# AC 2011-2749: ENGINEERING CREATIVITY AND PROPENSITY FOR INNOVATIVE THINKING IN UNDERGRADUATE AND GRADUATE STUDENTS

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# Engineering Creativity and Propensity for Innovative Thinking In Undergraduate and Graduate Students

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*Abstract*

Over the past two decades, various research studies across education and business fields have attempted to measure individuals' creativity and innovative behavior. The research on creativity has most often been accomplished in K-12 education while research in innovation has focused on workplace measurement. Business research has attempted to link metrics of innovation to entrepreneurship. Educational research has not broached this connection. Research is somewhat split as to whether creativity and innovation are domain or disciplinary characteristics or traits or whether they can be measured in general form. Such research has not been focused on engineering or the sciences. Interestingly, both engineering and scientifically focused industries are expecting both innovative and entrepreneurial skills in their degreed employees. To meet the need of measuring whether engineering programs are inspiring and cultivating creativity and innovation (a recognized precursor of entrepreneurship,) I designed an engineering creativity and innovation index. This paper reports on the development, theoretical grounding and reliability and validity testing and piloting of this new instrument.

**Introduction**

As described in the abstract above, over the past two decades, various research studies across education and business fields have attempted to measure individuals' creativity and innovative behavior. The research on creativity has most often been accomplished in K-12 education while research in innovation has focused on workplace measurement. Business research has attempted to link metrics of innovation to entrepreneurship. Educational research has not broached this connection. Research is somewhat split as to whether creativity and innovation are domain or disciplinary characteristics or traits or whether they can be measured in general form. Such research has not been focused on engineering or the sciences. Interestingly, both engineering and scientifically focused industries are expecting both innovative and entrepreneurial skills in their degreed employees. To meet the need of measuring whether engineering programs are inspiring and cultivating creativity and innovation (a recognized precursor to entrepreneurship,) I designed an engineering creativity and innovation index. This paper reports on the development, theoretical grounding and reliability and validity testing and piloting of this new instrument. The instrument, referred to as the Engineering Creativity and Propensity for Innovation Index (ECPII) has been utilized both in development and piloting with undergraduate and graduate engineering students at a major research university.

For the present study, the research measured students' creativity and their propensity for innovation. This metric is a new measure and is now also being used in three engineering programs nationally. This metric was designed and tested as a consequence of ongoing conversations with engineering educators nationally and the desire to assess the role that comprehensive educational and engineering experiences have in important industrial and

academic skill sets: creativity and innovation. Importantly, the instrument is aligned to several theoretical perspectives. With regard to creativity theory it is aligned to robust creativity research by Torrance,[1] Abedi's and Khatena's,[2] and Rogers'[3] work on innovation and entrepreneurship. The ECPII has 10 important constructs (described below). These constructs are closely aligned to the cited combined research on creativity and innovation and domains specific to engineering.

The study is guided by three important research questions: *Can we accurately measure engineering creativity and its relationship to propensity for innovation? What role do experiences and engineering education pedagogical practices play in development of engineering students creativity and associated innovation?*

These research questions were inspired by research in innovation in the business fields that posits that problem solving approaches link to innovation and that aspects of creativity including fluency and flexibility in thought and work processes.

*Instrument Specifics, Reliability and Validity Testing*
As previously described the ECPII has ten theoretically grounded constructs (measured in subscales) described below.

*Engineering Self-Confidence:* The degree to which the student exhibits self-confidence in his or her decisions.

*Engineering Self-Strength:* The degree to which the student is able to operationalize his or her decisions in the face of adversity.

*Engineering Artistry:* The students' ability to make sense and have fluency in engineering design.

*Engineering Intellectuality*: Students' intellectual ability specific to the engineering domain.

*Engineering Flexibility:* Degree of students' diversity in thinking processes within and beyond the engineering mindset in diverse engineering related settings.

*Engineering Fluency:* Students' level and depth of understanding of diverse aspects of the engineering discipline.

*Engineering Environmental Sensitivity*: Students' ability to recognize the importance of environment in his or her work.

*Disciplined Imagination:* Students' ability to imagine diverse problem solving approaches within the engineering discipline coupled with ability to use a diverse engineering problem solving skill set in the face of distractors.

