test Engineer Manufacturing Engineer Systems Engineer Design Engineer Vehicle Engineer	33% 22% 11% 22% 11%
What is your company name?	Northrop Grumman Pratt and Whitney Boeing Lockheed Martin Korean Aerospace U.S. Air Force	33% 11% 22% 11% 11% 11%
Years at current job	1 2 3 5	44% 33% 11% 11%
What is your Ethnicity?	Caucasian Hispanic Asian	78% 11% 11%
What is your gender?	Female	100%

Results

Key findings and results from the GSE, ASE, and PSE surveys are presented in this section. More specifically, we present the professional skills gained, as structured from the participants own words.

Overall Rating on the General Self Efficacy Scale

Table 2 presents the average ratings. When completing this survey, participants were instructed to reflect back holistically – to consider and measure personal, professional, and academic experiences when rating each item. It is observed that all responses are rated highly, with the lowest as 3.18/4.00, "if someone opposes me, I can find the ways and means to get what I want." When participants were asked to offer an example or an explanation of why they choose the rating that they did on this question, two distinct responses emerged. Approximately a third of the participants ranked this as a four, as they interpreted this question as if their personal knowledge or "ability was under scrutiny" and therefore would rise to the challenge and not back down until they achieved their goal. The remainder ranked this question as a three and would back down periodically because they were concerned with being "identified as difficult or bossy" at work. It is not surprising that the seven highest ranked items are fundamental skills critical to be successful in engineering: trying hard enough, confidence in unexpected events, resourcefulness in handling unforeseen situations, ability to solve problems, utilizing coping strategies, ability to generate multiple solutions, and ability to generate a solution when in trouble.

Table 2: List of average participant responses to the General Self Efficacy Scale

GSE Survey Item	Average Response
I can always manage to solve difficult problems if I try hard enough.	**3.55**
If someone opposes me, I can find the means and ways to get what I want.	**3.18**
It is easy for me to stick to my aims and accomplish my goals.	**3.36**
I am confident that I could deal efficiently with unexpected events.	**3.82**
Thanks to my resourcefulness, I know how to handle unforeseen situations.	**3.82**
I can solve most problems if I invest the necessary effort.	**3.82**
I can remain calm when facing difficulties because I can rely on my coping abilities.	**3.73**
When I am confronted with a problem, I can usually find several solutions.	**3.64**
If I am in trouble, I can usually think of a solution.	**3.73**
I can usually handle whatever comes my way.	**3.36**

Overall Rating on the Academic Self Efficacy Scale

Table 3 presents the average ratings for each item. When completing this survey, participants were instructed to reflect back on the impact that participation in the Collegiate Design Series had on their performance at their engineering job. It is not surprising that participants rated "participation in my engineering design courses" lower than most other items; this can be attributed to the fact that CDS at our University is not part of a design course but rather is a club. To participate in CDS students must source time from an already overloaded schedule and as such are often forced to choose between homework and meeting competition deadlines. However, many of the participants clarified during their interviews while CDS may have negatively impacted their grades, it positively impacted their understanding of engineering concepts. That CDS provided a context, one participant explained "I was taking engineering classes and doing Baja so I could relate things that I learned in shop to my classes, which made them a lot more interesting, especially my engineering design courses." This particular participant further stated that participation in CDS provided for her a deeper understanding to the intent behind the material presented in class; in fact, she was able to "see beyond the lesson." Many of the participants cited CDS as providing them the opportunity to develop their teaming skills. Faced with team members with different cultural backgrounds, different academic strengths, and different social skills, participants learned to listen to all members, and to leverage across the diversity of experience and viewpoints to arrive at a balanced and fair design choice. One participant explained "it helped me work in teams because it helped me realize that I might not necessarily like everybody on the team, but I do have to work with them and try to figure out a way to solve the problem." She further offers "I saw how others communicated with each other both positively and negatively and that helped me figure out how to approach people when I am trying to bring my ideas across or put my ideas on the table." The lowest ranking item was "ability to ask for support or guidance from my peers." Several interesting trends emerged from the interviews on this particular survey item: several participants cited natural shyness and reticence to ask for help, while others felt their peers could not offer the guidance needed, and the remainder felt they were already quite comfortable asking for guidance from peers and therefore CDS could not improve it much. This is finding is a bit troublesome, as Koebnick cites adequate mentoring and networking with other employees as a factor impacting women's retention and success in the engineering field. Specifically, networks provide a place where women can gather as colleagues in an environment where information and experiences can be shared[10]. It appears that CDS does have a significant impact on "my desire to persist in engineering design courses". One participant summed up the impact of CDS: "there are not that many labs in our course of study, and the ones we do have are quite simplistic and constrained in nature, they are limited. So Baja is a big experiment – one where you have to pay attention, ask further questions, pursue information, and branch out from what you are studying." Another cited joining Baja because she noticed in her class that anyone involved in CDS was well engaged in their design courses. One participant phrased it quite succinctly "without Baja I would have quit engineering years ago." This is an important finding, as Dr. Fouad reports 30% of women lost interest in engineering by the time they received their degree[4]. It does appear that CDS offers these women a context to be better engaged and more familiar with the design information presented in class and as such, are more likely to persist and complete their engineering degree.

