Assessing Creativity of Senior Design Projects Using an Engineering Expert Panel

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Abstract

Engineering and engineering technology students are usually required to complete a senior design course during the final year of their undergraduate studies. The students typically work in small groups with the goal of developing, designing, and building a working prototype of an engineering product. At the end of fall quarter of the 2013-14 academic year, senior student groups in an engineering technology program presented their design and plans for their projects (MET 421, Senior Design Project) to a panel of engineering experts that included representatives from industry. At the end of the spring quarter, the student groups presented their completed projects (MET 423, Senior Design Project) to the engineering expert panel and they were required to demonstrate the use and applicability of their final prototype. During both fall and spring presentations, the expert panel was asked to complete a creativity assessment rubric for each group to assess the creativity of the students’ project ideas and prototypes. The goal of our research was to determine 1) the degree of inter-rater reliability amongst the engineering expert panel when assessing creativity, 2) the changes in the experts’ creativity ratings from fall to spring quarter, and 3) using a focus group, determine any inhibitions to students’ creativity in the senior design projects. Using paired t-tests and kappa analyses we found that there was no significant change in the expert panel’s creativity ratings between the fall and spring quarters, and the inter-rater reliability was higher for the spring quarter than for the fall quarter. The focus group revealed some impediments to creativity in the senior design projects.

Background

Creativity - a desired attribute in engineering graduates - is the development of ideas, products, artifacts or solutions that are perceived as unique and novel, relevant and useful, and demonstrating excellence in a domain. The characteristics or attributes of creativity include originality, fluency, flexibility, elaboration, tolerance of ambiguity, resistance to premature closure, convergent thinking, divergent thinking, risk taking, intrinsic motivation and extrinsic motivation. Like other skills, creative skills can be developed, awakened and nurtured in our students. A number of universities have identified creativity or the development of creative skills as one of the learning outcomes for their graduates; however, published evidence of how the achievement of creative skills by students are assessed is sparse. In fact, in the authors’ experience, there are few courses available to engineering or engineering technology faculty or students that expose them to the theories or attributes of creativity. Furthermore, even at some universities that indicate in their mission or learning outcomes statement that they value creativity as an outcome for their graduates, “aspects of creative skill development are often missing from even exemplary engineering courses.” One approach taken by many engineering and engineering technology programs to assess the development of creativity in their students is through the use of senior design projects.
Senior engineering and engineering technology students from a variety of disciplines, including mechanical, chemical, and electrical engineering, are required to complete a senior design course during their final year of undergraduate coursework. The students work in small groups with the goal of developing, designing, and building a working prototype of an industrial engineering product. Examples include a low cost portable fluorimeter and a green energy solar collector (see Figures 2 and 3). At the end of the fall quarter course (MET 421 - Senior Design Project), student groups present their design and plans for building the prototype to a panel of engineering experts. At the end of the spring quarter course (MET 423 - Senior Design Project), the student groups present their projects to the engineering expert panel a second time in order to demonstrate the use and applicability of their final prototype. During both fall and spring presentations, the expert panel was asked to complete a creativity rubric for each group to assess the creativity of their project idea and prototype. The goal of our research was to determine 1) the degree of inter-rater reliability amongst an engineering expert panel when assessing creativity, and 2) changes in creativity ratings from fall to spring quarter; 3) Focus Groups are also discussed below.

Methods

The expert panel is made up of engineering faculty and staff from Drexel University and the University of Pennsylvania, as well as professional engineers from the community. At both the fall and spring presentations, each expert was asked to complete a creativity rubric (shown in Table 1) for each presenting group. As there were 9 student groups (2-4 students per group, total of 29 students), each expert was asked to complete 9 rubrics in the fall and 9 rubrics in the spring. Experts were asked to answer each question on the rubric, even if that meant selecting “Not Applicable” or “NA”. Experts who returned only partially completed rubrics were excluded from the final analysis.

Analyses were based upon the Consensual Assessment Technique. Kappa analyses were conducted with each set of evaluations in order to evaluate inter-rater reliability. In the fall quarter, 10 expert panel members completed all evaluations and were included in the analysis. In the spring quarter, 13 expert panel members completed all evaluations and were included in the analysis.

In order to assess changes between fall and spring quarter creativity ratings, paired t-tests were performed. Only experts who completed evaluations in the fall and spring were included (n=7). Results were considered significant at p<0.05.
Table 1: Expert Panel Creativity Rubric

<table>
<thead>
<tr>
<th></th>
<th>S A</th>
<th>A</th>
<th>D</th>
<th>S D</th>
<th>NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The Idea is highly creative</td>
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<tr>
<td>2. The idea could lead to a broadly applicable product</td>
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<tr>
<td>3. The idea could serve as a catalyst for further ideas/products</td>
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<tr>
<td>4. The problem does not respond to a clearly identified need</td>
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<tr>
<td>5. The proposed project fits the problem for which it was created</td>
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<tr>
<td>6. The problem description clearly communicates its purpose</td>
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<td>7. The problem description appears incomplete</td>
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<td>8. The idea shows evidence of careful thought and planning</td>
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<td>9. The idea is not very easy to understand</td>
<td></td>
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<tr>
<td>10. The idea is a truly new product</td>
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<tr>
<td>11. The idea is a new &quot;twist&quot; to an existing product</td>
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<tr>
<td>12. The idea is a routine product</td>
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</table>

SA = strongly agree; A = agree; D = disagree; SD = strongly disagree; NA = not applicable

Results

Results of the paired t-tests are displayed below in Table 2. Creativity ratings from fall to spring quarter did not change significantly for 8 of the student groups. In Group 5, however, there was a significant change in creativity scores as assessed by the expert panel.