*Engineering Initiative:* Students' ability to take action to work within the discipline without cuing or prompting.

_Engineering Inquisitiveness:_ Students' level and depth of curiosity about engineering processes, how things work, and diverse problem solving approaches within and beyond the discipline.

_Instrument Design and Testing_

There are total of forty items on the ECPII with 3-6 items per subscale (described above). This item distribution and scale total is supported by item response theory for designing difficult to observe (soft skill) constructs, as is the case of engivering creativity and innovation. The table (1) below provides sample items for each of the subscales.

A minimum of two items per subscale in the index are reverse scored items in the index in support of best practices in survey development, and true measurement of student ability (rather than student perception) beyond what is self-reported. A four point Likert-type scale was employed for the the majority of the ECPII items. A final set of items situated at the end of the index are open-ended and include the requirement that participants read a context and discipline embedded scenario and solve an engineering problem via a listing of steps to problem solving. This subset of items is rated using a 4-point checklist aligned with the subscales in the ECPII.

| Table 3: Reliability Coefficients | |
|---|---|
| Subscale | Cronbach's Alpha Value |
| Engineering Self-confidence | .77 |
| Engineering Environmental Sensitivity | .82 |
| Engineering Disciplined Imagination | .71 |
| Engineering Initiative | .76 |
| Engineering Inquisitiveness | .76 |
| Engineering Self-strength | .72 |
| Engineering Intellectuality | .78 |
| Enginering Individuality | .71 |
| Engineering Artistry | .73 |
| Overall Reliability | .75 |

With regard to the initial ECPII design, reliability testing and validation, an initial set of items were designed and piloted with a group of undergraduate and graduate engineering students in 2010. Reliability coefficients were computed. Following this, and once the initial set of items for the ECPII were developed, seven engineering Ph.D. students were chosen to engage in a "cognitive interviewing technique" to test the content and construct validitity of each index item. Accordingly, the Ph.D. students completed the draft ECPII and then were interviewed to understand the rationale that they followed for making specific response choices. Woolley, Bowen and Bowen[3] describe this cognitive interviewing process as having the individual discuss the message behind his or her responses. In particular, these scholars' measurement research has provided credibility for this instrument design technique as a powerful and viable means of developing content and construct validity of survey-type self-report instruments for measuring beyond perceptual skills. All ECPII items were revised with specificity according to the results of the cognitive interviews described above. Post

completion of the cognitive interview process and revision, the ECPII was administered with undergraduate and graduate engineering students across departments in three universities in the form of a research pilot. The pilot results are reported herein.

After the items were revised post validation, the reliability of the subscales was tested once again using Cronbach's correlational analysis procedures. Table 3 presents the reliability coefficients by subscale for the Index. This information provides inmportant indicators of the reliability of the ECPII. As revealed by Cronbach's work on instrument reliability, any alpha value that computes to ~ .70 or above is considered moderately to highly reliability in measurement of the knowledge and understanding that it is intended to measure. Accordingly, the ECPII is quite reliable per its alpha coefficients.

*Results*
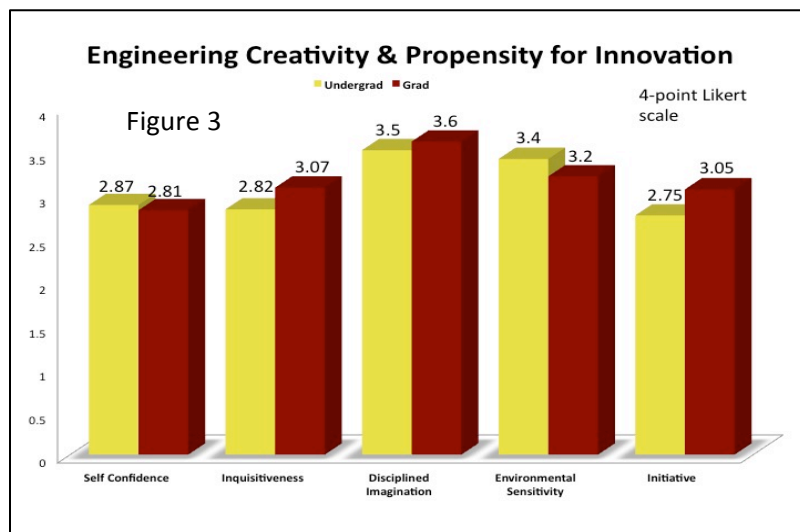
Results of the ECPII are interesting and diverse. Means by subscale are presented below as Figures 3 and 4 with comparisonsds between undergraduate and graduate students. The overall creativity and propensity for innovation for graduate students in the study was 3.12 and for undergraduate students it was 3.0 on a 4-point Likert-type scale, indicating the engineering students are creative and innovative across constructs.



