A Comprehensive Investigation on Industry-Sponsored Design Projects' Effectiveness at the First-Year Level: Phase I

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Abstract
This paper presents the preliminary work for developing guidelines to ensure that the industry sponsored projects in first-year courses aid, not hamper retention of students. Specifically, the overall research includes the following steps: (1) investigating the appropriateness of industry projects in a required introduction to engineering design course (~1,000 students/year), (2) assessing the impact of industry- sponsored projects on first-year students' learning and retention, and (3) promoting an awareness of issues involved in successfully introducing industry projects at the first year. It is expected that the outcomes of this work will result in guidelines widely applicable by other institutions looking into or currently using industry projects at the first year, thereby addressing the recognized national need of increasing retention rates, especially amongst women and minorities.

This paper covers a review of potential factors affecting industry-sponsored projects' appropriateness at the first year, and related preliminary data.

1.0 Introduction

The current criteria for ABET accreditation[1] state that "engineering programs must demonstrate that their graduates have: …an ability to design a system, component, or process to meet desired needs," and "an ability to function in multi-disciplinary teams…." Because engineering design in industry is a team activity, the integration of design into engineering curricula is generally done through the use of design teams. In many cases, this integration also uses industry-sponsored design projects.

Most of the industry-sponsored design project applications are at the capstone design level, and many examples of these are documented in the literature [2-9]. Capstone design courses are used to ease the transition from the education environment to industry by providing design problems originating from industry, and a setting for graduating engineers to work in design teams. Industry-sponsored projects not only provide a link between practicing engineers and graduating students, but also give students a deeper understanding for how they will use their discipline specific knowledge and skills in industry. Thus, although a few concerns are raised [11-12], there is overwhelming evidence for the success of capstone design courses that employ industry-sponsored design projects [2-10].

Among the benefits of industry sponsored design projects the following four items are frequently mentioned: (1) because of their inherent layers of complexity students confront issues that stretch them beyond textbooks, (2) because these projects are done for a company that cares about the outcome students feel more motivated, (3) their scope generally, demands teamwork and therefore, students learn project management, and (4) these projects give students exposure to industry cultures and practices. Accordingly, the use of industry-sponsored projects throughout the curriculum is advocated, and they are increasingly being used at the freshmen level [13-17].
At the first-year level, industry-sponsored projects can create a better understanding for what engineers do while instilling basic engineering and design principles. Despite the potential benefits outlined above, however, the outcomes of these projects can be mixed in multiple ways. From a faculty point of view, (1) each industry-sponsored project is assigned only once, limiting faculty's ability to improve upon the first offering and refine the project, which (2) increases the amount of course preparation for each course offering. From a student's point of view, motivation and self-efficacy may decrease when (1) the project domain (e.g., electrical engineering) is not directly related to their chosen major (e.g., chemical engineering), (2) the projects are perceived to be skewed toward a particular gender (e.g., masculine- or feminine- oriented), and (3) students may evaluate abstract, ambiguous projects from industry negatively because they lack the tools to address open-ended problem solving. These issues may be particularly problematic for introductory design offerings taken by first year students who are making critical decisions about whether to stay in the engineering major.

Most "coalition" schools (sponsored by the NSF Program 089-105) have adopted a common, design-driven engineering curriculum for all disciplines at the first year [18]. Therefore, all first year engineering students in these schools take their first engineering course in a setting where no discipline specific knowledge and skill development is expected. Rather, developing an understanding for engineering in general with its fundamental principles is sought. Frequently, however, when industry-sponsored projects are integrated into the curriculum, the projects are too narrowly defined limiting the integration of multidisciplinary view points to design solutions [19]. In such a situation, because of the potential mismatch in a student's chosen engineering discipline and the industry-sponsored design project domain, some students may feel less motivated compared to the ones who feel the project is closely related to the engineering discipline in which they would like to get their degree.

A similar motivation loss can occur, if the context of the industry sponsored design project is seen as more familiar to one gender compared to the other. Although potential issues due to the gender orientation of the design project domain have been pointed out [21-23], gender differences in design performance of first-year engineering students have been studied only in isolated cases [15, 21]. However, how the potential gender orientation of an industry-sponsored design project might impact students' design performance and the effectiveness of the project for providing a design learning environment have not been assessed.

