Instrument Development to Assess Design Project Appropriateness for Domain Relatedness, Ambiquity Tolerance, and Genderedness

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***Abstract*—This paper presents preliminary results of a currently funded NSF project that is developing and validating an instrument to assess the relationship between project appropriateness in domain relatedness, ambiguity, and genderedness and student efficacy in first-year engineering design courses. Because design is a defining activity for engineers, it is widely adopted as a means to introduce students to engineering. Many engineering schools now have first-year engineering courses, which feature engineering design learning in team-based settings. From a student's perspective, 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 overly complex and ambiguous vis-à-vis student preparation, and (3) skewed toward a particular gender (e.g., masculine or feminine oriented). With this work, we aim to assist engineering design instructors in refining content to achieve higher retention rates.**

Keywords—*industry-sponsored projects, engineering design education, project appropriateness, instrument development*

I. INTRODUCTION

Student success in their first-year engineering courses is instrumental in retaining students in engineering. Nationwide, first-year engineering curricula are implementing improvements to help students make a connection to engineering as a career [1]. According to Knight et al. [2] the intent of these curricula is to "*help budding engineers understand that engineering is a helping, people-oriented profession that underpins both our economy and our quality of life*." A primary way for students to gain this understanding is through team-based design projects. In particular, industry-sponsored projects are offered to give students a deeper understanding of how they will use their discipline specific knowledge and skills in industry.

There has been overwhelming support for the success of capstone design courses that employ industry-sponsored design projects in the literature [3 – 6]. Now, there is also recognition that first-year curricula can benefit from industry-sponsored projects intended to create a better understanding for what engineers do while instilling basic engineering principles and design process knowledge. Yet, offering real world projects to students can be problematic. In this paper, we will present three aspects of industry-sponsored projects — the domain-relatedness, ambiguity, and genderedness — that may impact first-year students as they work on these projects. A survey instrument was created and piloted in an effort to better assess these aspects. The findings of the survey will be shared in this paper. We will end with a discussion of the results along with an acknowledgment of next steps for the research.

II. PROJECT APPROPRIATENESS

A. Domain Relatedness

Students in our first-year design course, in general, are not admitted to a particular engineering discipline (e.g., civil engineering, aerospace), but most come with strong ideas on which area of engineering they will pursue. Although their understanding of what an engineer actually does in a particular discipline may be limited, their personal perspective often helps to fuel their interest in engineering. With the lines of engineering disciplines becoming blurry and an existing need for engineers with technical skills that span disciplines, there can be an issue when first-year students work on an

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industry-project that does not pertain to their choice of future field of engineering. These students may lack motivation that can affect their course grade and their perceptions of what engineers do. The research on this topic is limited, but [7] data suggests that selecting industry-sponsored projects with broad applications across many engineering disciplines may be an important factor to consider in trying to best meet the needs of first-year engineering students who come with diverse interests.

B. *Ambiguity*

Inherent in the industry-sponsored problems, just like in other ill-structured problems, is that step-by-step solutions are not provided. First-year students in engineering design may not be comfortable, or ready to experience and to handle ambiguity appropriately. The concept of tolerance of ambiguity (TA) dates back to its development by Frankel-Brunswik in 1948; through the years, it has generated a fair amount of research [8]. Budner defined TA as "the tendency to perceive ambiguous situations as desirable" [9]. Given the level of ambiguity inherent in a task or a project, individuals can be categorized as ambiguity averse, ambiguity seeking, or ambiguity indifferent [10]. Numerous instruments to measure TA exist; and according to [11], there are eight self-report measures. There is an instrument for first-year engineering students to distinguish whether students accept or reject the presence of ambiguity and the value of multiple perspectives [12], although it is still in pilot stages. Our intent is to study ambiguity as it relates to students' reactions to industry-sponsored projects that may be not only ambiguous, but also domain-specific and gendered.

C. *Genderness*

Gender and gender beliefs have many implications in our lives. For one thing, gender beliefs can influence attitudes, career aspirations, and vocational decisions [13]. Perceptions of work are not gender neutral [14] and research has demonstrated that individuals have perceptions regarding gender orientation for certain occupations [15]. Specifically, the field of engineering is perceived to be a more masculine oriented occupation [16 – 17]. Similarly, products "acquire" gender through aesthetics and design choices, which results in guidelines for creating "strongly gendered products" [18]. It could be that the design domain in which the students perform their design work is perceived as either masculine or feminine and while the tasks occurring in the process of design don't have a gender orientation, the domain of the task could accentuate gender differences in team functioning.

