Creativity in Design Engineers: Attitudes, Opinions and Potentially Influential Factors – Part II

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Abstract – In the latter half of 2015, a survey looking at attitudes and beliefs about creativity was distributed on the campus of the University of Saskatchewan. Over 2000 responses were gathered, including more than 200 in the College of Engineering. Initial quantitative results from this study were reported in 2016 in Neufeld et al [2].

In terms of the methods used in the study, as discussed in Neufeld et al [2], an online pilot survey was distributed to students and faculty from a variety of the Colleges at the University. Survey questions probed respondents' affinity for creativity, their personality characteristics, their opinions on state, trait and skill-based viewpoints on creativity, and demographic details.

The first part of the survey was a validated Creative Attitudes and Values measurement tool (part of the Runco Creativity Assessment Battery (rCAB)® 2012), as discussed in Acar and Runco [1]. This tool consists of 25, 5-point Likert scale items. Of these 25 items, 15 and 10 were indicative and contraindicative items, respectively. Contraindicative items were reverse coded so that they could be used along with the indicative ones. Both past research and our results showed good inter-item reliability scores for this measurement tool.

In Neufeld et al [2] we presented results covering all of the closed-form, quantitative questions along with some correlational calculations with the rCAB scores. The focus of the current paper is on the qualitative results, as well as on a factor analysis of the rCAB questions.

The factor analysis was quite successful. We used SPSS and forced a correlation of items, reducing to three factors. We have just over 29% of variance accounted for, with 10% non-redundant residuals. We have strong anti-correlation between one factor and the other two, and no correlation between the other two. These results will be compared to those of the rCAB authors [3].

As for the qualitative data, we asked several open-ended questions to probe how respondents defined creativity, whether they regarded it as a positive behavior, as well as how they felt about creativity in terms of it being a skill, trait and/or state. For example, pairs of questions asked when creativity is difficult and easy, when it should and should not be used, and when it grows and diminishes. For each of the 9 questions that had open-ended answers, concepts were extracted from individual responses. Concepts were then grouped into themes. Themes and

concepts were compared across questions and were aligned. Responses were then coded for concepts and themes. At this point, the text data could be quantitatively examined. This paper presents those results, and discusses the implications of the concepts, themes, and their statistics for how we talk about creativity, and how we can teach it. Comparisons will be made between the results from engineering students and staff versus non-engineers.

This paper completes the first level of evaluation of the results of this initial survey focused on attitudes and beliefs about creativity. Future work will focus on examining correlations between the results of different questions, including the rCAB scores.

Keywords: creativity, design, attitudes, opinions, influential factors, survey

1. INTRODUCTION

Recently, a research program in creativity and innovation was initiated in the College of Engineering at the University of Saskatchewan. It was founded on the premise that creativity is fundamental to well thought out design in all innovative contexts. It was driven by the question of whether we are enhancing creativity in our students, inhibiting it, or not affecting it at all. And it was motivated by the belief that creativity can be taught and therefore enhanced i.e. creativity is at least partly a skill.

In 2015, an online survey looking at attitudes and beliefs about creativity was distributed on the campus of the University of Saskatchewan. Over 2000 responses were gathered, including more than 200 in the College of Engineering. Initial quantitative results from this study were reported at CEEA in 2016 [2]. These results included basic statistics for each quantitative question, as well as selected correlational analyses between some questions. A few comparisons between engineering respondents and non-engineering respondents were also included.

Broadly speaking, the 2015 survey questions probed respondents' affinity for creativity, their personality characteristics, their opinions on state, trait and skill-based viewpoints on creativity, and demographic details. The first part of the survey was a validated Creative Attitudes and Values measurement tool (part of the Runco Creativity

Assessment Battery (rCAB)[®] 2012), as discussed in Acar and Runco [1]. This tool consists of 25, 5-point Likert scale items. Of these 25 items, 15 and 10 were indicative and contraindicative items, respectively. Contraindicative items were reverse coded so that they could be used along with the indicative ones. Both past research and our results showed good inter-item reliability scores for this measurement tool.