Finally, while the complexities of teaching with industry-sponsored projects due to their open-ended nature have been discussed (e.g., project management, unequal contributions from design team members) [24-27], no study so far has investigated the students' readiness for solving open-ended design problems such as industry sponsored design problems at the first-year level.

Overall, while symptomatic evidence exists for the above mentioned issues related to the integration of industry sponsored design projects at the first-year level, there is no comprehensive, conclusive, research based evidence or prescriptive guidelines to help faculty in this regard. Because there is an increasing trend in adopting these types of projects at the first year level [13-17], we address these issues. The overall goal is to provide guidelines for engineering educators that would make their implementations more successful in terms of enhancing student learning and student retention in engineering disciplines. To this end, we assert that a comprehensive study (which is underway), should involve the following steps:

1. Assessing the appropriateness of industry-sponsored project selection in terms of:
    a. Relatedness of the design project to the engineering discipline of choice for students,
    b. Gender orientation of the project domain,
    c. Ambiguity of the project and student readiness for open-ended problem solving.
2. Measuring the effectiveness of industry-sponsored project selection on outcomes at both the individual and team level of analysis:
    a. Student and team motivation (self-efficacy and collective efficacy)
    b. Student learning
    c. Student and team performance
    d. Student retention in the engineering major

However, due to space limitations, the remaining sections of this paper will only include a discussion of potential issues with industry-sponsored projects that impact appropriateness of the design project for first year students. These potential issues have been identified based on literature and the preliminary evidence from an ongoing experimental work at The Pennsylvania State University (Penn State).

2.0 Potential Issues with Industry-Sponsored Projects at the First-Year Level: A Review and Preliminary Evidence

The current trend for first year engineering education is the adoption of industry-sponsored, and/or service learning projects. The practice of using industry-sponsored projects for senior-level or capstone courses is being replicated at the first-year level, with the hope for the same level of success. With service learning projects, students engage in experiential design learning during which they apply their knowledge for design to meet local community needs [28]. Despite the trend of adopting industry- sponsored and/or service learning projects to the curriculum, there is no comprehensive and conclusive evidence of their added benefit in comparison to design projects that are not industry-sponsored. In addition, there are potential problems with the application of these projects at the introductory level, which are described below.

Engineering design teams can be considered a type of project team or task force in team typologies, and are the most widely accepted means of bringing products from initial concept to the commercial stage. Design teams differ from other teams in that they have ad hoc membership, limited time frames to complete their tasks and narrowly defined goals. Thus, it is not surprising that recent research has pointed out the existence of significant contextual differences of the engineering medium as compared to other team environments [29] as the underlying reason for different pattern of findings for design teams as compared to the team types used in previous studies. Therefore, investigations are underway to understand the best practices of teaming in the engineering environment.

Beyond not fully understanding teaming in the engineering medium, the application of industry-sponsored projects creates another unknown in terms of its impact on student learning and retention in the engineering major. In fact, this has been experienced first-hand at Penn State's University Park campus since incorporating industry-sponsored design projects into the Introduction to Engineering Design (ED& G 100) course since the fall of 2000. This course is required by all engineering majors. Table 1 shows the sequence of these projects with brief descriptions. With eight semesters of experience with industry-sponsored projects at the first-year level, now is an ideal time to analyze the effects in order to rethink and modify our approach to achieve better outcomes. Our goal is to accomplish these goals in a systematic, scientific, and comprehensive manner to improve the learning environment for first-year engineering students.

Figure 1 depicts student evaluation ratings for the ED & G 100 course and instructor for the past eight semesters since the introduction of industry-sponsored projects into the first-year curriculum. These data are averaged across eight instructors who teach a total of 14 sections each semester between fall 2000 and spring 2004. Although the instructor ratings for this course are higher than the course ratings, both follow the same general pattern and reveal significant variability across semesters. Because students work on the industry-sponsored project for a full half of the class duration and because this work accounts for a large part of the course grade (25%), it can be assumed that the variability across ratings reflects, in part, variability in student perceptions of the industry-sponsored project. Indeed, open-ended comments from students in their course evaluations revealed that the industry project featured prominently into their ratings of the course and instructor, and examples will be provided throughout the paper.