III. Development of Survey

Our goal is to develop and validate a succinct and psychometrically sound instrument for use in design project-based learning settings. This instrument of design project appropriateness include five sub-constructs as follows: (1) domain relatedness to a particular engineering discipline, (2) gender orientation of the project domain, (3) ambiguity level of the project, (4) students' tolerance for ambiguity, and (5) students' collective efficacy. The first three sub-constructs focus on design-project characteristics, while the last two are about students' characteristics with potential to affect their engagement and learning in project-based learning settings. In this paper, however, we will only report on our current findings with regards to the first four sub-constructs.

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 validated assessment instruments to help faculty with appropriately selecting, structuring and organizing the industry-sponsored design project courses. Given that ambiguity has a body of research, there are numerous instruments to assess it. Whether or not TA is a context-specific construct rather than a personality trait as proposed by Durrheim and Foster [19], and if TA is a contextualized measure [20] are still topics for debate. Whatever the dimensionality of the TA construct, generally it is measured on a one-dimensional scale with those who tolerate ambiguity seeing ambiguous situations as interesting, challenging, and desirable and those who have are intolerant and view ambiguity as a threat and a source of discomfort. We were able to use an existing instrument [21] with 22 questions to assess students' tolerance to ambiguity.

For domain relatedness, while students may not be admitted to a particular engineering field when they first begin their studies, most students tend to have a specific discipline of interest (e.g., mechanical engineering, aerospace engineering) that influences their interest in engineering and the projects they want to work on. Research indicates students leave engineering when their interests do not match what they have been exposed to in their classrooms [22]. Without an existing instrument to assess the domain relatedness of design projects, our team referenced the literature and pilot tested questions for inclusion on the instrument.

The addition of task gender orientation on the instrument was inspired by student end-of-course evaluation comments on design activities (e.g., kinematics, trajectory generation) resulted in students saying, "Military issues affect everyone, but men tend to be more interested" and "In our society, war is associated with masculinity" [7]. There is, however, little literature examining task gender orientation. As far back as 1987, Wood [23] suggested that tasks might be more masculine or feminine; however, there was no empirical support for this assertion. Some research [e.g., 24] offers measures of task gender orientation, but without any characteristics of task gender-type or what variables are relevant in making those assessments. Using the limited existing literature, we devised questions for pilot testing to be included on the instrument.

As discussed, questions for the survey came from a variety of sources including ones that are from existing validated instruments and ones that were developed based on the literature. The survey includes 64 questions under five different subscales: the first 22 questions were related to student's tolerance to ambiguity (TA) [19] following 25 questions related to students' collective efficacy (CE), eight questions related to project genderedness (PG), eight questions related to domain relatedness of the project (DR) and one question measured the project ambiguity level (PA).

A. *Methods*

Data for this project was collected over three semesters (fall 2016, spring 2017, and fall 2017) from a freshmen engineering design course at Penn State University. Students enrolled in the engineering design course were invited to participate in an online survey using the Qualtrics data collection platform at the end of their respective semester; they were offered extra credit for their participation. The survey was designed to obtain general information about student characteristics (i.e. gender, major) and perceptions regarding the domain relatedness, ambiguity, and genderedness of various industry-sponsored design projects. Table 1 provides descriptions of the project sponsors and projects.

TABLE I. PROJECTS & SPONSORS

Engineering design course project sponsor and project description by semester		
Semester	Sponsor	Project Description
Fall 2016	Chevron	Improvement of natural gas industry extraction practices to enhance sustainability in terms of water storage, waste stream management, and water and waste treatment.
Spring 2017	General Electric	Development of best strategy for extraction of fictitious ore deposits located in the Pocono Mountain region of northeast Pennsylvania
Fall 2017	Delphi	Modifications of existing features/functions, or creation of new technology, to improve the safety, sustainability, and connectedness of electric and autonomous vehicles or smart roads.