Last year's paper [2] included correlations between the rCAB scores of respondents and some of the other quantitative responses. This paper builds on last year's paper insofar as this paper covers the material from our 2015 creativity survey that was not covered in the first paper. This paper focuses on the results of 9 open-ended, qualitative questions as well as on a factor analysis of the rCAB questions.

2. METHODS

The methods for data gathering using the 2015 survey are described in detail in [2]. In short, an online pilot survey was distributed to students and faculty from a variety of Colleges, including Engineering, at the University of Saskatchewan during the Fall 2015 term. Ethics clearance was secured from the University of Saskatchewan Behavioural Research Ethics Board. Both open and closed questions were used in this survey with 500 character limits for answers to open-ended questions in terms of response length.

After the initial rCAB instrument, we asked a general question about personal definitions of creativity. The answers to this question will be described in this paper. This "definition" question was immediately followed by some closed form questions on the nature of creativity i.e. is it a state, trait, and/or skill. Some questions that focused on personality characteristics followed the state/trait/skill questions.

In the next block of questions, we probed opinions on creative behavior (e.g. is being creative generally a positive behavior?) and solicited open responses on why respondents felt that way. We also asked whether respondent opinions had changed since starting post-secondary education, again letting respondents explain how (if opinions had changed). Then a number of open-ended questions were asked such as: "If you feel that there are specific situations where *it is difficult to be / it is easy to be / one should be / one should not be* creative, please list them". Up to two extended answers could be recorded for each case. By deconstructing the concept of "state", these questions probed the degree to which respondents believed in a state-based conceptualization of creativity. Likewise, two additional questions were asked to assess opinions around creativity as a skill i.e. "In your opinion, can you *enhance/grow* your levels of creativity?" and "can you *lose/diminish* your ability to be creative?" For these yes/no questions, they could also list two extended

examples supportive of their position. The responses to all nine of the open-ended questions described above, are described in this paper.

The last block of questions asked for demographic information such as academic status, program, year of study (only if the respondent was a student), age, gender, language literacy, favourite childhood games/toys, main pastimes/hobbies, children (whether they had any or not), religious affiliation, and high school origin (urban, rural, or international). The literature identifies family background as an influential factor on creativity [4]. Therefore, family background questions were asked such as: what is your birth order, how many siblings do you have, what was your family's economic status when you were growing up, and what is the highest level of education that either of your parents has completed. These questions help us to examine effects that originate from family backgrounds and personality shaping factors, and to identify other variables explaining attitudes and values about creativity over and above these other factors. The highlights of the results for each of these demographic questions were shared in [2].

For the factor analysis in this paper, we used SPSS and forced a correlation of items, reducing to three factors. These results will be compared to those of the rCAB authors [3].

As for the qualitative data, for each of the nine questions that had open-ended answers, concepts were extracted from individual responses. There can be a significant amount of ambiguity in open responses, so our primary goal was to classify a "concept expression" the same way whenever we encountered it. For example, in defining creativity, many respondents said that it was "thinking outside the box". Ultimately, it was felt that this expression embodied two key concepts; the idea of being free/unconstrained, and of thinking differently. It is likely that not all of those who said this phrase intended to express these concepts. However, there was no way to gain further insight into their meaning, so the best that could be done was to codify such words/phrases as consistently as possible. Multiple passes were made over the responses for each question. After each iteration, concepts were grouped thematically and responses were relabeled with more representative group names. Response labels were revisited for a validity check. This process was often carried out 2-3 times. The first iteration was purely organic. Later iterations considered the merits of themes that aligned with the state, skill, trait concepts, where appropriate. In the end, once the thematic coding was felt to be complete and as correct as possible, the group concept names were then assigned code numbers, and the qualitative, open-ended responses were numerically coded.

The advantage in doing this is two-fold. First, the qualitative data is now quantitative and can be analyzed as such. It can also be broken apart and compared easily e.g. responses from engineers versus non-engineers. Second,

this coding sets the stage for a full-scale version of this survey which could be used at other universities.

