Design Ability Assessment Technique

Libby Osgood P. Eng, Dalhousie University and University of Prince Edward Island

Libby Osgood is an Assistant Professor at the University of Prince Edward Island in Canada, where she teaches dynamics and design courses. Concurrently, she is pursuing her PhD in Mechanical Engineering at Dalhousie University in Halifax, Nova Scotia. Her background is in aerospace engineering, specifically related to satellite design. She was a systems engineer for the integration, test, and launch of NASA Goddard's FERMI satellite. Her interests have shifted to studying active learning techniques in engineering education, specifically service learning and social justice.

Dr. Clifton R Johnston P.Eng., Dalhousie University

Design Ability Assessment Technique

There is an ongoing debate to determine which engineering design projects provide the greatest learning opportunity for students. Variations include: whether the client is hypothetical, from industry, or a member of a community organization, whether the product is a paper design, prototype, or fully functioning product, and whether the length of the project is a few weeks long, multi-semester, or multi-year. In order to compare the merit of each of the factors and measure the impact on student learning, an assessment technique must be developed.

While students develop many versatile skills through design projects, such as communication, teamwork, leadership, and engineering science content, the largest impact is shown in students' ability to design. Design projects can be the sole location that students are exposed to lessons in how to design, so this is the ideal skill to measure, as it is less likely to be affected by external factors.

Using a combination of four-point Likert scale items, multiple-choice questions relating to a design scenario, and quantitative self-assessment, a design ability assessment technique was piloted in the Winter of 2013 at Dalhousie University in Halifax, Nova Scotia. The design ability construct was defined as an ability to define the problem, evaluate alternatives, and communicate the design. This was derived from a literature review and accreditation materials. Four-point Likert-scale items were also included concerning ethical awareness, which was defined as knowledge of equal treatment of all persons, ethical conduct in all situations, appreciating cultural diversity for all ethnicities, and possessing a keen awareness of engineers' responsibility to society.

The quantitative instrument was piloted to 240 students with a 10% response rate. While some items displayed a statistically significant result, other items were highly skewed, indicating a poorly written item. Using this information, the instrument was updated and is in the process of validation. This paper will discuss the original instrument, results of the pilot study, and the changes that were inspired by the study.

Introduction

The focus for engineering educators has shifted from teaching problem solving skills in a traditional classroom setting, where equations are derived and examples are written on the board, to allowing students to learn and develop these skills experientially in hands-on projects.[1-2] Design projects are the ideal location for problem solving skills to be learned in a real, meaningful way. However, there is great variability in the execution of design projects. Some projects utilize a client from industry or a community project while other projects are represented by the professor. The length of project varies from a few days to multiple semesters. The maturity of the design product varies from submitting CAD and design documents, to building a prototype, to delivering a working product to the client. The merits of each type of project is often the topic of debate among engineering educators, however it is difficult to declare a superior method as there is not currently an assessment tool to quantify student learning.

Additionally, while design projects have the potential to address all eleven of the student outcomes of the Accreditation Board for Engineering and Technology (ABET), it is difficult to prove what was retained by the students without a valid assessment tool[3]. Therefore, it is the intent of the author to develop and validate an instrument to measure student learning during design projects. This paper will present the results of a pilot study at Dalhousie University in Halifax, Nova Scotia that employed the first iteration of the assessment tool and suggest necessary revisions to the instrument.

Literature Review

Through design projects, students learn how to interact in teams, communicate more effectively through speech and text, complete engineering analyses, make drawings, conceive, build, and test ideas, and additional intangible lessons. An assessment tool cannot successfully measure all of these factors, necessitating a more refined definition of what is to be measured. From the ABET criteria[3], two complementary yet separate constructs are identified for further study: design ability and ethical awareness, as shown in Table 1. This paper is focused on the design ability construct but will provide information on the ethical awareness construct as well.