Table 1. Industry-Sponsored Projects Integrated to the EDG&100 Curriculum*

Company/Project	**Brief Description/Semester**
SIEMENS Siemens Fume Hood Face Velocity	Design and construct a prototype device to maintain a specified fume hood face air velocity. (Spring 2004)
BAE SYSTEMS BAE Systems RPG Defense	Develop a concept that is effective in defending against a rocket-propelled grenade attack. Students will be introduced to the basic principles of Systems Engineering through both an understanding of the sequence of design steps they traverse, as well as the nature of the work performed in each of those steps. (Fall 2003)
BOEING Boeing Future of Space	Define a new space mission with supporting rationale. Using today's existing or planned space hardware designs, configure a new system that accomplishes your mission's goals. (Spring 2003)
FLEETWOOD Folding Trailers Fleetwood Folding Trailers, Inc.	Design and prototype the next-generation human-powered system for set-up and tear-down of a folding trailer (pop-up camper) that does not rely on any external power source other than manual power. (Fall 2002)
BorgWarner BorgWarner Chain Assembly Process	Design and prototype all (or part) of the process (machine) required to assemble an inverted tooth chain assembly from its individual components. BorgWarner is interested in innovate new ideas for the assembly process. (Spring 2002)
PENNSTATE Hazleton 1855 Penn State Hazleton Access Project	Design a mechanical, manual, or service system that will provide access for people with disabilities and the non-disabled population from an area between the Highacres Café and residence halls up to the Graham Academic Building on the Penn State Hazelton campus. (Fall 2001)
Marconi Switch Chasis Shipping Crate Design	Design and prototype a recyclable shipping crate or container to hold Marconi's BXR-48000 Switch through its assembly and during shipping to customer. (Spring 2001)
Kimberly-Clark Corporation Rain Protection Garment	Design a "single-season" protective rain garment and its associated manufacturing process. (Fall 2000)

*: Although we label these projects as industry-sponsored design projects, the project for Fall 2001 (designing a handicap access system for the Penn State Hazelton campus) would best be described as a service-learning project.

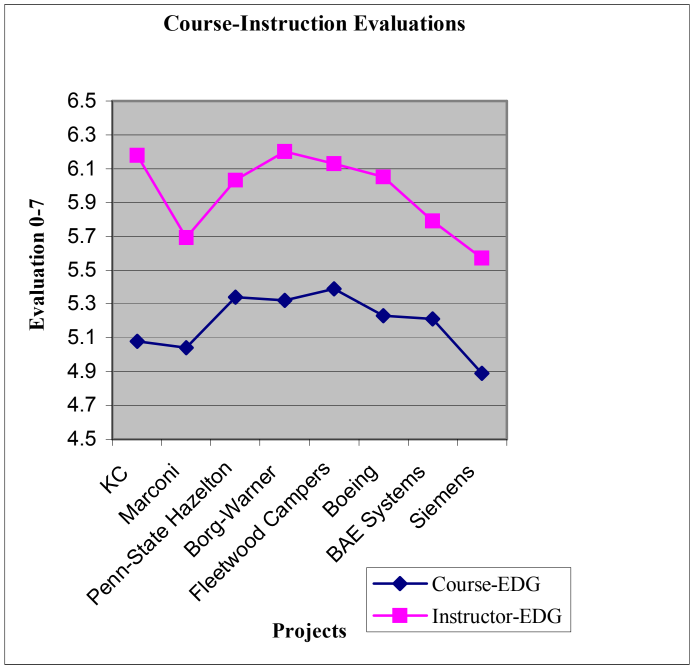

Figure 1. Course and instructor evaluations for ED & G 100 over the past 8 semesters

Clearly, Figure 1 reveals that some industry-sponsored projects were viewed less favorably than others. What accounts for these differences in student perceptions, and what effect does project selection have on outcomes such as first-year self-efficacy for success in engineering, the collective efficacy of the design team, student learning, and retention in the major? We hypothesize that the following three factors accounted for a large part of the variability in student evaluations and are important features to consider in industry-project selection:

1. Discipline-relatedness of the project
2. Gender-orientation of the project domain
3. Ambiguity of the project and student readiness for open-ended problem solving.