Table 3: List of average participant responses to the Academic Self-Efficacy Scale

ASE Survey Item	Average Response
my academic performance in my engineering design courses	**3.33**
my ability to work collaboratively on teams in my engineering design courses	**3.78**
my comfort to assume a leadership role within my engineering design courses	**3.56**
my ability to maintain a leadership role within my engineering design courses.	**3.67**
my ability to effectively communicate my ideas to my peers	**3.56**
my ability to orally defend my ideas under scrutiny	**3.33**
my ability to offer support and guidance to my peers	**3.44**
my ability to ask for support and guidance from my peers	**3.11**
my ability to ask for support and guidance from faculty	**3.56**

my interest in engineering design courses	**3.89**
my desire to persist in engineering design courses	**3.78**
Overall, I was extremely satisfied with my academic experience at ERAU	**3.89**

Overall Rating on the Professional Self Efficacy Scale

Table 4 presents the average ratings for each item. When completing this survey, participants were instructed to reflect back on the impact that participation in the Collegiate Design Series had on their performance at their engineering job. As many graduates report how stressful the job interviewing process can be, we were curious if participation in CDS had a positive impact on this skill. All of the study participants reported that participation gave them an ample resource from which to pull relevant leadership experiences and technical challenges. During one participant's final interview she was not asked about any specific engineering concepts but instead she was interviewed in detail about her leadership experience in Baja as well as her manufacturing experience in Baja – she was offered the job. Several participants cited the constant outreach presentations, preliminary design reviews, and competition design presentations all contributed to their self-confidence, increased their comfort to discuss their achievements, and allowed them to easily talk to industry professionals.

All of the participants also referenced the importance of time management and the appropriate balancing between the competing demands of academics and completion of the competition vehicle. They were able to leverage across the experience of the team and as one member needed to focus elsewhere another team member would step in and increase their commitment. This is an important finding, as Dr. Fouad reports that women who could confidently manage both their office's political landscape and their multiple life roles were more satisfied both at work and at home, and more likely to stay in the profession[4].

One participant, who is currently working as a manufacturing engineer explained that Baja impacted her current job, "it is an amazing hands-on job and I am lucky to have gotten it straight out of college. Without Baja's experience I would not have realized what an incredible opportunity this job is." Another participant, while praising the education she received from our University, placed the skills she gained from Baja as more impactful on her career, " Embry-Riddle gave me the background I needed to get the interview but I know that the skills from Baja were more significant because they got me the job." While another directly attributes Baja for staying in school *and* getting a job she is satisfied with, "Like I said, Baja is what kept me going in engineering, it opened up my eyes to understand that there are more things out there than what I am currently studying. Desire to persist in engineering - the same thing; my Baja experience is why I got this job and I why I got it right out of college." Another important finding, as Koebnick[10] reports, is that the development of "hands-on" skills (by working with equipment and learning more about analysis and real-life problem solving) instills a greater sense of self-confidence. The CDS provides such an opportunity to women, who otherwise might not have had the chance to gain this type of experience through their life experiences. It helps to level the playing field between them and their more experienced male counterparts.

Table 4: List of average participant responses to the Professional Efficacy Scale

PSE Survey Item	Average Response
my initial job interviewing skill to be hired	**3.86**
my ability to negotiate a salary	**2.29**
my job negotiating skills to be promoted	**3.29**
my ability to negotiate a raise	**2.67**
my ability to receive my performance evaluation	**3.38**
my technical performance during my engineering job	**3.78**
my ability to work collaboratively on teams in my engineering job	**4.00**
my comfort to assume a leadership role within my engineering job	**3.78**
my ability to maintain a leadership role within my engineering job	**3.67**
my ability to effectively communicate my ideas to my peers at my engineering job	**3.89**
my ability to orally defend my ideas under scrutiny at my engineering job	**3.56**
my ability to offer support and guidance to my peers at my engineering job	**3.89**
my ability to ask for support and guidance from my peers at my engineering job	**3.33**
my ability to ask for support and guidance from superiors (supervisors, team leads, etc) at my engineering job	**3.56**
my interest in engineering as a profession	**3.78**
my desire to persist in engineering as a profession	**3.78**
Overall, I am extremely satisfied with my job	**3.56**

Discussion and Conclusions

In this paper, we presented preliminary findings from a mixed-methods study designed to assess women's success and persistence in engineering, academically and professionally, as a result of participating in an SAE Collegiate Design Series. Nine students from a private university participated in the study and were administered the GSE, ASE, and PSE surveys and finally participated in an in-depth interview. A majority of the students participants were aerospace engineers, 88% were hired immediately after graduation, and all but one are employed in the aerospace industry as engineers. All participants highly valued their participation in the Collegiate Design Series.