Table 1: ABET Criteria Mapping to Design Ability and Ethical Awareness Constructs[3]

Design Ability	***Ethical Awareness***
(a) apply knowledge	(f) an understanding of professional and ethical responsibility
(b) design and conduct experiments	
(c) design to meet desired needs within realistic constraints	(h) understand the social impact of engineering
(d) function on multidisciplinary teams	(i) need for life-long learning
(e) identify, formulate, and solve problems	(j) a knowledge of contemporary issues
(g) communicate effectively	
(k) use the techniques, skills, and tools necessary for engineering practice.	*Note: Text has been condensed for formatting purposes*

Existing Assessment Instruments

Existing assessment tools for design ability rely on self-assessment and analyze student grades from design reports, presentations, and logbooks[4-5]. This type of assessment relies on students providing accurate responses and provides a shallow assessment. For example, a student may score very poorly on a report because of their communication skills but have a very advanced design. An instrument is needed to target the different aspects of a students' design ability.

Various less-traditional tools that are utilized include qualitatively observing behavior[6], analyzing creativity[7], responding to sample design scenarios[8], coding design journals[9], and focus groups[10]. The Transferable Integrated Design Engineering Education (TIDEE) project[11] produced the most comprehensive tool that utilizes a short-answer pre-knowledge exam, team design assignment, reflective essay, and self-assessment. This tool, while thorough, requires intensive analysis of the qualitative data and is subjective to the reviewer. Additionally, the knowledge of the design process is assessed in short-answer definition form, a lower level of recall on Bloom's Taxonomy[12]. An instrument that assesses knowledge of the design process *through* the higher form of evaluation or reflection could be immediately employed, such as the Experimental Design Ability Test (EDAT)[13]. The Design Task Test (DTT)[14] provides 60 minutes for an open ended design scenario and the EDAT utilizes open-ended essay questions asking students to test a claim and scores responses based on a developed rubric. The DTT is too broad and EDAT too limited to analyze the different aspects of the design process, necessitating a tool to separately target multiple aspects of a students' design ability.

The most prominent source for assessment of ethical awareness is the Defining Issues Test-2 (DIT-2)[15], which proposes scenarios to assess students' ethical response to a situation. The DIT-2 though validated with over 500 studies and a Chronbach's alpha over 0.7 reliability[15], is an expensive tool[16] that does not provide an immediate response. Using the information from the DIT-2 and the Simulator for Ethics Engineering Education (SEEE2)[17], an ethics-training tool, an instrument could be developed to provide a complimentary, faster analysis.

Developing the Construct

The design ability construct must be further refined to determine which design abilities are deemed most critical to measure. Kim, Jin, and Lee[18] (2011) utilized a three-part design model: problem understanding, idea generation, and design elaboration. In a phenomenographic study[6] novice designers displayed decent idea generation but poor problem definition and idea evaluation, whereas expert designers spent considerable time defining the problem. Passow[19] identified teamwork, communication, data analysis, and problem solving as statistically distinct ($p < .05$) competencies required for engineering practice by engineering alumni. TIDEE[11] divides the design ability into design process, communication, and teamwork. The literature[5,6,14,19-24] revealed that the following three components of the design ability construct were identified among the most important competencies required for an engineer:

- define the problem,
- evaluate alternatives, and
- communicate the design.

This necessitates the need to measure the change in these three design abilities.

The ethical awareness construct must be similarly refined. According to Al-Khafaji and Morse[25] students' awareness, cultural sensitivity, and empathy are among the qualities and skills that are enhanced in certain design projects when the client is a member of a community organization. Finelli et al[26] described three concepts within ethical development: (a) knowledge of ethics, (b) ethical reasoning, and (c) ethical behavior. The study compared curricular and co-curricular experiences to ethical development for 4,000 engineering students in 18 universities. Knowledge of ethics was lower than expected, ethical reasoning and positive ethical behavior met expectations, and negative ethical behavior was much more rampant than expected; significance was not included. Though presenting only descriptive statistics, the study elucidates the need to further measure ethical awareness. A review of the literature[10, 27, 28] indicates that further study is required to measure the ethical awareness in SL projects. The construct for ethical awareness in this study includes:

- equal treatment of all persons,
- ethical conduct in all situations,
- cultural diversity for all ethnicities, and
- keen awareness of responsibility to society.

Note the construct does not attempt to measure the students' ethical reasoning or ethical behavior, merely determine whether they consider ethics during the design process. Do students use ethical reasoning to make design decisions, whether conscious or subconscious? Are students aware of the ethical implications of their work?