These three factors were chosen based on instructor observations and student comments over the past eight semesters as well as previous research that highlights the importance of these constructs for student and team functioning. Below, we elaborate on each of these variables and describe their hypothesized relationship to outcomes of interest (self-efficacy, collective efficacy, student learning and performance, as well as retention in the major).

2.1. Discipline relatedness of the industry-sponsored project

Although students are not admitted to a particular engineering field at the freshmen level, most do have a specific discipline of interest (e.g., mechanical engineering, industrial engineering) that influences how they view project selections. Thus, if the industry sponsored project is seen by students as not being related to their chosen discipline, motivation may decline, resulting in a less than optimum learning environment.

During the Spring of 2001, the ED & G 100 course project involved designing a shipping crate to house the 700 lb Marconi Communications switch (see Table 1). As shown in Figure

1, student evaluations from this semester were more negative than other semesters. One of the reasons for this may be due to the project being primarily industrial and mechanical in nature, which may have created lower motivation for students with strong interests in other engineering areas (e.g., electrical, chemical). In contrast, other industry projects such as those sponsored by Borg Warner and Boeing allowed for solutions that were more inclusive of many engineering disciplines. This may help account for the higher student evaluation ratings in these semesters. In examining Table 1, none of the eight projects listed directly relate to chemical engineering, and faculty observations reveal that this has been a common complaint from students seeking to specialize in this area, undermining their motivation to devote maximum effort.

Although there has been little research on this topic, the preliminary data discussed above suggests that selecting industry-sponsored projects with broad applications across many engineering disciplines may be an important factor to consider in seeking to enhance first-year student motivation and learning.

2.2. Gender orientation of the project domain

Research has shown that occupations are perceived to have a gender orientation. For example, Shinar [30] and a later replication by Beggs and Doolittle [31] revealed that engineering is generally perceived as a masculine occupation. Not only is the engineering field perceived to have a gender orientation, but the specific design domain in which individuals perform tasks may also be perceived by team members to be more masculine or feminine. Although the process of designing (e.g., generating alternatives, evaluating the final design) would not have a gender orientation, the domain of the task may accentuate gender differences in team functioning.

During the fall of 2003, the ED & G 100 course project, sponsored by BAE Systems Inc., involved a countermeasure design for rocket propelled grenade (RPG) attacks (see Table 1). Design activities included generating and selecting concepts for detection of the RPG attack and deployment of the countermeasure for the attack. As shown in Figure 1, student evaluations from this semester were more negative than many other semesters, and one reason for this may be due to the male-orientation of the project domain. Although the design activities (e.g., kinematics, trajectory generation) were not gendered, the military context of the project was viewed by some students as more masculine in orientation. For example, open-ended student responses to course evaluations from this semester included the following: "Guns, rockets, and explosives usually point toward males," "In our society, war is associated with masculinity," "Military issues affect everyone, but men tend to be more interested," "Guys seem to know more about military stuff." As indicated by these comments, the gender orientation of the project may affect interest and motivation as well as perceptions of expertise and self-efficacy. In contrast to the BAE systems task, other industry-sponsored projects such as Borg-Warner and Fleetwood Campers may have been perceived as more gender-neutral, resulting in more positive student evaluations.

A literature search revealed that little research has examined task gender orientation. For example, most gender composition studies have not included this variable, although the results discussed above indicate that it may be relevant (e.g., 29, 32-33). In addition, the research that has been done may be improved upon by giving more systematic attention to the measurement of gender orientation of the project domain. For example, some authors have simply suggested that tasks may be more masculine or feminine without directly measuring the variable to provide empirical support (e.g., 34). Others have examined the dimension in a cursory and indirect manner. For example, LePine et al. [35] utilized a simulation of a military task for command and control teams, which was assumed to be masculine, but the gender orientation was not directly assessed or validated. Studies that have directly measured gender orientation have typically selected stereotypically sex-typed tasks based on previous work on gender differences and then validated those assessments on a pretest sample. To illustrate, Vancouver and Ilgen [36] found that tasks based on sports, changing oil, and designing a tool shed were rated to be more masculine, whereas tasks based on flowers, cooking a meal, and designing a store window were rated to be more feminine. In addition, Wentworth and Anderson[37] utilized pre-tested masculine (investment decisions), feminine (wedding planning), and gender-neutral tasks (advising a married couple on how to spend an inheritance). In contrast to previous research, design projects should rely less heavily on obvious gender stereotypes and be directed at a more technical context.