Key findings and results from the GSE, ASE, and PSE were presented. More specifically, we presented the professional skills gained from participating in a CDS as described by the participants –

- improved communication
    - conveying ideas verbally
    - in formal presentations
- significant gains in teamwork,
- increased understanding of team dynamics,
- increased persistence in completing an engineering degree, and

- increased persistence in pursuing a professional career in engineering.

Participants revealed that learning problem solving skills in a real-world setting and applying the engineering process to solve problems helped to contextualize and clarify their understanding of their engineering design courses. The findings revealed that participation in CDS did help to bridge the gap in skills not provided by most co-ops. Participants further clarified these additional professional skills gained:

- exploiting new opportunities for intellectual and professional growth,
- increased leadership skills,
- increased self-confidence,
- improved organizational skills (managing the planning and organization of project tasks),
- realization of the importance for asking for help/guidance.

Additional skills or benefits discovered through the individual interviews:

- networking
- persistence and increase motivation
- appropriately dealing with authority
- learning how to ask the right questions.

The emergence of these skills were fairly consistent across the participants, indicating that independent of previous backgrounds – either educational or in practical skills – that participation in a Collegiate Design Series allows these female students to gain the much needed skills to be successful, self-confident engineers in the professional workplace.

Clearly enough is not being done to slow the loss of diversity in the field of engineering; women continue to leave in record numbers. We must find ways to contextualize engineering to these young women early enough in their academic careers to make a lasting impact. We offer one such method: a dynamic, exciting design activity where girls meet and work with professional women engineers – to develop, test, build and compete an off road vehicle. The women leave this team with a high level of self-confidence and a much clearer and more defined understanding about the field of engineering. Most importantly, they gain the belief that engineering, as a career, is something they are more than capable of pursuing and successfully achieving.

There are limitations to this study: small sample of participants, more detailed quantitative analysis of the survey responses is warranted, additional qualitative analysis of the interviews, and perhaps of most significance, two of the surveys (the Academic Self-Efficacy and the Professional Self-Efficacy) were developed for this research and as such do not have reliability and validity numbers to report. However there are still important preliminary findings which can aid engineering educators, engineering departments, diversity offices, career service offices, and industry review boards.

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Appendix A

Additional Interview Questions

Pre Interview Questions

- Tell us about your job
- How big is your group?
- Are you the newest employee in your work group?
- How many are females (in your group)?
- How do you like living in ____________?
  City name

Interview Questions

The primary intent was to get an understanding as to how the participants understood the question and how they arrived at the rating they reported. Specifically, what experiences or reflections guided them as they chose their rating. Participants were asked to review each question of the surveys. They were instructed to review the item, their ranking of the item, and then to provide an example or two to support the ranking they chose. We followed-up with clarification questions as needed.

Post Interview Questions

- How can we use Baja to better prepare the participants for industry? What could or should we be doing differently?
- Do you remember receiving unsolicited advice or critiques at competition? Was that helpful? Did it prepare you for working in the industry? What about the technical inspection process?
- Considering any fundraising you did, vendor interface and/or interaction at competition, how did this impact your interpersonal skills at your internship or job?
- Do you feel you received mentoring from Baja?
- Do you receive or provide mentoring in your career?
- How can we make the Baja experience better?
- Is there anything else you want to add?

Appendix B
Additional Participant Information

Table 5: Competitions Attended

	A	B	C	D	E	F	G	H	I	Total
Auburn 2006				X		X		X		**3**
Ocala 2007	X	X		X*	X	X		X		**4**
Rochester 2007	X	X	X	X*		X				**5**
Cookeville 2008	X	X*			X	X	X	X	X	**4**
Montreal 2008						X	X*		X	**3**
Auburn 2009					X		X*		X	**3**
Washougal 2009					X		X*		X	**3**
Greenville 2010					X*				X*	**2**
Pittsburg 2011					X*				X*	**2**
Total	**3**	**3**	**1**	**3**	**6**	**5**	**4**	**3**	**6**	

*: denotes team captain or co-captain

Table 6: Years of Participation

	A	B	C	D	E	F	G	H	I	Total
2005-2006	X	X	X	X		X		X		**6**
2006-2007	X	X	X	X	X	X		X		**7**
2007-2008	X	X			X	X	X	X	X	**5**
2008-2009					X		X	X	X	**4**
2009-2010					X				X	**2**
2010-2011					X				X	**2**
Total	**3**	**3**	**2**	**2**	**5**	**3**	**2**	**4**	**4**	

Table 7: Baja Subsystems Lead

	A	B	C	D	E	F	G	H	I
2005-2006	Steering		Drivetrain	Braking		Chassis			
2006-2007		Chassis Drivetrain	Drivetrain Chassis	Braking Suspension Rear		Chassis		Floatation	
2007-2008	Drivetrain	Chassis			Drivetrain	Chassis	Cost Report	Floatation Suspension Front	
2008-2009					Drivetrain		Cost Report	Braking	Chassis
2009-2010					Drivetrain				Chassis
2010-2011					Drivetrain				Suspension Front and Rear