Method

This implementation was the first iteration of an instrument to assess design ability and ethical awareness. The study was administered to a purposive sample of 240 multi-disciplinary engineering students enrolled in a second year design course. The students participated in one of four design projects, six weeks in length, with the professor as the client, culminating in a working prototype. The next iteration of the instrument will be delivered before and after the design activity and will include more variability in the project duration, client, and maturity of the design. In order to produce a comprehensive snapshot of the student and project, there are multiple independent variables that were recorded for possible use in future studies, as described in Table 2.

Table 2: Independent Variables to Compare Against Design Ability and Ethical Awareness Constructs

Descriptive Variables	***Project Variables***
Gender	Amount of time spent with the professor
Age	Amount of time spent with the client
Year of studies	Project length
Engineering discipline	Whether the course was mandatory
Type of client	Maturity of the product: paper, prototype, or final product
Whether the participant identifies as a racial minority	Whether the length of the project was sufficient
The amount of time participants travelled outside of America	Whether the amount of time with the professor or client was sufficient

The instrument contains three types of items: assessment, self-assessment, and a proposed design scenario; items shown in Appendix A. The assessment and self-assessment items are on a labeled four-point Likert-scale from Strongly Agree (1) to Strongly Disagree (4), with an option for ‘Don’t Know’. Approximately half of the items are reverse scored (negatively worded to prevent students from selecting only ‘Strongly Agree’). The proposed design scenario is addressed by four multiple-choice items, examining students’ design ability with a sample design scenario that requires them to design a chair for a person over six feet tall. A score out of four is assigned that parallels the self-assessment questions. Table 3 delineates the number of items for each construct.

Table 3: Number of Instrument Items per Construct by Type

	Design Ability			***Ethical Awareness***
Type of Item	*Define the Problem*	*Evaluate Alternatives*	*Communicate Design*	
Assessment[a]	2	3	7	7
Self-Assessment[a]	3	1	7	3
Design Scenario[b]	3	0	1	

[a]Item employs Likert-scale. [b]Item employs multiple-choice.

The data were entered into IBMs Statistical Package for Social Sciences (SPSS) and cleaned by removing discrepant values and data entry errors, reverse-coding negatively-worded items, recoding the multiple-choice items, and recoding 'Don't Know' as missing data. Reliability was determined using Cronbach's alpha. An exploratory principal component factor analysis was performed and correlations (Pearson's r) were found between the dependent variables and independent variables. Assumptions of normality and homogeneity of means and variances were reviewed. Finally, one-way analyses of variance (ANOVA) were performed.

Results

Of the 240 potential participants, only 10% responded to the survey. Participation was voluntary and delivered in an online format. The sample was representative of the participant population: 13% of the sample were male, 76% were between the ages of 18 and 21, and 7% identified themselves as a racial minority. Due to the small participation, reliability of constructs could not be accurately determined. The reliability of design ability construct was found to be $\alpha = .18$ ($n = 13$) and $\alpha = .252$ ($n = 11$) for ethical awareness. An exploratory factor analysis was performed using the scree-plot method, a factor load of > .3, and varimax rotation, disregarding the fact that the sample size ($n = 21$) was substantially smaller than is required for factor analysis. Five factors were identified from the 36 items, accounting for 83% of the variance, however there was no identifying link between the items in each new factor. Table 4 displays the descriptive statistics for the 7 dependent variables.

Table 4: Descriptive Statistics of Dependent Variables with Reliability

Dependent Variable	*Mean*[a]	*Standard Deviation*	*Reliability (α)*
Design Ability[c]	*1.99*	*0.29*	*.18 (n=13)*
Ethical Awareness[b]	*1.99*	*0.32*	*.252 (n=11)*
Factor 1[b]	*1.92*	*0.43*	*.862 (n=11)*
Factor 2[c]	*1.89*	*0.46*	*.733 (n=14)*
Factor 3[c]	*2.00*	*0.44*	*.758 (n=8)*
Factor 4[b]	*2.06*	*0.53*	*.743 (n=9)*
Factor 5[b]	*2.30*	*0.43*	*.609 (n=9)*
[a]Scale: 1 = High ability to 4 = Low ability			

Correlation coefficients (Pearson's r) were calculated between the 7 dependent variables (design ability, ethical awareness, and Factors 1-5) and 14 independent variables (age, gender, year, international travel, and remaining items in Table 2). There were significant correlations within the dependent variables, including design ability and ethical awareness. The highest correlation found between an independent and dependent variable was between Factor 3 and the number of hours spent with the professor. With an N of 20, the more hours spent with the professor, the lower the ability of the student.

