Creative Confidence and the Arts: Measuring a Potential Contributing Factor to Students’ Motivation to Engage in Engineering Creativity

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Abstract – Engineering is well established as a profession which requires complex, open-ended problem solving. Creativity is instrumental in these processes, but graduating engineering students have been found to lack creative thinking skills. In order to engage in creative thinking, students must first be motivated to do so. Creative self-efficacy (or creative confidence) has been tied to increased internal motivation, and involvement in creative arts activities can lead to increased self-efficacy beliefs. This paper will discuss the development of a survey instrument that will be used to investigate the potential correlation between student involvement in creative arts and their internal motivation to engage in engineering creativity.

The survey instrument includes 1 open-ended question, a creative arts inventory, and 46 closed-ended questions to measure creative self, creative mindset, and tolerance of fears that hinder creative confidence. Evidence for validity of the instrument is established through the pilot study.

Keywords: Creativity; engineering creativity; creative confidence; motivation theory; interdisciplinary thinking; creative arts; survey instrument development.

1. INTRODUCTION

As today’s world develops and changes, the work of the engineer must develop and change with it. Constantly evolving problems and needs demand constantly evolving problem solving, and, as David Cropley posits, “Engineering – as a problem-solving process – connects those new needs and new technologies together” [1, p. 161]. It falls into the hands of engineering educators, then, to effectively instill in future engineers the skills they need to adapt to a changing industrial and professional climate.

Engineers Canada reflects this need for complex, open-ended problem solving in their graduate attributes, particularly the design attribute [2]. How then, can we ensure that graduating engineering students are equipped with the problem-solving skills they need to combat these complex problems?

Creativity and creative thinking is recognized in the literature as imperative to complex problem solving [1] [3], but not necessarily a skill which engineering students possess [4] [5]. Engineering education research in creativity often focuses on curriculum and pedagogical practices for teaching creative thinking through tools or processes [6] [7]. Some literature explores student attitudes toward engineering creativity, in an attempt to consider creativity in modern engineering education more deeply [8] [9]. This study attempts to add to the depth of this research by investigating interdisciplinary connections between engineering creativity and the creative arts, as well as adding to the existing literature regarding student motivation and perception.

This work relies upon fact that, in order to successfully solve complex problems, engineers must think creatively. To engage in creative thinking, they must be motivated to do so. However, little is known about internal motivation to engage in engineering creativity, and potential factors which influence this motivation. As part of a larger study on exploring the creative confidence of engineering students, this paper considers the specific research question as follows: How can undergraduate engineering students’ creative confidence to engage in engineering creativity and involvement in creative and performing arts activities be measured using a survey instrument?

2. LITERATURE REVIEW

Literature was reviewed to illustrate potential connection between creativity in engineering, the creative arts, and creative confidence.

2.1 Creativity in Engineering Education

The definition of engineering creativity continues to be a source of uncertainty, even with advancements in research. Zappe, Mena, and Litzinger investigated the conceptualization of creativity in engineering education research and found no consistent definition across 16 different articles. Common themes, however, included problem solving, originality, and usefulness [10].

For this study, and based on the definitions present in the literature, engineering creativity is defined as follows: “the ability to transcend ideas, rules, patterns, relationships, or the like, and to create meaningful new ideas, forms, methods, and interpretations, as applied in engineering to solve problems in novel, relevant, and efficient ways”. This definition encompasses the common themes identified above and incorporates aspects of engineering problem solving as suggested by Cropley [1].
Creativity has also been found to be a teachable skill in engineering. Scott, Leritz, and Mumford reviewed 70 studies on teaching creativity, concluding that well designed workshops and training modules have been proven effective in developing creative thinking and problem-solving abilities [11]. Cropley and Cropley support this in an engineering context, with an increased in demonstrated innovation seen in students who participate in structured ‘creativity counselling’ [12]. If methods for creativity training exist, why then do we still see a lack of creativity present in graduating engineers?

2.2 Barriers to Creativity in Engineering Education

Many studies identify barriers to student engagement in creativity in engineering. Kazerounian and Foley have developed 10 Maxims of Creativity in Education, proposing that these maxims constitute and educational environment conducive to fostering creativity in students. The maxims are as follows: (i) keep an open mind; (ii) ambiguity is good; (iii) iterative process that includes idea incubation; (iv) reward creativity; (v) lead by example; (vi) learning to fail; (vii) encouraging risk; (viii) search for multiple answers; (ix) internal motivation; and (x) ownership of learning. They then used these maxims to investigate the perceptions of university professors and students in engineering. This exploration revealed that current engineering undergraduates experienced almost none of the maxims in their academic experience [5].

