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Investigating the Relationship Between Students' Creative Self-Efficacy and their Creative Outcomes

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Abstract

This paper examines the relationship between creative self-efficacy and creative outcomes for students participating in an engineering summer camp at a major research institution. The case has been made for an increased emphasis on creativity in technology and engineering education yet, a perceived inability to assess creativity in students' work coupled with a lack of research in this area has prevented the inculcation of instructional strategies promoting creativity in STEM classrooms. In order to identify instructional strategies that help promote creativity in design, it is important to examine the relationship between students' creative self-efficacy and their creative outcomes as measured by the Consensual Assessment Technique (CAT). High school students participating in a weeklong engineering summer camp engaged in an engineering design challenge that produced a physical and/or working model. Images of the resulting models, technical drawings, and poster presentation materials were displayed on a website which was accessed by a team of nine independent expert raters. Creative outcomes were evaluated using a web-based version of the CAT as measured by the expert raters. Online survey software featuring a series of Likert-type scales was used for ratings. The raters viewed project images on larger computer screens and used iPads to input their assessments. Student participants also completed a self-reporting creative self-efficacy inventory scale. Using nonparametric bivariate correlation researchers investigated the relationship of creative outcomes and creative self-efficacy. Results of the study found no association between students' self-efficacy and their creative outcomes. This study also reported on the inter-rater reliability of the web-based version of the CAT and its discriminant validity. Results proved that the web-based version of the CAT is a valid and reliable means of measuring student's creative outcomes. The results and implications for K-12 technology and engineering education are discussed in this report.

Introduction

Not only is creativity seen as an essential component of human cognition, its promotion is essential to a global economy and creating globally competitive citizens ([1]; [2]). The cultivation of our high school students as innovative and creative problem solvers for today's technological problems has become a focus for science, technology, engineering and mathematics (STEM) education in the 21st Century ([2]; [3]; [4]). With this noted, it is vital that teachers of STEM content are able to effectively impart 21st Century skills, including creativity and innovation, to our students which include creative and innovative skills [4]. STEM classrooms are essential because they are uniquely positioned to offer a potentially fertile environment for developing these skills and students' problem solving abilities and creative behavior [5]. With an emphasis on problem-based learning and open-ended questions, instructors of technology, engineering and science education can provide students with a milieu conducive to the promotion of creativity.

Creativity in Informal Learning Environments

Informal environments, where teachers can create environments that are not bound by the standard-based restrictions of formal learning environments, may be the key to providing content with an increased emphasis on creativity. It is estimated that during the schooling years of students, 85% of their time will be spent outside of a classroom [6]. This illustrates the importance of providing opportunities for learning that are outside of the traditional learning environment. Informal learning environments provide these opportunities and have been an integral part of education for years [7].

Informal learning environments can be categorized into three major settings: 1) everyday experiences, 2) designed settings, and 3) programmed settings [8]. The informal learning environment that frames this research study is classified as a programmed setting. Program settings are characterized by structured programs that take place at a school and/or community-based organizations and science organizations [8].

Engineering Summer Camp

Founded in 1999 as an extension of the Women in Engineering Program, the Engineering Summer Camp at North Carolina State University offers a week-long engineering camp each summer for 9-12 grade students interested in experiencing engineering, science and technology. Participants for this study attended a multidisciplinary session for rising 9th and 10th grade students. Student campers must pay to participate in the engineering summer camps. Financial aid is provided to those in need. Approximately 144 students were placed in design teams of three students, providing the study with 48 student groups. Participants were provided with $20 gift cards as remuneration for their participation in this study.

Three high school teachers with backgrounds in science and/or math were selected as instructors for the engineering summer camp. Instructors were divided among the engineering disciplines of Aerospace, Biomedical, Civil, Mechanical, Industrial and Chemical engineering with instructors teaching 24 students each equaling 48 student groups (144 students total). The instructors provided guidance and instruction for the student teams while facilitating the engineering design experience. Undergraduate students as well as high school students who supported the engineering summer camp assisted instructors.

Instrument

Consensual Assessment Technique (CAT)

The Consensual Assessment Technique (CAT) is an evaluation tool used by creativity researchers for assessment of creative products by panels of raters. The method is based on the assumption that “a panel of independent raters familiar with the product domain, persons who have not had the opportunity to confer with one another and who have not been trained by the researcher," are best able to make judgments regarding "the nature of creative products and the conditions that facilitate the creation of those products" [9].

Digital CAT interface

Creative assessment conducted using the CAT have traditionally followed similar implementation processes: students create products which are collected by researchers, spread around a single physical space, and viewed and assessed in that space by one rater at a time until the ratings were completed. It may prove valuable to expand the accessibility of consensual assessment beyond the traditional method characterized by displaying student projects throughout a physical space and having raters complete the assessments in person. For this study the researchers developed a web-based assessment interface consisting of 1) an overview video displaying all project images for raters to view prior to the rating session; 2) a website built for the display of project images and documentation; and 3) a web-based version of the consensual assessment instrument, accessed by raters via iPad while viewing the project website on desktop computers.