B. *Student Participants*

A total of 371 surveys were completed over three semesters. Presented in Table 2 is a summary of student responses to specific characteristics items. The majority of responses were obtained from the fall 2017 semester (43%), with the spring 2017 and fall 2016 semesters accounting for 34% and 23% of responses, respectively. Not surprisingly, the majority of students were male (71%), which is generally typical of engineering disciplines. Three students selected the “other” gender category; however, when required to specify their preferred gender, these responses were incoherent (i.e., “I am a bicycle”). In terms of students’ majors, 1 in 4 students were mechanical engineers, with biomedical and chemical engineering making up the next highest proportions (16% and 12% respectively). Roughly, 5% of students fell into the “other” category, which included student responses such as business, criminology, and undecided majors.

TABLE II. STUDENT DEMOGRAPHICS

Summary of student characteristics			
		Frequency	Valid %
Semester			
	Fall 2016	85	22.9
	Spring 2017	127	34.2
	Fall 2017	159	42.9
Major			
	Mechanical Engineering	93	25.1
	Biomedical Engineering	59	15.9
	Chemical Engineering	43	11.6
	Aerospace Engineering	34	9.2
	Civil Engineering	34	9.2
	Industrial Engineering	33	8.9
	Electrical Engineering	13	3.5
	Engineering Science/Pre-Major	11	3.0
	Biological Engineering	10	2.7
	Computer Engineering/Science	9	2.4
	Nuclear Engineering	8	2.2
	Architectural Engineering	3	0.8
	Material Science and Engineering	2	0.5
	Other*	13	5.1
Gender			
	Male	264	71.2
	Female	103	27.8
	Other**	4	1.1

*Non-engineering students and include athletic training, business, communication sciences, criminology, security risk analysis, and undecided students.
**These were incoherent responses

In order to investigate potential differences in student major and gender, student majors were further collapsed based on the nature of the engineering domain and a cross tabulation was performed. Student majors were collapsed into six groups. The first grouping included mechanical, aerospace, and nuclear engineering. The second grouping was composed of biological, biomedical, and chemical engineering. The third grouping was civil engineering along with material sciences. The fourth grouping was electrical and computer engineering. The fifth grouping was industrial engineering. The sixth and final grouping included the engineering pre-majors, architectural engineering, and all others.

The cross tabulation yielded significant differences between students’ self-reported gender and their major. Women were more likely than men to be chemical, biological, or biomedical majors (49% vs. 23%) and industrial engineers (15% vs. 7%). Men, however, were more likely than women to be mechanical, aerospace, and nuclear engineers (43% vs.

19%) and civil or material and science engineers (11% vs. 7%). These differences were statistically significant with χ^2 (5) = 35.760, p < .001, Cramer's V = .312.

IV. Results

An exploratory factor analysis (EFA) was performed to test the underlying structure of 23 items designed to investigate the three constructs of project domain relatedness, project genderedness, and student's tolerance to ambiguity (Table 3). Items were listed in a battery and were rated on a scale, where "1" indicated the student strongly disagreed with the statement, and "5" indicated they strongly agreed with the statement. Items were both positively and negatively worded, and all items that were negatively worded were recorded prior to conducting the EFA. The EFA employed a principal component analysis (PCA) with Varimax rotation and Kaiser normalization. Factor structures were investigated by both analyzing Eigenvalues and scree plots. Items that failed to load on a factor with values greater than 0.4 were eliminated from the analysis, and the EFA was rerun. An EFA using PCA with Direct Oblimin rotation was also performed and yielded almost identical results. Due to the ease of interpretation of EFA with Varimax rotation, this analysis is presented.

As conceptualized, the EFA yielded three factors with items loading on the hypothesized constructs. The project genderedness (PG) factor contained seven items with factor loadings ranging from .764 - .906. The project domain relatedness (PR) factor contained five items with factor loadings ranging from .553 - .855. Lastly, the student tolerance to ambiguity (TA) factor contained six items with factor loadings ranging from .558 - .747. Eigenvalues for the three factors were all greater than 1.00, with no other factors emerging with Eigenvalues greater than 1. The scree plot analysis also confirmed this. Eigenvalues for the PG, PDR, and STA were 5.332, 3.591, and 2.407, respectively. In summary, these three factors accounted for approximately 63% of the variance. On completion of the EFA, scale reliabilities were tested and scales were created for their respective constructs.