Examing the maxims more closely, they can be sorted into two categories: (i) external factors (reward creativity, lead by example, and iterative process, for example); and (ii) internal factors (such as an open mind, favouring ambiguity, and ownership of learning). Through such categorization, we see a division of barriers to creativity in engineering, namely those barriers that are due to the educational environment (curriculum, instructor, and activities), and barriers that are due to the individual's personal attitudes, perceptions, motivations, and characteristics. Cropley and Cropley also identify personal characteristics important to creative engineers, such as openness, willingness to take risks, tolerance of ambiguity, and self-efficacy [13]. We see again a focus on internal characteristics which, when lacking, hinder the creative potential and output of engineers. Much of the literature regarding increasing creativity in engineering students focuses on external factors such as creative thinking tools and curriculum [3] [4] [6] [7] [14], classroom environment [15], and developing assessment measures for engineering creativity [4] [16].

There is little investigation of engineering students’ motivation to engage in engineering creativity, and no investigation focused specifically on internal or intrinsic motivation.

2.3 Creativity in the Arts

Traditionally considered to be skills associated with “soft” subjects like arts and humanities, there is evidence to suggest that involvement in arts activities leads to the development of creativity, imagination, and risk-taking behaviours that are transferable across disciplinary lines.

Burton, Horowitz, and Abeles tested 2,406 students in grades 4, 5, 7 and 8 to determine if cognitive skills developed through arts have an effect on learning and thinking in general, as well as on other subject matter domains. Through mixed methods, they found that students with high arts exposure exhibited high instances of personal learning indicators such as risk-taking, confidence, ownership of learning, and task-perspective. These same personal learning indicators were present in other subject matter disciplines, such as science lessons that called for “figuring out ideas” [17].

Many studies suggest that young children exposed to varied arts experience both in and out of school are more confident and willing to take risks than students who are uninvolved in the arts [17]–[20]. Indeed, we see a blatant connection between the skillset developed by creative and performing arts involvement and the personal characteristics important to creative engineers.

Hong, Peng, and O’Neil found relationships between general creative self-efficacy, performance, and arts involvement in adolescents [21]. This scenario may be called a “chicken or the egg” situation – perhaps students who are by nature possessed of higher levels of creative self-efficacy self-select arts activities, rather than develop this confidence through their involvement. This study, however, attempts to illustrate grounds for a plausible connection between discipline, rather than attempt to completely explain students’ creative development. This connection has never been examined from an engineering perspective, considering the concept of transfer highlighted by Burton, Horowitz, and Abeles. How does engagement in the arts develop creative confidence in engineering students?

3. CONCEPTUAL FRAMEWORK

Bandura’s self-efficacy theory of motivation was deemed to be an appropriate conceptual framework [22]. This framework is based on social-cognitive motivational theory, which posits that people learn through reciprocal interactions with their environment and by observing others [23]. In this context, we examine the construct of ‘pre-task’ self efficacy, based in past experiences. Bandura states that this pre-task self efficacy is a contributing factor to the success of an individual during the task in question [24]. In the context of this study, an individual who believes they will be successful in engaging in creative thinking will be more likely to do so. Kelley and Kelley (2012) expand Bandura’s motivational theory to creativity,
highlighting the existence of “creative confidence” – the belief in one’s ability to be successfully creative and the courage to do so. They posit that there are four fears which hinder the creative confidence (or self-efficacy) of an individual: (i) fear of the messy unknown; (ii) fear of being judged; (iii) fear of the first step; and (iv) fear of losing control.

We then balance the self-efficacy framework with goal orientation theory, based in incremental (or growth) mindset. This theoretical motivation framework, created by Dweck, focuses on the intrinsic value of learning with mastery goals [23] [25]. Learners with a mastery goal orientation have a self-theory that ability can grow through learning (an incremental mindset), leading them to seek out challenge and thrive on initial failure [23].

Creative self-efficacy has been shown to be a predictor of creative output [26], particularly when measured in connection with creative identity and creative growth mindset [27]. We see that those individuals who have high self-efficacy beliefs and growth mindset regarding specific abilities have higher intrinsic motivation to engage in those tasks.

4. INITIAL SURVEY INSTRUMENT DESIGN

The initial survey instrument was based on three existing scales to measure elements of the conceptual frameworks: (i) creative-self; (ii) creative mindset; and (iii) ambiguity tolerance. Items measuring the three other fears outlined by Kelley and Kelley were created [28]. The initial survey contained demographic questions, a creative and performing arts inventory, 1 open-ended question, and 48 close-ended Likert style questions to measure creative confidence predictors as follows: (i) creative self (10 items); (ii) creative mindset (10 items); and (iii) tolerance of fears that hinder creative confidence (28 items).