What is not clearly understood from previous studies is the set of factors that determine whether a task is perceived as more masculine or more feminine. Existing measures of task gender orientation (e.g., 36-37) do not provide insight about the characteristics of task gender-type or what variables are regarded as important when those assessments are made. Accordingly, factors that shape the gender domain orientation of design projects should be better understood.

2.2.1. Gender Composition and Gender-Orientation of Project Domain

A male-oriented project domain may potentially alienate women, who are already the minority in the design team (typically one female to three males), in the engineering classroom (19%) as well as in industry (9%)[38]. Male engineering students were found to have a significantly higher active learning preference than female engineering students, and males were significantly more confident in actually trying things out rather than merely thinking about how to accomplish a task[39]. The gender composition of engineering design teams as well as the gender orientation of the project domain may account for these results. For example, a study by Gilbert and Thompson[40] revealed that females became angrier following a masculine task than a feminine task. In addition, females who performed better on the male task than their male competitors reported the highest levels of depressed affect, even higher than the males and females who performed worse than their competitors[40]. Clearly, more research is needed on the relationships between gender, task gender orientation, and team performance. Furthermore, "future research should be conducted over longer-term periods to test whether indeed time does reverse the effects of gender, gender orientation of the task, and proportional representation" (Karakowsky and Siegel[41]).

2.3. Ambiguity of the project and student readiness for open-ended problem solving

The ED & G 100 course features two design projects, the first of which is guided and fairly straight-forward, while the second is industry-sponsored and more open-ended (Table 1). Instructor observations reveal that students generally seem less comfortable with the industry-sponsored project because it is less defined than the first project. In addition, industry-sponsored projects across semesters have differed with respect to their level of abstraction and ambiguity. As shown in Figure 1, student evaluations for the semester in which they were assigned the Siemens fume hood project were the lowest of the ratings made. Among the reasons for this may be the abstractness of dealing with concepts such as air-flow and the difficulty in visualizing what was required. Indeed, open-ended comments from students during this semester repeatedly refer to the confusing and ambiguous nature of the project and the need for more detail and clarity. Sample comments include, "Give us a better defined problem," "It was hard to tell what needed to be done," "Maybe explain thoroughly what the hell we are doing instead of having everyone ask questions." These reactions suggest that project ambiguity may lead to decreased self-efficacy and student learning if interventions are not conducted to mitigate negative effects.

Ambiguity refers to perceived insufficiency of information and is used to describe decisions for which the odds of an uncertain event are not precisely known[42]. Much has been written regarding making decisions under conditions of ambiguity or uncertainty, and models have been proposed to describe this process (e.g., 43). In addition to the level of ambiguity inherent in a task or project, individuals can be categorized as ambiguity averse, ambiguity seeking, or ambiguity indifferent[42]. Tolerance for ambiguity is a personality variable defined as the tendency to perceive ambiguous situations as desirable[44]. Need for closure is a related construct referring to a desire for definitive knowledge, for a firm answer to a question and an aversion to ambiguity[45].

Clearly, design tasks will differ with regard to their level of abstractness and ambiguity, and first year engineering students will display varying degrees of readiness to deal with open-ended problem solving. Insufficient attention has been given to these issues in the literature, despite their potential importance for building self-efficacy as well as increased student learning and performance. Project management interventions may be needed to help students with low tolerance for ambiguity succeed during projects requiring abstract problem-solving.

3.0. Preliminary Evidence

3.1. Relatedness of the design project to the engineering discipline of choice for students

While a more comprehensive plan to elicit this information is underway, in this paper we would like to present written student perceptions regarding the industry-sponsored projects completed as part of the open-ended course evaluations. Table 2 presents the comments tabulated for the question: "What did you like least about this course?", to provide industry sponsored project related comments.

As seen in the table, for RPG countermeasure design project 23 out of 82, and for the air velocity controller design project 22 out of 26 students put down negative comments during the open ended end of semester course evaluations. These results clearly point to issues regarding project topic/domain/scope selection.

Table 2. What Did You Like Least About This Course?