Figure 3. Engineering Creativity & Propensity for Innovation

In an effort to examine differences among the students in the study, statistical comparison tests were conducted. A paired samples t-test was utilized to determine the significance that existed between the means of the two groups. The paired samples t-test revealed that the graduate student cluster had higher scores on the majority of the



Figure 4. Engineering Creativity & Propensity for Innovation

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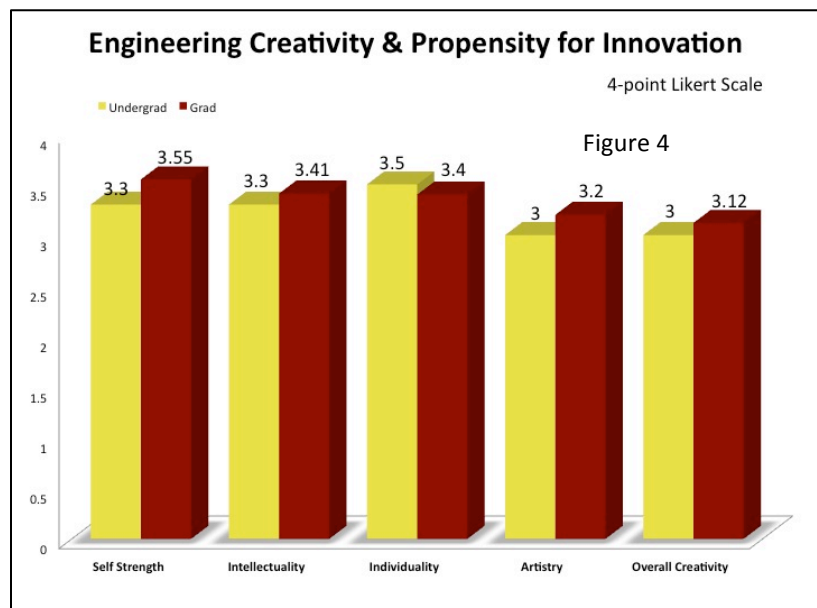
ECPII subscales (overall means for both undergraduate and graduate groups, m=3.14 and m=3.24, respectively, with the difference according to the t-test approaching significance, $t(9)=-1.837$, $p=0.09$). This comparative difference in means between the undergraduate and graduate groups may be attributable to increased experiences and exposure to creative and innovative thinking opportunities throughout the participants' undergraduate careers and as they transition into their graduate careers.

In addition a paired samples t-test was conducted to examine the differences between the two groups in relation to ECPII subscales and overall ECPII. The t-test revealed significant findings ($t(4)=-3.202$, $p<0.05$). The graduate group mean was found to be significantly higher (m=2.61 and m=2.72, undergraduate and graduate student means respectively). This again may be attributable to increased experiences and opportunities as the participants move from undergraduate to graduate education.


**Summary, Conclusions and Future Work**

The results of this pilot study on the newly developed ECPII reveal that students in the study are both creative and innovative. These results indicate that graduate students are understandably more advanced in all areas than the undergraduate students in the pilot. These results are preliminary as they represent a "one-time" measurement of these skills. Comparative results across the years of students' engineering educational experiences will reveal more powerful results and those that can be most accurately attributed to particular pedagogical practices. This pilot study has potential for informing engineering education practice as it may be used in the future to help engineering educators design programs that inspire creativity and innovation. This may be particularly helpful if the measure is used in combination with diverse pedagogical practices and engineering education models.

**References**

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