Initial survey items regarding creative self-efficacy and creative personal identity were modified from Karwowski, Leduc, et al.’s Short Scale of Creative Self [29]. The items pertaining to creative self-efficacy were modified to relate to an engineering context (“I can efficiently solve even complicated problems”, for example, became “I can efficiently solve even complicated open-ended engineering problems”). The modifications were made to reflect the creative problem-solving skills required in engineering course work. Creative personal identity items were left to reflect students’ general creative identity, rather than in an engineering context.

Karwowski’s Creative Mindsets Scale was used as a measure of creative fixed and growth mindsets (10 items) [30]. These items were included directly in the initial survey instrument with no modification, again to reflect a general creativity mindset of the participant. The personal identity and mindset items were not modified to allow comparison between creative identity and engineering creativity self-efficacy, and investigation of a possible transfer of creative mindset.

To include an investigation of potential barriers to creative confidence, measures for Kelley and Kelley’s fears which hinder creative confidence were both collected and created. McClain’s Multiple Stimulus Types Ambiguity Tolerance Scale (13 items) was modified to reflect an engineering context and used to address Kelley and Kelley’s ‘fear of the messy unknown’ [31]. Scales to measure tolerance of judgement (7 items), the first step (4 items), and losing control (4 items) were created, again reflecting an engineering context.

All Likert style questions were modified to include a 7-point scale, ranging from Strongly Disagree to Strongly Agree. The 7-point scales were used to increase response variance by allowing respondents to indicate small deviations from neutral.

An inventory of creative and performing arts involvement was also created, highlighting the following activities: (a) singing and vocal music, (b) dance and/or choreography, (c) drama and theatre, (d) painting, sketching, and fine art, (e) instrumental music and/or composing/writing music, (f) photography, (g) creative writing, (h) other. A wide range of activities was purposefully chosen to invite an open exploration of potential connection to engineering creativity. Respondents are also asked to specify age ranges when they involved in the specified activity (from ages 4-12, 13-17, and 18-Present), average involvement per week, if the they have ever publicly performed as part of their involvement in that activity and if so, how often over an average year, and whether any awards had been won for activity involvement. Average involvement per period of time was specified based on the above highlighted age ranges.

Face validity of the initial survey was established through a two-step review. The first review was undertaken by a colleague specializing in engineering education, ensuring that survey items did not contain leading, confusing, or double-barreled questions. The second review was done by an expert in engineering creativity and design, ensuring that the modified items properly reflected the intended survey topics.

5. PILOT STUDY

With the creation of a new survey instrument, researchers must address several key issues, namely, checking and making adjustments for misunderstandings, incomplete concept coverage, inconsistent interpretations, and context effects (among others). These concerns can be addressed with a pilot study of the survey instrument. Pre-testing of data collection instruments allows for the collection of three types of evidence to evaluate the performance of survey questions: (i) statistical; (ii) direct study of the question-and-answer process; and (iii)

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experimental [32]. These methods allow testing and identification of potential sources of measurement error, classified by Oksenberg et al. in a task-focused model, including four components: (i) comprehension problems; (ii) validity problems; (iii) processing difficulties; and (iv) pronunciation or communication difficulties [33].

For this study, a pilot study of the initial survey instrument was undertaken to reduce measurement error and provide evidence to evaluate survey question performance. The pilot study followed a convergent parallel mixed methods design, where quantitative data was collected through survey responses and qualitative data was collected through think-aloud interviews. The survey data provided statistical evidence, while the think-aloud interviews allowed for direct study of the question and answer process. The think-aloud interviews also addressed all types of measurement error but for communication and pronunciation components, which were not applicable for an online survey.

5.1 Sampling Design

Graduate engineering students at Queen’s University were selected by convenience sampling to be recruited for the pilot study. The survey was distributed electronically to all graduate engineering students (including students in PhD, MASc, and MEng programs). At the end of the survey, participants were asked if they would like to participate in a think-aloud interview. Purposeful sampling was used to select participants from a range of engineering disciplines and programs for think-aloud interviews. An English Language Learner was also selected to participate, regardless of program and discipline.

5.2 Think-Aloud Interviews

Cognitive interviewing methods are derived from social and cognitive psychology. They enable us to investigate the responses provided by participants, exploring both the processes by which survey questions are answered and the factors which influence the answers they provide [32], [34].