Results of the Kappa analyses are displayed below in Tables 3 and 4. During the fall quarter, there was no evidence of any inter-rater reliability, with Kappa statistics for each group ranging from “less than chance agreement” to “slight agreement”. During the spring quarter, some amount of inter-reliability began to emerge. While one group still showed only “slight agreement”, the remaining 8 groups displayed “fair” to “substantial” agreements in expert creativity ratings.
Table 2: Paired t-tests assessing change in creativity rating from fall to spring quarter (N=7)

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
<th>Group 7</th>
<th>Group 8</th>
<th>Group 9</th>
<th>Group 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.62</td>
<td>0.35</td>
<td>0.38</td>
<td>0.45</td>
<td>0.02*</td>
<td>0.06</td>
<td>0.37</td>
<td>0.21</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 3: Kappa analysis, fall quarter (MET 421) (N=10)

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
<th>Group 7</th>
<th>Group 8</th>
<th>Group 9</th>
<th>Group 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kappa</td>
<td>0.11</td>
<td>0.13</td>
<td>-0.01</td>
<td>0.18</td>
<td>0.16</td>
<td>0.12</td>
<td>0.13</td>
<td>0.12</td>
<td>0.11</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.68</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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</tbody>
</table>

Table 4: Kappa analysis, spring quarter (MET 423) (N=13)

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
<th>Group 7</th>
<th>Group 8</th>
<th>Group 9</th>
<th>Group 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kappa</td>
<td>0.4</td>
<td>0.5</td>
<td>0.27</td>
<td>0.55</td>
<td>0.67</td>
<td>0.39</td>
<td>0.38</td>
<td>0.12</td>
<td>0.41</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.06</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Focus groups

Students enrolled in MET 423 were invited to attend a one hour focus group during the final month of their undergraduate career to discuss creativity in engineering. We made many attempts to encourage as many students as possible to participate in the focus group session – which was voluntary, but only four students signed up and attended the session. Though small in the number, the four students shared their thoughts on creativity, specifically, their ability to be creative while developing their senior design project. The focus group questions are presented in the appendix. All of the participating students reported their awareness of some aspects of the creative process, and were incredibly interested in becoming more creative. However, the students stated that their creativity was limited in the senior design project for a number of reasons. Firstly, in order to successfully complete the course, they had to produce a working prototype, and therefore, they felt that that they could not take risks on products that might not work. Two examples of the working prototypes developed by the students in the senior design class are shown in Figures 2 and 3. One student stated that, “you’re limited to re-engineering something”, rather than creating a truly new product. Secondly, financial, material, and time resources were limited. Undergraduate students were constrained by the available materials and equipment, as well as access to professors. Additionally, the students were enrolled in other

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1 Significant at p<0.05
classes, leaving them with limited time to devote to their senior design project. These factors, according to the students, limited their creative output in their final projects.

Figure 2: Low Cost Portable Fluorometer
Conclusions

The findings show that the creativity ratings by the expert panelists in this study did not significantly change between the fall and spring quarters, but the inter-rater reliability increased between the two quarters. Kappa statistics showed a greater degree of inter-rater reliability during the spring quarter when students presented an actual working prototype compared to the fall quarter when students presented just a sketch and description of their proposed prototype. This limited study points to the need for the expert panelists, at the very least, to be exposed to the attributes and definition of creativity – such as the expert creativity handout presented in Appendix 1 - before they rate the students’ presentations - so that all the panelists are on the same page when using the creativity assessment rubric. In future work, we would like to investigate the impact on the reliability of the creativity ratings of expert panelists who attend a creativity training workshop prior to assessing student design projects versus expert panelists who are not exposed to any creativity training or literature.
The focus group session highlights some of the impediments to achieving a high degree of student creativity in the senior design projects. These impediments lead to a lower degree of risk-taking by the students since they have to produce a working prototype within a limited time frame (i.e., by the end of the spring quarter) and a limited budget.

Acknowledgements

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References


Biography

Michelle Klawans. MPH, was until June 2014 a research assistant for the NSF RIGEE project. She is currently a research associate at the University of Texas Health Science Center in Houston, Texas.

Dr. Abi Aghayere is a professor in the Department of Civil, Architectural, and Environmental Engineering in Drexel University’s College of Engineering.

Dr. Jen Katz-Buonincontro is an assistant professor in the School of Education at Drexel University where she teaches, researches and publishes on the topic of creativity and learning.

Dr. Fredricka Reisman is professor and founding director of the School of Education at Drexel University, is Program Director of the Creativity and Innovation online Masters Degree as well as the EdD Creativity concentration, is Director of the Drexel-Torrance Center for Creativity and Innovation, and is immediate past President of the American Creativity Association.
Appendix 1: Expert Panel Creativity Handout

3-Part Definition of Creativity

- Creativity is not simply “thinking outside the box” or coming up with new ideas
- Creativity is the development of ideas, products, or solutions that are perceived as:
  - Unique and novel
  - Relevant and useful
  - Demonstrates excellence in a domain

Figure 1 Creativity definition (developed by Dr. Jen Buonincontro)

Appendix 2: Student Focus Group Questions

Monday May 5th and Tuesday May 6th, 5:00-5:50pm

1. Do you believe creativity is an important characteristic of being an engineer?
2. How can your learning experience be made more creative?
3. Do you want to become more creative?
4. How have you become more aware of your creative strengths and weaknesses, as a result of participating in this project (learning awareness and metacognition)?
5. Describe what a creative engineer is like, in your mind (definition of creativity)?
6. Do you believe that you are good at coming up with new ideas (creative self-efficacy, cognitive engagement)?
7. As a student, what are some barriers to being creative?
8. When you feel creative, do you feel excited versus stressed or a combination of both (positive and negative emotion)?
9. Please share any new awareness of your creativity with examples.