TABLE III. FACTOR ANALYSIS

Final factor loadings from exploratory factor analysis of various survey items

	PG	PR	TA
The project my group worked on was associated with a masculine or feminine institution	**.906**	-.054	-.068
The project my group worked on was associated with a masculine or feminine interested	**.889**	.049	-.073
The project my group worked on is associated with a masculine or feminine product or object	**.881**	.001	-.007
The project my group worked on was associated with a masculine or feminine action.	**.880**	.009	-.063
TABLE III CONTINUED			
The project my group worked on was associated with a masculine or feminine background knowledge.	**.870**	.074	.009
The project my group worked on was associated with a masculine or feminine experience.	**.863**	.015	-.067
The project my group worked on was associated with a masculine or feminine idea generation.	**.764**	.027	-.010
The satisfaction I have felt throughout this industrial sponsored project has helped me easily decide/choose/or stay with my major.	.027	**.855**	.047
The industrial sponsored project this semester has positively impacted me to stay with my major/anticipated major.	-.017	**.828**	.021
The industrial sponsored project has motivated/inspired me to learn.	.008	**.805**	.111
The industrial sponsored project has motivated/inspired me to learn.	.002	**.770**	.146
The industrial sponsored project this semester relates to my major/anticipated major.	.063	**.553**	.058
I try to avoid situations which are ambiguous.	-.020	.063	**.747**
I dislike ambiguous situations.	-.027	-.008	**.746**
I am tolerant of ambiguous situations.	-.067	.020	**.745**
I don't tolerate ambiguous situations well.	-.025	-.004	**.745**
I prefer a situation in which there is some ambiguity.	.018	.146	**.635**
I enjoy tackling problems which are complex enough to be ambiguous.	-.100	.249	**.558**

A. *Scale Reliabilities – Project Domain Relatedness*

Table 4 presents scale reliability analysis for the project domain relatedness factor. One item of the PD scale, *The industrial sponsored project this semester relates to my major/anticipated major,* was removed because deletion of this item improved the Cronbach's α; it had a factor loading of .553, and it had no inter-item correlations greater than .42. This lead to the conclusion that this item might not fit this scale properly. The final PR scale contained 4 items and had a good reliability with a Cronbach's α of .852. The scale mean was 3.15 (SD = .85), indicating that on average students were neutral in their beliefs about the relatedness of the project to their specific domains.

TABLE IV. PROJECT DOMAIN RELATEDNESS

Reliability analysis of project domain relatedness (PD)*				
	Item Mean (SD)	α if item deleted	Cron. α	Scale Mean (SD)
The industrial sponsored project has motivated/ inspired me to learn.	3.25 (1.06)	.850	.852	3.15 (.85)
The industrial sponsored project this semester has positively impacted me to stay with my major/anticipated major.	3.17 (1.05)	.791		
The skills I learned through this industrial sponsored project has helped me easily decide/choose/or stay in my major.	3.10 (1.11)	.774		
The satisfaction I have felt throughout this industrial sponsored project has helped me easily decide/choose/or stay with my major.	3.06 (1.16)	.831		

*items measured on a scale from "1" strongly disagree, "3" neither agree nor disagree, "5" strongly agree.

B. *Scale Reliabilities – Tolerance to Ambiguity*

Table 5 presents the scale reliability for the student tolerance to ambiguity (TA) scale. The TA scale also showed a good reliability with a Cronbach's α of .798. There were no variables that could be deleted that would improve the reliability of this scale. The final scale contained six items and had a scale mean or 3.39 (SD = .64) indicating that on average students were mostly neutral in their tolerance to ambiguity.

TABLE V. TOLERNANCE TO AMBIGUITY

Reliability analysis for student tolerance to ambiguity (TA)*				
	Item Mean (SD)**	α if item deleted	Cron. α	Scale Mean (SD)
I try to avoid situations which are ambiguous.	3.41 (.93)	.752	.798	3.39 (.64)
I dislike ambiguous situations.	3.27 (.91)	.759		
I don't tolerate ambiguous situations well.	3.26 (.95)	.761		
I enjoy tackling problems which are complex enough to be ambiguous.	3.58 (.93)	.790		
I prefer a situation in which there is some ambiguity.	3.28 (.83)	.780		
I am tolerant of ambiguous situations.	3.53 (.87)	.754		

In Table 5, * denotes the scale definitions where "1" strongly is for disagree, "3" is for neither agree nor disagree, and "5" is for strongly agree. Items marked with "**" are reverse coded so that higher means indicated a stronger level of ambiguity tolerance.