Project	RPG Countermeasure Design	Air Velocity Controller Design
Comment	N=82	N= 26
	n	n
Industry sponsored project overall	15	11
Too advanced of a problem for us	3	1
Building bridges, pipelines is more appropriate	1	0
Project is not fun	1	4
Project was very unorganized	2	1
Vagueness of the project	1	4
The outcome is not useful to companies	0	1
Total number of project related negative responses	23	22

3.2. Gender-orientation of the project domain

As preliminary evidence we provide task domain gender orientation ratings, collected during Fall 2003 and Spring 2004 from selected sections of the ED&G 100 course. As seen in Table 3, majority of students (51.4%) judged the RPG countermeasure design project to be predominantly male oriented. For the air velocity controller design task, 83.9% of the students judged the project to be gender neutral, although 14% rated it as male-oriented, and 2.1% rated it as female-oriented.

Table 3. Task Domain Gender Orientation Ratings

Project	RPG Countermeasure Design		Air Velocity Controller Design	
Rating	N=111		N= 144	
	%	Cumulative %	%	Cumulative %
1	16.2	16.2	8.4	8.4
2	35.1	51.4	5.6	14.0
3	47.7	99.1	83.9	97.9
4	00.9	100.00	2.1	100.0
5	00.0	100.00	0.0	100.0

1=very masculine, 3= neither masculine nor feminine, 5=very feminine

3.3. Ambiguity of the project and student readiness for open-ended problem solving

During the Fall of 2003, data were collected in several sections of ED & G 100, which is required for all freshmen engineering majors. After completion of an open-ended industry-sponsored design project at the end of the semester, 113 students completed a questionnaire measuring tolerance for ambiguity, individual self-efficacy, collective efficacy, satisfaction with their team, and conflict resolution.

Tolerance for ambiguity was measured using the MSTAT-I, a 22-item measure[46] with an internal consistency reliability (Cronbach's alpha) of .89. Self-efficacy was measured by asking students to estimate the grade that they would individually earn in the course. Collective efficacy was measured by means of a 4-item scale with an alpha of .76, as well as by asking students to estimate the grade that they would receive on their industry-sponsored team project. Team satisfaction was measured with a 3-item scale (alpha = .86), and team conflict resolution was measured with a 3-item scale (alpha = .87).

Correlational analyses revealed that the personality trait of tolerance for ambiguity was positively correlated with the grade that students individually expected to earn in the course (r =.22, p=.02), the grade that students expected to earn for their industry-sponsored team project (r = .24, p=.01), and the collective efficacy scale (r= .26, p =.005). In addition, tolerance for ambiguity was significantly, positively related with team satisfaction (r = .19, p = .04) and team conflict resolution (r = .24, p = .01). This pattern of results reveal the beneficial effects of higher tolerance for ambiguity on increased efficacy, satisfaction, and conflict resolution in the context of an open-ended, team-based, industry-sponsored engineering design project.

4. Conclusions

These preliminary findings support our hypotheses. First of all, as seen in Table 2, a considerable number of students pointed to the industry-sponsored project as their worst experience related to their introductory engineering design course. Second, although design tasks themselves are not gender biased, the domain of the task might favour one gender or the other. The findings presented in this paper indicate that the RPG countermeasure design task was perceived to have masculine overtones (male oriented task domain), as revealed by items asking students about the gender orientation of the domain. On the other hand, the air velocity controller design was mostly seen to be gender-neutral. Finally, based on the Fall 2003 data, the beneficial effects of higher tolerance for ambiguity on increased efficacy, satisfaction, and conflict resolution in the context of an open-ended, team-based, industry-sponsored engineering design projects are evident.

Overall, based on these findings we assert that we have adequate evidence regarding the potential issues with industry-sponsored design projects at the first year. During the next phase of this work we plan to develop guidelines for successful industry-sponsored project implementations at the first year.

References

1. ABET (2002). http://www.abet.org/images/Criteria/E1%200304%20EAC%20Criteria% 2011-15-02.pdf, accessed on April 10, 2003.

2. Coleman, R.J. and Shelnutt, J.W. (1995). Fostering university/industry partnerships through sponsored undergraduate design. Proceedings of the Frontiers in Education Conference, v. 1, p. 8-11.

3. Ray, J.L. (2003). Industry-academic partnerships for successful capstone projects. Proceedings of the Frontiers in Education Conference, v. 3, p. S2B24-S2B29.