3. RESULTS

3.1 rCAB Principal Axis Factoring (PAF)

A Principal Axis Factoring (PAF) analysis, using SPSS V24, was performed to investigate whether the 25 items in the rCAB could be reduced to a few factors. As past theory suggests, factors might be correlated to one another. Therefore, the Oblique rotation was used to allow for inter-factor correlation. Since PAF analysis doesn't lead to a unique solution, we used the following criteria to select the best solution. First, past theories and studies were considered for guidance. Second, a simple conceptual structure was sought. Third, as one of the main objectives of any Factor Analysis, we tried to get the maximum variance accounted for by the final set of factors. Last but not least, we tried to minimize residuals between observed and reproduced correlations.

Using these criteria, our PAF achieved a three-factor solution which accounted for a respectable 30% of variance. There were 23 (equivalent to 12%) non-redundant residuals with absolute values greater than 0.05. This implies a fairly good reproduction of the correlation matrix. In order to achieve the simple structure, we dropped five items. These items either were not loading on any factor or were loading but with a correlation less than 0.325 which was used as a threshold. All in all, our final PAF solution consisted of twenty items, twelve of which loaded on the first factor. Another six items loaded on the second factor. Two items were loaded on the third factor. As mentioned earlier, we allowed for inter-factor correlation. Results show positive though somewhat weak correlation between factors i.e. 0.271, 0.221 and 0.256. This confirms theories which imply correlation between different scales of creativity.

We named our three factors "take on/seek new perspectives", "be different" and "time is well spent being creative with others". Corresponding to a well-known three-index theory of creativity, these factors are closely related to flexibility, originality and fluency, respectively [3]. In short, flexibility refers to the number of categories tapped by a set of given ideas i.e. different perspectives on the same subject. Originality refers to strangeness and rarity of ideas, and fluency refers to the number of meaningful ideas.

3.2 Q1: Define "creativity"

After the rCAB, respondents were asked to define creativity. They could use up to 500 characters to do so, though most answers were less than 100 characters in length. A total of 1176 useful definitions were gathered.

Each definition was coded for the concepts contained within. We identified between one and eight concepts per definition.

This data set is not yet fully processed. Table 1 shows the results of the second iteration, which is expected to be very similar to the final result. Note that any redundancies of concepts in a given response were discarded. Table 1 shows how frequently, on a percentage basis, different concepts appeared over the 1176 definitions. Note that the sum does not equal 100% as many definitions contained multiple concepts. Also, smaller concept categories were excluded from the table.

Table 1 - Q1 concept frequency in "define creativity"

Creativity Concept	% of Respondents
being novel/clever/unconventional/imaginative/original	45%
see/think/act differently	39%
an ability	37%
realized/applied novelty or novel creation/production/expression	32%
freedom/without restrictions/expressing individuality	23%
novel problem solving	17%

3.3 Q6 and Q7: Is being creative generally a positive behavior, and has your opinion on this changed since starting your current degree?

Question 6 asked respondents if they felt creativity was a positive behavior, and if they did, why was it positive. Over 96% of respondents believed that being creative was generally a positive behavior. The reasons of those 46 who disagreed can be seen in Figure 1. Note that the percentages shown are of respondents, not responses. Some respondents in Q1 and Q6-Q11 provided more than one response concept. As such, percentages will usually total to more than 100, although some minor categories have also been left out.

Figure 1: Reasons why creativity is not a positive behavior

Of note, only “wastes resources” was a true negative in Figure 1. The rest of the reasons were really a rejection of the question for being black and white e.g. was both +/-, and unrelated to +/- . The reasons 1240 respondents who agreed that creativity is generally a positive behavior are shown in Figure 2.

Figure 2: Reasons why creativity is a positive behavior

Promoting change was the reason 42% of respondents listed creativity as being positive. There was little variation in this pattern of responses between engineering and non-engineering respondents. However, most of the engineering respondents were more concise in expressing their opinions than non-engineering respondents.

To analyze whether post-secondary education has influenced attitudes on creativity, respondents were asked in Q7 if their opinion of creativity as a positive quality (or not) changed since starting post-secondary. Justifications for the 17% of respondents (a total of 210) whose perspectives did change are shown in Figure 3.

Figure 3: Reasons why opinions on creativity changed

The 24% of respondents who find creativity is now hindered in post-secondary education is nearly matched by the 22% of respondents who now find creativity to be of value. The other reasons also have a primarily positive connotation.