24 out of 43 items (including the factors) met assumptions of normality, with 19 skewed items and 14 items displaying kurtosis. Figure 1 shows dependent variables that meet assumption of normality, with a scale where 1 corresponds with a high ability and 4 with a low ability.

One-way ANOVA was performed multiple times to determine if the 7 dependent variables were reliant upon the 14 independent variables. Significance ($p < .05$) and power ($F > 1$) were examined and post-hoc Tukey HSD analyses were performed. Due to the limited sample size, Tukey HSD did not produce any findings. However, there was a statistically significant difference between the time spent with the professor and Factor 3 (F = 3.428 and p=.035), as was found in the correlation analysis.

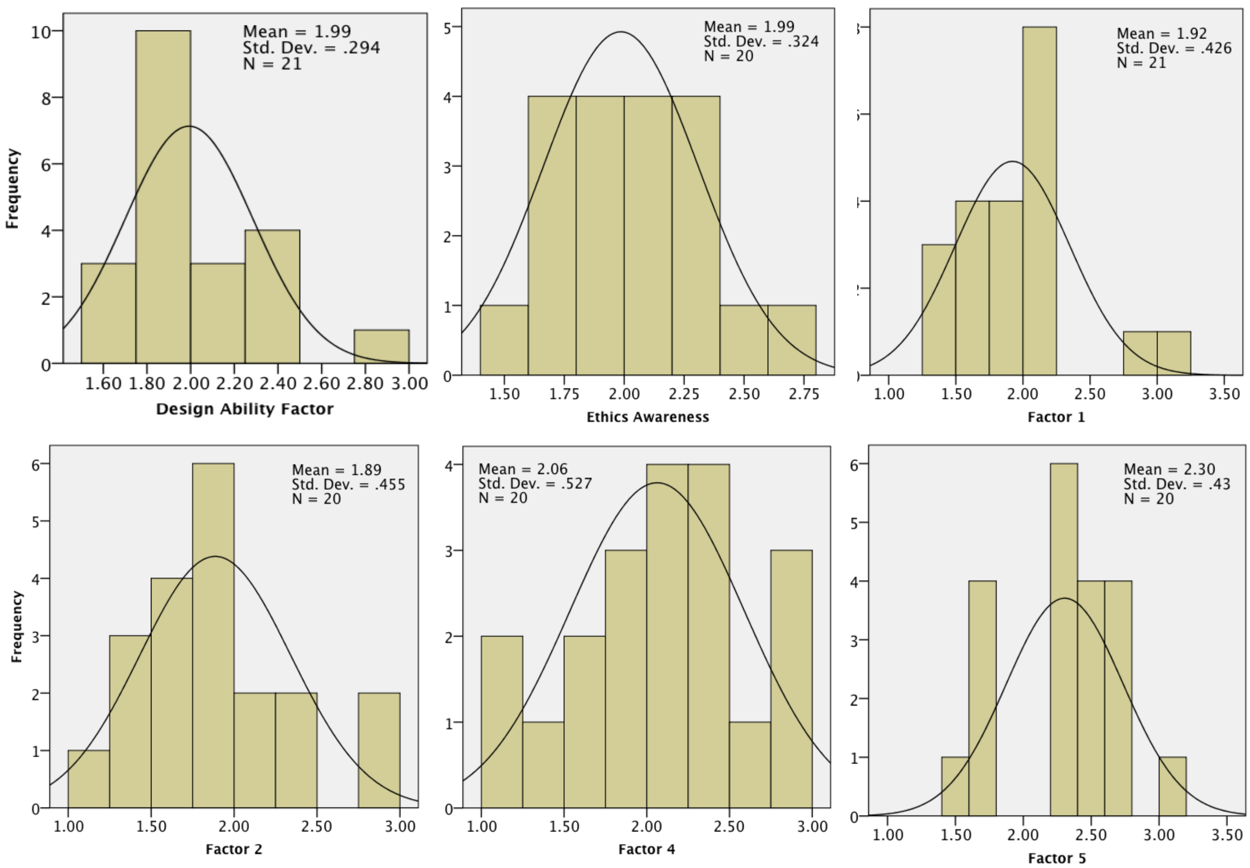

Figure 1: Assumptions of Normality for Factors 1-5 and Constructs

No significant differences were found for design ability or ethical awareness constructs. The only correlation observed was between Factor 3, a combination of design ability and ethical awareness items determined by a factorial analysis, and the time spent with the professor. The correlation showed that the students with the lower ability spent more time with the professor, presumably seeking aid. Perhaps with a larger sample size, a description of each factor could be determined.