4. Magleby, S.P., Sorensen, C.D., and Todd, R.H. (1991). Integrated product and process design: a capstone course in mechanical and manufacturing engineering. Proceedings of the Frontiers in Education Conference. Twenty-First Annual Conference. Engineering Education in a New World, p. 469-74.

5. Freckleton, J.E. (1995). Student design projects in a design for manufacturing course. ASEE Annual Conference Proceedings, v. 1, Investing in the Future, p. 633-638.

6. Moore, D. and Berry, F. (1999). Industrial sponsored design projects addressed by student design teams. Proceedings of the 29th Annual Frontiers in Education Conference, pt. 1, p. 11B2/15-20.

7. Conn, A.F. and Sharpe, W.N., Jr. (1993). An industry-sponsored capstone design course. Proceedings of the Frontiers in Education. Twenty-Third Annual Conference. Engineering Education: Renewing America's Technology, p. 493.

8. Bales, W.J., Counce, R.M., Dodds, H.L., Edmondson, A.J., Ford, R.E., Raman, D.R., Speckhart, F.H., Shannon, T.E., Tompkins, F.D. and Yoder, R.E. (1997). Industry-sponsored student design teams in engineering at the University of Tennessee, Proceedings. Frontiers in Education 1997, 27th Annual Conference. Teaching and Learning in an Era of Change, pt. 1, p 310-15 vol.1.

9. Ruud, C. and Deleveaux, V.J. (1997). Developing and conducting an industry based capstone design course. Proceedings of the Frontiers in Education Conference, v 2, 1997,p.644-647.

10. Bradford, D.T., (1991). Beneficial aspects of industrial sponsorship of design projects, National Conference Publication - Institution of Engineers, Australia, n 91 pt 7, Improving the Manufacturing Climate, p 35-39.

11. Dekker, D.L., (1997). Issues when using company sponsored projects to provide a design experience for students, Proceedings of the Frontiers in Education Conference, v 1, p 304-306.

12. Magleby, S.P., Todd, R.H.; Pugh, D.L.; Sorensen, C.D. (2001). Selecting appropriate industrial projects for capstone design programs. International Journal of Engineering Education, v17,n 4-5,2001,p400-5.

13. Mourtous, N.J., Furman, B.J. (2002). Assessing the effectiveness of an introductory engineering course for freshmen, 32nd Annual Frontiers in Education Conference Proceedigns, pt.2, pF3b-12-16, v. 2.

14. Broduer. D.R., Young, P.W., Blair, K.B. (2002). Problem-based learning in aerospace engineering education. Proceedings of the ASEE Annual Conference & Exposition, Session 2202.

15. Moskal, B.M., Knecht, R., Lasich, D. (2002). Engineering design: Using a scoring rubric to compare the products of teams that differ in gender composition. Proceedings of the ASEE Annual Conference & Exposition, Session 2630.

16. Hirsch, P., Anderson, J., Colgate, J.E., Lake, J., Shwom, B. and Yarnoff, C. (2002). Enriching freshman design through collaboration with professional designers. Proceedings of the ASEE Annual Conference & Exposition, Session 1353.

17. Design Projetcs, http://www.ecsel.psu.edu/design-projetcs/, viewed on July 6th, 2004.

18. Sheppard, S., Jenison, R. (1997). Freshman engineering design experiences: An organization framework. International Journal of Engineering Education, 13(3), p 190-197.

19. Amon, C.H., Finger, S., Siewiorek, D.P., and Smailagic, A. (1995). Integration of design education, research, practice at Carnegie Mellon University: A Multi-disciplinary course in wearable computer design. Proceedings of the FIE Conference, p.4a1.14-17.

20. Interviews with faculty teaching Introductory Engineering Design at Penn State.

21. Okudan, G.E., Bilén, S.G. and Wu, X. (2003). Gender orientation of the design task: Product domain and familiarity issues. International Conference on Engineering Design ICED, August 19-22, 2003, Stockholm, Sweden.

22. Okudan, G.E. and Bilén, Sven. G. (2003). Effect of gender orientation of the design task on team performance: A preliminary study. ASEE Annual Conference & Exposition, June 21-24, 2003, Nashville, TN.