C. *Scale Reliabilities – Genderness*

Table 6 presents the reliability analysis of the project genderedness (PG) scale. The PG scale showed a good reliability with a Cronbach's α of .946. Deletion of one item, *The project my group worked on was associated with a masculine or feminine idea generation,* marginally improved the Cronbach's α. However, because it was only a marginal improvement (.946 vs. .947), this item was included in the finalized scale. The final scale contained seven items and had a mean of 2.30 (SD = 1.01), indicating that on average students mostly disagreed that their industry-sponsored design projects were gendered towards either masculine or feminine constructs.

TABLE VI. GENDERNESS

Reliability analysis of project genderedness (PG)*				
	Item Mean (SD)	α if item deleted	Cron. α	Scale Mean (SD)
The project my group worked on is associated with a masculine or feminine product or object.	2.32 (1.18)	.936	.946	2.30 (1.01)
The project my group worked on was associated with a masculine or feminine experience.	2.25 (1.13)	.937		
The project my group worked on was associated with a masculine or feminine institution.	2.33 (1.17)	.932		
The project my group worked on was associated with a masculine or feminine action.	2.21 (1.12)	.935		
The project my group worked on was associated with a masculine or feminine interest.	2.38 (1.20)	.934		
The project my group worked on was associated with a masculine or feminine idea generation.	2.34 (1.19)	.947		
The project my group worked on was associated with a masculine or feminine background knowledge.	2.32 (1.13)	.936		

*items measured on a scale from "1" strongly disagree, "3" neither agree nor disagree, "5" strongly agree.

D. *Factors Affecting PDR, TA, and PGO*

A series of independent sample T-tests, cross tabulations, and bivariate correlations were performed to examine factors that affect PD, TA, and PG. Specifically, an independent samples t-test was performed to compare students' gender and PD, TA, and PG. There were no significant differences between gender and the TA and PG scales. This finding suggests that male and female students do not differ in terms of their tolerance to ambiguity or their perceptions regarding the masculine or feminine orientation of their industry-sponsored design projects. However, there was a significant difference for the PD scale between males ($M = 3.19$, $SD = .81$) and females ($M = 2.83$, $SD = .92$); $t(362) = 3.511$, $p = .001$. This suggests that males were more likely to agree that the industry-sponsored project was more related to their chosen engineering domain than females.

Regarding the genderedness of their industry-sponsored design projects, the PG scale suggested that students mostly disagreed or were neutral in terms of their evaluation of the genderedness of the projects. However, a follow up question asked students to rate their perceptions of the genderedness of the project on a scale, where "1" indicated a very masculine project and "5" indicated a very feminine project, with "3" representing a gender-neutral project. Based on responses, this variable was collapsed into a dichotomous variable, where "0" indicated a general neutral project, and "1" indicated a masculine oriented project (Table 7). Surprisingly, a cross tabulation yielded no significant differences between gender and response to this variable, indicating that men and women were equally as likely to report a masculine oriented or gender-neutral project. However, an independent samples t-test found a significant difference between the PG scale and students who reported a masculine oriented project ($M = 2.84$, $SD = 1.00$) and gender-neutral project ($M = 2.09$, $SD = .93$); $t(363) = 6.718$, $p < .001$. This finding suggests that as students viewed a project to be gendered, they were more likely to perceive the project to be of a masculine orientation.

TABLE VII. STUDENT PERCEPTIONS OF GENDERNESS

Student perceptions of project genderedness and project gender expertise.			
		Frequency	Valid %
Student perceptions of ISDP genderedness	Masculine Oriented Project	100	27.1
	Gender Neutral Project	269	72.9

Lastly, bivariate correlations were performed to test for relationships between TA, PD, and PG (Table 8). Of the variables included, only two showed significant relationships. PD and TA showed a weak, positive correlation with $r = .204$. This finding indicates that as students view a project to be more closely related to their chosen discipline, their tolerance to ambiguity increases.

TABLE VIII. BIVARIATE CORRELATIONS

Bivariate correlations testing the relationships between TA, PD, and PG			
	STA	PDR	PG
STA	1		
PDR	.204***	1	
PG	-.094ns	.052ns	1

V. DISCUSSION

Several findings warrant further discussion. In terms of instrument development, it appears that items designed to assess students' perceptions of project domain relatedness (PD), project genderedness (PG), and student tolerance to ambiguity (TA) are factoring into the appropriate hypothesized constructs. Results of the exploratory factor analysis confirm this with clear factor loadings, and few if any, items cross loading on multiple factors. Furthermore, when scale reliabilities were tested, the PDR and PG scales had Cronbach's α of .852 and .946, respectively. The STA scale had a Cronbach's α of .798. While there is some disagreement in appropriate Cronbach's α levels, values between .6 and .8 are typically acceptable, with higher Cronbach's α indicating greater internal scale validity.