Creativity Raters

Following an online solicitation for recommendations and volunteers, the authors selected nine raters who were familiar with the engineering design process and experienced in teaching high school aged students. To secure "expert" raters for this study researchers developed an online solicitation explicitly stating in the criteria that raters needed to be familiar with the engineering design process and experienced in teaching high school aged students. It was important that raters understood the nuances of assessing engineering design products while still understanding the quality of work to be expected from high school age students. The raters included: 5 high school teachers with experience teaching engineering design; 2 professors with experience teaching engineering design; a 6th grade science teacher with 13 years teaching experience and a adjunct professor who formerly taught engineering design at the high school level.

Raters were asked to commit approximately two to three hours to a rating session during which they would evaluate student projects on dimensions such as creativity, aesthetic value, and technical strength. Raters were compensated with a $250 honorarium for their participation.

Procedures

After receiving their team assignments and a brief introduction to the engineering summer camp, student teams received their engineering design challenge on Day 1 of the five-day camp. Each day throughout the week, teams participated in ancillary activities designed to promote critical thinking and problem-solving skills. Student teams were asked to produce a series of modeling artifacts as part of the design requirements. The models that the teams produced included a conceptual model, a mathematical model, a graphical model and a working model illustrating their design solution. This design process culminated in group presentations to all camp participants, staff and students' families on Day 5.

Following presentations, photographs of students' working models and presentation materials were taken. Images were catalogued by project number on a website built for rater access. Once raters were contracted as participants they were given instructions via email as well as the project website URL and each rater's unique CAT survey URL.

Validity and Reliability (Pilot Study)

Prior to the administration of this study, researchers conducted a pilot study to verify the reliability and validity of the newly adapted digital version of the CAT. To test inter-rater reliability, Cronbach's alpha was calculated using adult raters' scores for the 12 separate dimensions rated. It can be seen in Table 1 that all twelve items have reliabilities greater than .70, and that ten of the 12 have reliabilities greater than .80. This includes creativity, with an inter-rater reliability of 0.86. According to the [10]scale, a reliability coefficient between 0.6 and 0.8 is "substantial" and agreement beyond 0.8 is "almost perfect."

Theoretical framework

Creative Self-Efficacy

The last construct identified in this study is creative self-efficacy. Creative self-efficacy extends Bandura's [11]broader theory of self-efficacy and is defined by Tierney and Farmer as "belief one has the ability to produce creative outcomes" [12]. Tierney and Farmer [12]called this self-belief in one's ability to generate novel and useful outcomes *creative self-efficacy.* To understand why some students are adept at developing novel and innovative solutions to technological problems compared to others, it may prove useful to study creative self-efficacy of students engaged in an engineering design challenge.

This study will complement the work of Tierney and Farmer [12] and that of Amabile [9, 13]by investigating the appropriateness of using the CAT as a way to assess creativity in students' work as a way of correlating these outcomes with students' creative self-efficacy. Beghetto [14]contends that much remains to be known about the correlates of creative self-efficacy. This is particularly true in the domain of technology and engineering education, where creativity is sometimes seen as an ambiguous construct that is not easily assessed.

Creativity

The second construct investigated in this project is students' creative outcomes. When sorting through the profuse definitions and conceptual frameworks available for discussing the concept of creativity, it is useful to identify those most applicable to the task at hand; in this case the topic of interest is the potential for fostering students' creativity in hands-on problem-solving activities in STEM classrooms. Two types of definitions are useful to this discussion. Hennessey, Amabile, and Mueller [15]whose work in creativity assessment has had tremendous influence upon the design of this study, offered the following:

· *Conceptual definition of creativity*: "A product is considered creative to the extent that it is both a novel and appropriate, useful, correct or valuable response to an open-ended task" [13].

· *Operational definition of creativity*: "A product or response is considered creative to the extent that appropriate observers independently agree that it is creative. Appropriate observers are those familiar with the domain in which the product was created or the response articulated" [13].

Hennessey et al.'s conceptual definition is a useful guide for evaluating student products in technology and engineering education because student products and design processes will vary widely due to many factors and problems are often open-ended. The definition assimilates many prior conceptual definitions [16]and can be helpful in clarifying to students what is being asked of them when they are told that creativity is a part of their grades. The operational definition establishes the framework and justification for the use of Amabile's [13]Consensual Assessment Technique (CAT) for evaluating creativity and other dimensions of student responses to open-ended design and problem-solving activities—if knowledgeable raters independently, and with an acceptable level of inter-rater reliability, determine that a student product is creative in its context, then by definition it is.