23. Okudan, G.E. (2002). On the gender orientation of the product design task. 32nd ASEE/IEEE Frontiers in Education Conference, November 6-9, 2002, Boston, MA.

24. Okudan, G.E. and Devon, R. (2002). Embedding engineering management to product design education. ASEE Annual Conference & Exposition, June 16-19, 2002, Montreal, Canada.

25. Koen, B.V. (1994). Toward a strategy for teaching engineering design. Journal of Engineering Education, 38,3, 193-201.

26. Fentiman, A.W. and Demel, J.T. (1995). Teaching students to document a design project and present the results, Journal of Engineering Education, 84,4, 329, 333.

27. Moor, S.S. and Drake, B.D. (2001). Addressing Common Problems in Engineering Design Projects: A Project Management Approach. Journal of Engineering Education, 90,3,389-395.

28. Tsang, E., Van Haneghan, J., Johnson, B., Newman, E.J., Van Eck, S. (2001). A report on service learning and engineering design: Service-learning's effect on students learning engineering design in "Introduction to Mechanical Engineering'. International Journal of Engineering Education, 17(1), 30-39.

29. Laeser, M., Moskal, B., Knecht, R. and Lasich, D. (2003). Engineering design: Examining the impact of gender and the team's gender composition. Journal of Engineering Education, 92, 1, 49-56.

30. Shinar, E. H. (1975). Sexual stereotypes of occupations. Journal of Vocational Behavior, 7, 99-111.

31. Beggs, J. M. and Doolittle, D. C. (1993). Perceptions now and then of occupational sex typing: A replication of Shinar's 1975 study. Journal of Applied Psychology, 23, 17, 1435-1453.

32. Harrison, D. A., Price, K. H., Gavin, J. H., and Florey, A. (2002). Time, teams, and task performance: Changing effects of surface- and deep- level diversity on group functioning. Academy of Management Journal, 45, 5, 1029-1045.

33. Randel, A. E. (2002). Identity salience: A moderator of the relationship between group gender composition and work group conflict. Journal of Organizational Behavior, 23, 749-766.

34. Wood, W. (1987). Meta-analytic review of sex differences in group performance. Psychological Bulletin, 102, 53-71.

35. LePine, J. A., Hollenbeck, J. R., Ilgen, D. R., Colquitt, J. A., and Ellis, A. (2002). Gender composition, situational strength, and team decision-making accuracy: A criterion decomposition approach. Organizational Behavior and Human Decision Processes, 88, 1, 445-475.

36. Vancouver, J. B. and Ilgen, D. R. (1989). Effects of interpersonal orientation and the sex-type of the task on choosing to work alone or in groups. Journal of Applied Psychology, 74, 6, 927-934.

37. Wentworth, D.K. and Anderson, L. (1984). Emergent leadership as a function of sex and task type. *Sex Roles* 11, 5/6, 513-523.

38. National Science Foundation. (2000). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2000*. Arlington, VA. (NSF 00-327).

39. Rosati, P.A. (1997). Gender differenced I the learning preferences of engineering students, Proceedings of the ASEE Annual Conference and Exposition.

40. Gilbert, S., Thompson, J.K. (1999). Winning or losing against an opposite-sex per on a gender-based competitive task, Sex Roles, 41(11/12), 875-875-899.

41. Karakowsky, L. and Siegel, J. P. (1999). The effects of proportional representation and gender orientation of the task on emergent leadership behavior in mixed-gender work groups. Journal of Applied Psychology, 84, 4, 620-631.

42. Kahn, B. E. and Sarin, R. K. (1988). Modeling ambiguity in decisions under uncertainty. Journal of Consumer Research, 15, 265-272.

43. Einhorn, H. J. and Hogarth, R. M. (1986). Decision making under ambiguity. Journal of Business, 59(4), pp. 225-250.

44. Furnham, A. and Ribchster, T. (1995). Tolerance for ambiguity: A review of the concept, its measurement, and applications. Current Psychology: Developmental, Learning, Personality, Social, 14, 179-199.

45. Kruglanski, A. W. and Webster, D. M. (1996). Motivated closing of the mind: "seizing" and "freezing." Psychological Review, *103*, 263-283.

46. McLain, D. L. (1993). The MSTAT-I: A new measure of an individual's tolerance for ambiguity. Educational and Psychological Measurement, 53, 183-189.

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