Discussion

The instrument was developed in order to allow for prompt quantitative analysis with emphasis on determining the design ability and ethical awareness of students in design courses. However due to a sample size of between 8 and 24, depending on the item, reliability of scale and statistically significance correlations were not found. A sample of 8 when determining significance is misleading and cannot be generalized to the engineering population. Additionally, all of the responses to 6 of the 14 independent variables were constant for the entire sample, such as year in studies or length of project. More design projects are required for a more prolific assessment.

Due to the small sample size, however, any significance that was determined could be attributed to a type I error. Similarly, the absence of significance could be attributed to a type II error due to the small sample size. The ANOVA and factor analysis techniques require a larger sample than was available during the pilot study. In addition, all of the items were missing values. This affected the reliability of the dependent variables, as listwise deletion occurred when Cronbach's alpha was calculated, which reduced the number of participants.

In order to increase sample size, the instrument will be delivered on paper during class rather than in an online format at the end of the semester. Additionally the instrument will be divided into a pre/post format to determine whether design ability or ethical awareness increased throughout the course of the design project.

Much was gained through the quantitative pilot study. An analysis of normality and the low reliability score illustrated a need for specific items to be reworded. Participants all responded the same way to some of the ethical awareness items, demonstrating that there is a socially correct answer, e.g. 'Men make better engineers than women'. Such items were reworded to better assess ethical awareness.

Additionally, it was determined that a purely quantitative approach will not achieve the goal of measuring design ability or ethical awareness, requiring iteration 2 of the instrument to employ qualitative assessment as well. Iteration 2 will also focus on design scenarios rather than self-assessment to measure students' ability to design using higher order learning. The self-assessment items will be removed, as they are a measure of confidence rather than an accurate measure of design ability. It was determined that the ethical awareness items were not validated, in that the questions did not actually measure ethical awareness. Instead, a qualitative assessment directly targeted to an engineering problem will be posed in iteration 2 of the instrument.

The construct, though still considered valid as it was obtained from the literature, will be refined and individual items will be mapped to the accreditation board's individual objectives. In order to increase the sample size, the method of delivery will be altered to be during class rather than online, though steps will be taken to ensure the professors are unaware of which students participate. A larger sample will increase the validity of the results and allow for more variables to be tested.

Conclusion

The primary intent to develop an instrument to measure design ability and ethical awareness from the literature was achieved. The intent to validate the instrument was not achieved, as the pilot study elucidated the need for a second iteration of the instrument, refinement of questions, and change in the method of delivery. The instrument will be updated to more accurately measure design ability through the removal of self-assessment items, reword poor items, and require a larger sample. There is the potential for significant findings, however a second pilot study will be necessary in order to validate an instrument to assess design ability and ethical awareness.

Appendix A: Instrument

Design Ability Construct
Proposed Design Scenario Items

You were asked to design a chair for a person over 6 feet tall, for their office. Answer the following three questions with this information.

You just finished the first meeting with the client to discuss the problem, which lasted 15 minutes. Of the following, the first task you should complete is:

a. Develop a schedule of all tasks to be completed.
b. Find out more about chair design and background information.
c. Brainstorm ideas based on what the client said was important.
d. Write requirements to define the problem.

When developing ideas, the chair should be:

a. Treated as one unit.
b. Broken up by sections: base, armrest, and seat.
c. Broken up by components: wheels, stem, seat, backrest, armrest, screws, bolts, and springs.
d. Broken up by function: height adjustment, mobility, back support, and arm support.

The best requirement for the chair would be:

a. The chair seat must be 2 feet plus or minus 3 inches from the floor.
b. The chair height should be adjustable.
c. The chair must fit a 6 ft tall person.
d. The chair should be tested before delivery.

When presenting to a large audience for a formal design presentation, it is most appropriate to:

a. Read your speech off a piece of paper.
b. Glance at notecards.
c. Focus on one person in the audience.
d. Read from the screen behind you.