Within the constructs, it is noteworthy that the TA construct originally contained 11 items but data reduction and internal validity testing resulted in a construct of only six items. This may be a result of the specificity of these questions and how students perceive ambiguity in different situational contexts. While some students may like the creative freedom that comes with ambiguity, in terms of ambiguity within industry-sponsored design projects; some students may prefer to have better directions and expected outcomes of said project. Future research could examine this further by looking at general ambiguity and ambiguity related specifically to certain aspects of design projects. Furthermore, a better understanding of various aspects of TA is important because of the correlation between TA and PD.

Looking at PD, a significant difference was found between men and woman in their perceptions of how the industry-sponsored design project related to their discipline. This is most likely due to the nature of the projects and the fact that females were more likely than males to be chemical, biological, or biomedical engineers, while males were more likely than females to be mechanical, aerospace, or nuclear engineers. Because the projects lacked a focus on the biological, biomedical, and chemical engineering disciplines, it is not surprising that individuals in these disciplines would find the projects to be unrelated to their majors. However, student comments to open-ended questions highlight that many students are able to find aspects of their chosen disciplines within the design projects, regardless of the overall theme of the project.

Preliminary results from this data showed a weak, positive correlation between TA and PD ($r = .204$). Depending on the conceptualization of these variables, this could have two different meanings. Accepting that the PDR scale measures students' perceptions of domain relatedness, this finding would indicate that as students perceive their industry sponsored design project to be more related to their chosen discipline, their tolerance to ambiguity of their project increases. However, the PD scale could potentially be measuring students' intentions to remain in their chosen disciplines. Because the item, *The industry-sponsored project this semester relates to my major/anticipated major,* failed to remain in the scale, there is potential that this scale lacks construct validity. In this vein, it could be hypothesized that students who have a higher tolerance to ambiguity are more likely to remain within their chosen engineering discipline. Future analyses should further examine the PD construct and how it relates to specific aspects of industry sponsored design projects.

Lastly, and more importantly, the investigation of project genderedness seems to be a contentious issue. Overall, students mostly disagreed that the project they worked on was gendered. This is further supported by the fact that the majority (73%) identified their project as being gender neutral. No significant differences were found between students' self-reported gender and any measure of their perceptions of the genderedness of their industry design project. However, students who identified their project as masculine oriented were more likely to view their project as being gendered. But again, students' gender played no significant role in this.

What is most interesting are students' contentions that examining the genderedness of industry-sponsored design projects is unnecessary. When asked to elaborate on what aspects of their project made them view it as being masculine or feminine oriented, both men and women students were vocal in detailing that placing gender orientations on industry-sponsored design projects are archaic and overly stereotypical. Both men and women students were adamant in pointing out that both genders possess the capacity to be effective in the engineering disciplines and that other student characteristics (i.e., culture, personality traits) are more important. It would seem the underlying issue is not the genderedness of the industry-sponsored design projects, but the genderedness of the engineering field. What might be at work are students' perceptions, or reality, of the genderedness of their peers.

While a self-identified woman might be neutral in her beliefs about the genderedness of the project, her male peers might hold traditional gender attitudes potentially driving her out of the field. Future research should investigate this further.

VI. Conclusion

This paper set out to examine the preliminary analysis of an instrument developed to assess the project domain relatedness, project genderedness, and student tolerance to ambiguity as they pertain to industry-sponsored design projects. While industry-sponsored design projects are hailed as being an integral part in educating engineering students about the design process, these factors have the potential to affect student success and retention in the field. The present research has the potential to provide deeper insights into the relationships between project domain relatedness, project genderedness, student tolerance to ambiguity, and student efficacy with industry-sponsored design projects. It is acknowledged that some adjustments to the delivery and presentation of industry-sponsored design projects could eliminate issues related to aspects of the project that fail to relate to specific engineering disciplines or varying levels of ambiguity of projects. The issue of project genderedness, however, may be more systemic in the field of engineering and should be better understood in order to improve retention of both genders in their pursuit of engineering education.