Methodology/Methods

After receiving their team assignments and a brief introduction to the engineering summer camp, student teams received engineering design challenges on Day 1 of the five-day camp that encompassed five different disciplines to include; aerospace engineering, mechanical engineering, biomedical engineering, industrial engineering, chemical engineering and civil engineering. Each day throughout the week, teams participated in ancillary activities designed to promote critical thinking and problem-solving skills. These activities included experimentation, analysis, mathematical modeling, and other engineering ways of thinking and doing.

In groups of three each team was "responsible for defining, developing, and testing a design which takes into account all relevant specifications and constraints" for a proposed engineering design prompt. Besides a rooftop schematic, the students were not given any more guidance on the design brief. The design challenge was left ambiguous for the student designers so that they could further formulate the problem, take deeper ownership of the design, engage in questioning, and express creativity.

Additionally, the teams were asked to produce a series of modeling artifacts as part of the design requirements. The models that the teams produced included a conceptual model, a mathematical model, a graphical model and a working model illustrating their design solution [17]. The modeling artifacts gave the students something tangible to which they could work while giving the instructors and teaching assistants opportunities to offer concrete feedback and assessment. This design process culminated in team presentations to all camp participants, staff and students' families on Day 5.

Following the presentations, photographs of students' working models and presentation materials were taken. Images were catalogued by project number on a website built for rater access. Once raters were contracted as participants they were given instructions via email as well as the project website URL and each rater's unique CAT survey URL. To measure student's creative self-efficacy students completed a paper-based Likert-type inventory. Students' project numbers were the only identifiable information include on the self-reporting survey. Students completed this survey at the conclusion of the engineering summer camp.

Studies conducted using the CAT have traditionally followed similar implementation processes: students create products which are collected by researchers, spread around a single physical space, and viewed and assessed in that space by one rater at a time until the ratings were completed. To address the logistical challenge of procuring nine "expert" raters for this study the researchers developed a web-based assessment interface consisting of 1) an overview video displaying all project images for raters to view prior to the rating session; 2) a website built for the display of project images and documentation ; and 3) a web-based version of the consensual assessment instrument, accessed by raters via iPad while viewing the project website on desktop computers.

Once the camp ended and documentation of student products was organized on the rater website, raters were provided with the URL for the website and a link to the rating form. They were given the following instructions:

> *Please begin the rating process by reading the problem definition contained in the student's artifacts and viewing the short video on the project landing page. This video is an overview of the images you will find on the website. It serves as an introduction to the products created by the students, and it will give you a sense of the range of abilities represented in the sample. It is essential to our methodology that you look over all the products prior to rating any projects, and that you rate projects relative to each other rather than making ratings based on some absolute standard. In other words, consider what the camp students were able to do given time, instruction, supplies, etc., rather than what you think they should be able to do.*

To ensure a consistent rating experience, raters were offered loaner iPads, laptops, and office space in which to conduct ratings if needed. Raters also assessed each student's product relative to its respective discipline. As an example: Raters who were engaged in assessing students' creativity for biomedical engineering were instructed to review all of these products first and provide a rating that is relative to other products in said discipline.

Results

Distributions of ratings were examined per dimension, and it was determined that no individual's ratings appeared to display systematic bias.

To test inter-rater reliability, Cronbach's alpha was calculated using adult raters' scores for the 12 separate dimensions rated. It can be seen in Table 1 that all twelve items have reliabilities greater than .70, and that seven of the 12 have reliabilities greater than .80. According to the Landis and Koch [10] scale, a reliability coefficient between 0.6 and 0.8 is "substantial" and agreement beyond 0.8 is "almost perfect."

Table 1.
Cronbach's α for twelve dimensions measured

Dimensions of Judgment	**Cronbach's α**
Creativity	0.7073
Aesthetic Appeal	0.8018
Technical Strength	0.7760
Complexity	0.7977
Liking	0.7605
Novel Idea	0.7315
Novel Use of Materials	0.8455
Shape/Form	0.8133
Color/Value	0.8463
Organization	0.8501
Neatness	0.8413
Effort Evident	0.8395

To test the rater's discriminant validity principal component analysis was conducted featuring each dimension. Figure 1. provides a list of subdimensions associated with each of the three major dimensions. Optimally items within each of those three clusters will consistently load together.