Assessment Items

	Strongly Agree	Agree	Disagree	Strongly Disagree	Don't Know
Research is not necessary to develop product requirements.	1	2	3	4	5
Only one person in each group needs to work on the design document.	1	2	3	4	5
Requirements are measureable and specific pieces of information.	1	2	3	4	5

	Strongly Agree	Agree	Disagree	Strongly Disagree	Don't Know
When evaluating possible designs, it is best to choose the least expensive design.	1	2	3	4	5
It is necessary to rehearse before a presentation for the client.	1	2	3	4	5
A design document has sections with headings.	1	2	3	4	5
Tables are a concise way to display data.	1	2	3	4	5
A decision matrix is optional when deciding which design to select.	1	2	3	4	5
The disadvantages should be considered as well as the advantages when deciding which design is best.	1	2	3	4	5
There are never too many slides in a presentation for the client.	1	2	3	4	5
My client was not pleased with my design.	1	2	3	4	5
When working on a team, my teammates contribute less than I do.	1	2	3	4	5

Self-Assessment Items

	Strongly Agree	Agree	Disagree	Strongly Disagree	Don't Know
My ability to compare the advantages and disadvantages of different designs improved during this project.	1	2	3	4	5
When I make oral presentations, I say 'um' a lot.	1	2	3	4	5
I know the necessary components of a professional engineering report.	1	2	3	4	5
I feel comfortable sharing ideas with my teammates.	1	2	3	4	5
In my last engineering report, there were at least 3 errors.	1	2	3	4	5
My ability to define client specifications or requirements improved during this project.	1	2	3	4	5
My ability to determine the tasks required to complete a design during a limited time improved during this project.	1	2	3	4	5
My ideas were heard and incorporated nicely into this project.	1	2	3	4	5
This project helped me gain a better understanding of the engineering design process.	1	2	3	4	5

	Strongly Agree	Agree	Disagree	Strongly Disagree	Don't Know
My ability to communicate in oral presentations improved during this project.	1	2	3	4	5
In my last oral presentation, I confidently explained how the product was designed.	1	2	3	4	5

Ethical Awareness Construct
Assessment Items

	Strongly Agree	Agree	Disagree	Strongly Disagree	Don't Know
Acting ethically is the most important part of being an engineer.	1	2	3	4	5
I don't need to worry about ethics until after I graduate.	1	2	3	4	5
The best teams have at least one female.	1	2	3	4	5
Men make better engineers than women.	1	2	3	4	5
It is better for society if people who are part of a minority isolate themselves.	1	2	3	4	5
The best teams have people who think and feel the same way.	1	2	3	4	5
Engineers have a responsibility to protect society.	1	2	3	4	5

Self-Assessment Items

	Strongly Agree	Agree	Disagree	Strongly Disagree	Don't Know
I am more engaged in a project that helps the community.	1	2	3	4	5
My design for this project is more meaningful to society than other design projects I worked on.	1	2	3	4	5
If I was hired today as an engineer in my field, I could do whatever is asked of me.	1	2	3	4	5

Bibliographic Information

1 Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (1999). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

2 Gelmon,S.B. (2000). How do we know that our work makes a difference? *Metropolitan Universities, 11*(2), 28-39

3 ABET Accreditation Board for Engineering and Technology. (2010). Criteria for accrediting engineering programs. http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2008-09%20EAC%20Criteria%2012-04-07.pdf.

4 Schuburt, T. F., Jacobitz, F. G., & Kim. E. M. (2012). Student perceptions and learning of the engineering design process: an assessment at the freshmen level. *Research in Engineering Design,* 23, 177-190. DOI 10.1007/s00163-011-0121-x

5 Carberry A. R., & Lee, H. S. (2010). Measuring engineering design self-efficacy. *Journal of Engineering Education, 99*(1), 71-79.

6 Zoltowski, C. B., Oakes, W. C., & Cardella, M. E. (2012). Students' ways of experiencing human-centered design. *Journal of Engineering Education, 101*(1), 28-59.

7 Charyton, C. et al. (2011). Assessing creativity specific to engineering with the revised creative engineering design assessment. *Journal of Engineering Education,* 100(4), 778-799.

8 Schilling, W. W. (2012). Effective assessment of engineering design in an exam environment. Proceedings from the 2012 ASEE Conference.