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References

[1] J. Froyd, and M. Ohland, "Integrating engineering curricula," *Journal of Engineering Education*, *94*(1), 147-164.
[2] Knight, D., Carlson, L., and Sullivan. J., "Improving engineering student retention through hands-on team based, first-year design projects," *International Conference on Engineering Education Research*, Honolulu, HI, 2007.
[3] Ray, J., "Industry-academic partnership for successful capstone projects," in *Proceedings - Frontiers in Education Conference, FIE*, Boulder, CO, 2003.
[4] Baker, J., Raber, M., and Berkey, R., "Welcome to the 'real-world' - balancing practical, legal, and educational issues in implementing industrial sponsored student design experiences," in *ASEE Annual Conference and Exhibition, Conference Proceedings*, Honolulu, HI, 2007.
[5] Khalid, A., "An industry-sponsored capstone project: A story of success," *ASEE Annual Conference and Exhibition, Conference Proceedings*, Louisville, KY, 2010.
[6] Bethel, C., "Improving student engagement and learning outcomes through the use of industry-sponsored projects in human-computer interaction curriculum," in *15th IEEE International Conference on Emerging eLearning Technology and Application*, The High Tatras, Slovakia, 2017.
[7] Okudan, G., and Mohammed, S. "Task gender orientation perceptions by novice designers: Implications for engineering design research," *Engineering Design Research, Teaching, and Practice, 27*(6), 723-740, 2006.
[8] Merrotsky, P., "Tolerance of ambiguity: A trait of the creative personality," *Creativity Research Journa*l, 25, 232-237, 2013.
[9] Budner, S., "Intolerance of ambiguity as a personality variable," *Journal of Personality*, 30, 29-50.
[10] Kahn, B., and Sarin, R., "Modeling ambiguity in decisions under uncertainty," *Journal of Consumer Research*, 15, 265–27, 1988.
[11] Furnham, A., and Marks, J., "Tolerance of ambiguity: A review of the recent literature," *Psychology, 4*(9), 717-728.
[12] Dringeberg, E., and Wertz, R., "How do first-year engineering students experience ambiguity in engineering design problems: The development of a self-report instrument," *ASEE Annual Conference and Exhibition, Conference Proceedings*, New Orleans, LA, 2016.
[13] Ramaci,T., Pellerone, M., Ledda, C., Presti, G., Squatrito, V., andRapisarda, V., "Gender stereotypes in occupational choice: A cross-sectional study on a group of Italian adolescents," *Psychology Research and Behavioral Management*, 10, 109-117, 2017.
[14] Crawley, D. "Gender and perceptions of occupational prestige," *Sage Open, 4*(1), 2014.
15] Atli, A. "High school students' gender role perceptions regarding various professions," *International Journal of Progressive Education, 13*(3) 6-15, 2017.

[16] Beggs, J. and Doolittle, D., "Perceptions now and then of occupational sex typing: a replication of Shinar's 1975 study," *Journal of Applied Psychology*, 23, 1435 –1453, 1993.
[17] Shinar, E., "Sexual stereotypes of occupations," *Journal of Vocational Behavior*, 7, 99–111, 1975.
[18] van Tilburg, M., Lieven, T., Herrmann, A., and Townsend, C., "Beyond, 'pink it and shrink it' perceived product gender, aesthetics, and product evaluation," *Psychology and Marketing, 32*(4), 422-437, 2015.
[19]. Durheim, K., and Foster, D., "Tolerance of ambiguity as a content specific construct," *Personal Individual Differences*, 22, 741-750, 1997.
[20.] Herman, J., Stevens, M., Bird, A., Mendenhall, M., and Oddou, G., "The tolerance of ambiguity scale: Towards a more refined measure for international management research," *International Journal of Intercultural Relations*, 34, 54-65, 2010.
[21] McLain, D., "The Mstat-1: A new measure of an individual's tolerance for ambiguity," *Educational and Psychological Measurement*, 53, 183-189, 1993.
[22]. Santiago, l., Hensel, R., Marbouti, F., Diefes-Dux, H., Siller, T., Paguyo, C., Knott, T., and Matusovich, H. "Attrition and university detention," *ASEE Annual Conference and Exhibition, Conference Proceedings*, Louisville, KY, 2012.
[23]. Wood, W. "Meta-analytic review of sex differences in group performance," *Psychological Bulletin, 102*(1), 53-71, 1987.
[24]. Karakowsky, L, and Siegel, J.P. "*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, 1999.