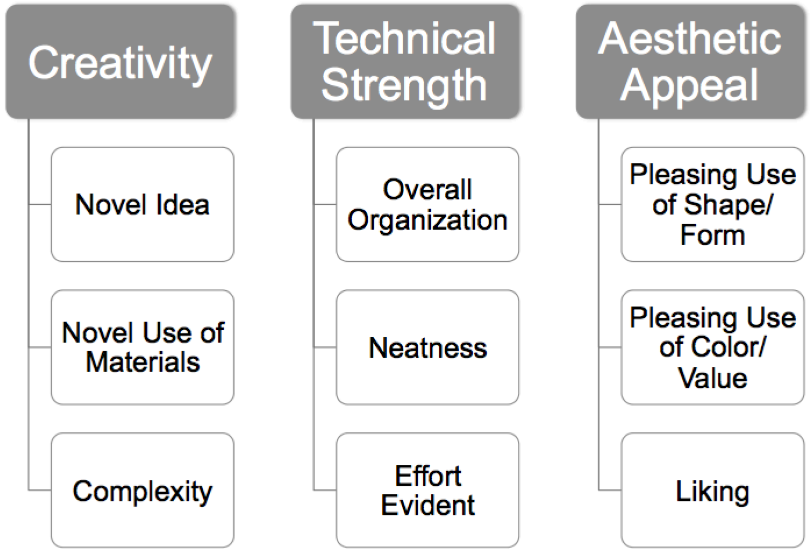

Figure 1. Subdimensions associated with each major dimension measured.

Using promax rotation, the analysis illustrated that the raters were able to distinguish creativity from other features more closely associated with technical strength and aesthetic appeal. The principal component analysis (see Figure 2) illustrated that dimensions associated with creativity loaded together in this study.

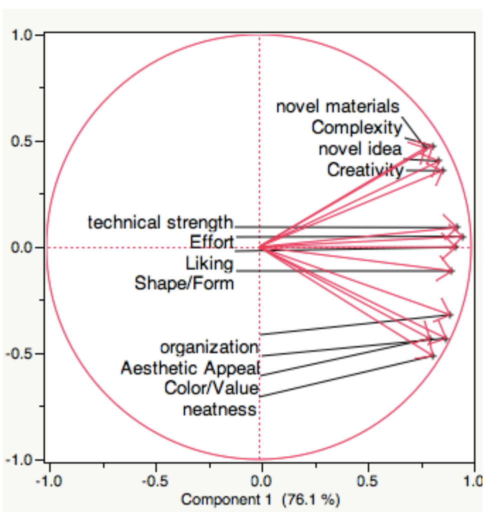

Figure 2*. Factor Loading of 12 dimensions for engineering camp*

This project set out to determine if there was a relationship between creative self-efficacy and creative outcomes. Using nonparametric bivariate correlation the researchers investigated the relationship of creative outcomes and creative self-efficacy.

Creative outcomes where measured for using the web-based version of the CAT. Creativity scores are represented as variable 2 in the table below.

Creative self-efficacy was self-reported using a fill in scale. Students were asked ten questions in regards to their creative self-efficacy. Students were asked to provide a number between 1 and 7 with 1 representing “strongly disagree” and 7 representing “strongly agree”. 12 students declined to participate in the creative self-efficacy survey dropping the total number to 134 student participants. Students were also eliminated if they were not able to complete the engineering design challenge resulting in a total of 126 student participants. In table 2, variable 1 represents the variable of creative self-efficacy. The second variable in this study are students’ creative outcomes as measured by the CAT. The results show that there was not a statistically significant relationship between student’s creative self-efficacy and their creative outcomes r (124)=-.009, p >.05.

Table 2.

Nonparametric Correlations

Correlations

			VAR00001	VAR00002
Spearman's rho	VAR00001	Correlation Coefficient	1.000	-.009
		Sig. (2-tailed)	.	.916
		N	126	126
	VAR00002	Correlation Coefficient	-.009	1.000
		Sig. (2-tailed)	.916	.
		N	126	126

```
DESCRIPTIVES VARIABLES=VAR00001 VAR00002
  /STATISTICS=MEAN STDDEV MIN MAX.
```

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
VAR00001	126	2.40	7.00	5.6716	.73528
VAR00002	126	4.11	8.22	6.2405	.84993
Valid N (listwise)	126				

Spearman’s rho for creative self-efficacy and creative outcomes

Conclusion

This study illustrates that the assessment of creativity in student products is possible using the CAT. The Consensual Assessment Technique shows promise for the assessment of creativity in the domain of engineering design education. The web-based CAT tools used in this study allow instructors to bypass the limitations posed by implementing consensual assessment in a single physical location. The likelihood of obtaining well-qualified raters is improved, and logistical challenges such as displaying a large number of student projects simultaneously are ameliorated. Using the web-based version of the CAT still produced inter-rater reliability among the nine raters that was consistently high for all 12 dimensions of judgment measured in this study.

Creative self-efficacy was also measured for each student participant. Spearman's correlation revealed that there was not an association between students' creative self-efficacy and their creative outcomes. Further tests should investigate the relationship between creative self-efficacy and other dimensions as measured by the CAT including looking for differences among the engineering disciplines featured in the study.

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