9 Sobek, D. K. (2002). Preliminary Findings from Coding Student Design Journals. Proceedings from the 2002 ASEE Conference.

10 Nesbit, S. E., Sianchuck, R., Sleksejuniene, J., & Kindiak, R. (2012). Influencing student beliefs about the role of the civil engineer in society. *International Journal for the Scholarship of Teaching and Learning, 6*(2). Retrieved from http://academics.georgiasouthern.edu/ijsotl/

11 Gentili, K.L., McCauley, J.F., Christianson, R.K., Davis, D.C., and Trevisan, M.S. (1999, November). Mid-program assessment and classroom improvement of engineering students in engineering design. Paper presented at the the Frontiers in Education Conference, Puerto Rico.

12 Bloom, B. S. (1956). Taxonomy of educational objectives. Handbook I: Cognitive domain. Handbook II: Affective domain. New York, NY: David McKay.

13 Sirum, K. & Humburg, J. (2011) Experimental design ability test study – MEASURING EXPERIMENTAL DESIGN ABILITY: A TEST TO PROBE. *Bioscene*, 37(1)

14 Kim, Y. S., Jin, S. T., & Lee, S. W. (2011). Relations between design activities and personal creativity modes. *Journal of Engineering Design*, 22(4), 235-257.

15 Rest, J. R., et al. (2000). A Neo-Kohlbergian Approach to Morality Research. *Journal of Moral Education,* 29**,** 381-396.

16 DIT-2 Prices. http://www.ethicaldevelopment.ua.edu/prices. Retrieved January 3, 2014.

17 Alfred, M. & Chung, C. A. (2012). Design, Development, and Evaluation of a Second Generation Interactive Simulator for Engineering Ethics Education (SEEE2), *Science and Engineering Ethics,* 18, 689-697. DOI 10.1007/s11948-011-9284-0

18 Kim, Y. S., Jin, S. T., & Lee, S. W. (2011). Relations between design activities and personal creativity modes. *Journal of Engineering Design, 22*(4), 235-257.

19 Passow, H. J. (2012). Which ABET competencies do engineering graduates find most important in their work? *Journal of Engineering Education, 101*(1), 95-118.

20 Sevier, C., Chyung, S. Y., Callahan, J., & Schrader, C. B. (2012). What value does service learning have on introductory engineering students' motivation and ABET program outcomes? *Journal of STEM Education, 13*(4), 55-70.

21 Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A., & Hornstein, M. (2010). Destination, imagination and the fires within: Design thinking in a middle school classroom. *International Journal of Art & Design Education, 29*(1), 37-53. doi:10.1111/j.l476-8070.2010.01632.x

22 Dym, C. L., Agogino, A. M., Ozgur, E., & Frey, D. D. (2005). Engineering design thinking, teaching and learning. *Journal of Engineering Education, 94(1), 103-120.*

23 Oehlberg, L., & Agogino, A. (2011, June). *Undergraduate conceptions of the engineering design process: Assessing the impact of a human-centered design course.* Paper presented at the 118th American Society for Engineering Education Annual Conference and Exposition, Vancouver, BC.

24 Genco, N., Hölttä-Otto, K., & Seepersad, C. C. (2012). An experimental investigation of the innovation capabilities of undergraduate engineering students. *Journal of Engineering Education, 101*(1), 60-81.

25 Al-Khafaji, K., & Morse, M. C. (2006). Learning sustainable design through service. *International Journal for Service Learning in Engineering, 1(*1), 1-10.

26 Finelli, C. J., Holsapple, M. A., Ra, E., Bielby, R. M., Burt, B. A., Carpenter, D. D., … Sutkus, J. A. (2012). An assessment of engineering students' curricular and co-curricular experiences and their ethical development. *Journal of Engineering Education, 101*(3), 469-494.

27 Moely, B. E., McFarland, M., Miron, D., Mercer, S., & Ilustre, V. (2002). Changes in college students' attitudes and intentions for civil involvement as a function of service-learning experiences. *Michigan Journal of Community Service Learning, 9*(1), 18-26.

28 Brown, B., Heaton, P., & Wall, A. (2007). A service-learning elective to promote enhanced understanding of civil, cultural, and social issues and health disparities in pharmacy. *American Journal of Pharmaceutical Education, 71*(1). Retrieved from http://www.ncbi.nlm.nih.gov