Debbie Collins highlights two main cognitive techniques: think-aloud interviewing and probing. In the think-aloud method, the participant is asked to complete the questionnaire and ‘think-aloud’ as they do so. The probing method involves the interviewer asking specific questions (probes) which are designed to prompt the respondent to elaborate on how they answered the question. Comprehension, retrieval, judgement, and response processes are often explored through the use of standard probes. The methods differ in the driving force for the interview — probing is traditionally interviewer-driven, while think-aloud methods are respondent driven. However, in order to fully explore participant thought processes both techniques can be combined successfully in a single interview. [32]

A semi-structured format was used for the think-aloud interviews, with probes allowing for exploration within the think-aloud protocol. The interview itself began with an introduction to the study. Participants were then provided with an explanation of the think-aloud method and given an example of the think-aloud process for a survey question. Once the interview began, comprehension and retrieval probing questions were used when necessary to gain a more in-depth understanding of the participants’ thought process. Each interview was a maximum of 75 minutes in duration. All names have been replaced with pseudonyms to ensure participant anonymity.

5.3 Data Analysis

A total of 19 survey responses were collected and 3 think-aloud interviews were conducted. All interviews were audio recorded, and the recording was then transcribed. Minimal field notes were taken during the interview process, which were used to augment the interview transcriptions when appropriate.

Descriptive statistics were analyzed for the quantitative data. For all initial survey questions, the standard errors were 0.53 and 1.01 for skewness and kurtosis respectively. Acceptable values for skewness and kurtosis are within twice the standard error, according to Field [35]. Thus, acceptable ranges were within ±1.06 and ±2.02 for skewness and kurtosis respectively. Most items fell within these ranges. However, 3 items created to address the fear of judgement fell outside of the acceptable ranges, suggesting a departure from normality.

5.3.1 Deductive Coding Analysis. Deductive coding analysis was completed on the interview transcripts. Special care was taken to address the root causes of potential measurement error, and thus Collins’ task-focused model of measurement error was used as a baseline for possible emergent themes. Two main themes were revealed through this analysis: (i) significance of context and (ii) significance of terminology. A number of questions failed to explicitly state the context, which resulted in varied interpretations by participants. This included variation between academic and professional engineering contexts, and engineering or personal contexts. The lack of specification of context resulted in comprehension and processing difficulties from all participants. The variations in interpretations tended to impact participants’ responses. Thomas, for example, discussed how his opinion of the importance of creativity varies dependent on context:

“If I’m thinking about myself, like cooking food for myself, I don’t care if I’m creative or not. But creativity is important in an engineer.”
Terminology was determined to be another large contributing factor to comprehension and processing difficulty in the survey questions. Lack of standardized definitions for terms also contributed to validity error present in the instrument. Participants had varying definitions and understanding of the following terms: creative thinking tools and processes, ambiguous engineering problems, and losing control in problem solving. In many cases, the meaning of these terms was inconsistent with the intent of the question. Helen sums up concerns of terminology succinctly:

“The word ambiguous is ambiguous”.

5.4 Modifications to the Survey Instrument

The results of the quantitative and qualitative analyses were used to inform several modifications to the survey instrument. By addressing the two identified themes, modifications were made to improve validity and reliability.

To improve comprehension and validity, terminology was altered. All instances of the words “ambiguous” and “ambiguity” were removed and replaced with more concrete definitions. Two items from the scale of ambiguity tolerance were removed to reduce redundancy and validity concerns. Items were also altered to reflect more specific context. Introductory instructions were added prior to the creative personal identity and mindset scales, guiding participants to consider these questions from the perspective of their general personality and not in an engineering context. In total, the wording of 26 items were modified to reflect more specific context or clarify terminology. Skewness and kurtosis concerns were addressed in survey items by increasing or decreasing the strength of statements to mitigate ceiling or flooring effects.

The updated survey instrument included demographic questions, 1 open-ended question, a creative and performing arts inventory, and 46 closed-ended questions distributed among the self-efficacy and goal-orientation theory elements as follows: (i) creative self (10 items); (ii) creative mindset (10 items); and (iii) tolerance of fears that hinder creative confidence (26 items).

6. VALIDITY AND RELIABILITY ANALYSES

To fully address instrument validity and reliability, further analyses will be undertaken following the completion of a national study. The national study will use Ex-Post Facto research design and will provide statistical evidence to evaluate the performance of the survey. An exploratory factor analysis will be completed to support statistical evidence of validity, and Cronbach’s alpha will be calculated to investigate instrument reliability.

7. CONCLUSIONS

The proposed survey instrument provides a measurement tool to assess potential correlation between students’ creative and performing arts involvement and their internal motivation to engage in engineering creativity. The survey includes 1 open-ended question, 46 closed-ended questions, and a creative arts inventory. The development process of the survey instrument and think-aloud interviews provide evidence of face validity and content validity, with reduction in comprehension, process, and validity error. Further reliability analyses must be undertaken through exploratory factor analyses. The survey in its current state considers interdisciplinary transfer of creative motivation in a single instrument.

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References