3.4 Q8 and Q9: If you feel that there are specific situations where it is difficult/easy to be creative, please list them

In order to capture state-based opinions on creativity, respondents were asked to generate situations in which they felt it would be difficult or easy to be creative. Circumstances under which (1079) respondents felt that it would be difficult to be creative were characterized in themes aligned with the state/trait/skill conceptualization of creativity. Almost all answers were state-based answers, as expected. However, “state” was able to be broken up into internal state (of self) and external/social state variables. The results are shown below in Figure 4.

Figure 4: Themes of answers pertaining to when it is difficult to be creative

A corresponding analysis was carried out on the answers for the circumstances under which (1095) respondents felt that it would be easy to be creative. These results are shown below in Figure 5. It would appear that most people regard one’s internal and external state as being very influential in facilitating or inhibiting one’s creativity.

Figure 5: Themes of answers pertaining to when it is easy to be creative

3.5 Q10 and Q11: If you feel that there are specific situations where one should be/should not be creative, please list them

In order to further capture state-based opinions on creativity, respondents were asked to generate situations in which they felt they should be, or should not be, creative. Circumstances under which (760) respondents felt that

they should be creative are listed below in Figure 6, distinguishing responses from engineers and non-engineers.

Figure 6: When you should be creative

The largest category, at 38% overall (43% engineers, 37% non-engineers), incorporated forms of innovating such as problem solving and improving efficiency. Indeed, 15% of individuals overall (16% engineers, 15% non-engineers) believed that creativity should be applied to almost all aspects of life. When comparing engineers to non-engineers, the results show that more engineers believe one should be creative when innovating and less so in social situations such as when interacting with others and in one's personal life. To contrast, Figure 7 shows situations where one should not be creative (from 512 respondents).

Figure 7: When you should not be creative

The largest grouping, consisting of 29% of all responses, encompasses procedures, protocols, and standards. This includes legalities, taxes, recipes, and other tasks requiring a standardized format or completion method. It is also interesting to note that some members of the university community think that one should not be creative in math or science.

3.6 Q12 and Q13: In your opinion, can you enhance/grow (or lose/diminish) your levels of creativity?

These questions pertain mostly to creativity as a skill, although some responses related to state. Answers of "no" would generally correspond to a trait perspective. The answers to these questions were determined for engineers and non-engineers, and were compared. At first glance, the initial answers appeared to be somewhat similar as 93% and 84% of engineers believed that one's levels of creativity can go up and down, respectively. Similarly, 94% and 82% of non-engineers believed this as well.

Those respondents (for Q12: 197 engineers and 925 non-engineers; for Q13: 178 engineers and 812 non-engineers) who answered "yes" to these questions i.e. they believed that one's levels of creativity can go up or down, were directed to a blank field where they could explain how this could occur. Figure 8 shows the results for factors that enhance/grow creativity. There are some obvious differences between engineers and non-engineers. First, to many engineers, practice is believed to have a greater positive impact i.e. 24% of engineers versus 16% of non-engineers. Second, fewer engineers believe in the role of personality traits as increasing one's levels of creativity i.e. 10% for non-engineers versus 3% for engineers.

Figure 8: How can you enhance your levels of creativity?

Figure 9 shows the results for factors that lose/diminish creativity. These results also show a few differences between engineers and non-engineers. In particular, fewer engineers believe in the role of personality traits in decreasing one's levels of creativity i.e. 7% versus 13% for non-engineers. Also, for a greater proportion of engineers than non-engineers, routine is felt to have a negative impact i.e. 17% of engineers versus 12% of non-engineers. Of interest, only 1% of engineers felt that communication was a diminishing factor, while 5% of non-engineers felt that communication could be detrimental.

It should be noted that in terms of enhancing factors, a majority of respondents mentioned "communication" in

regards to communicating with creative people, diverse people, and people working within the same field. On the other hand, in terms of hindering factors, a majority of respondents mentioned “communication” with negative, like-minded and uncreative people.

Figure 9: How can you diminish your levels of creativity?

Some respondents (for Q12: 15 engineers and 63 non-engineers; for Q13: 33 engineers and 173 non-engineers) did answer “no” to these questions i.e. they did not believe that one’s levels of creativity can go up or down. They were asked to explain why they felt that way. Figure 10 shows the results for those who felt that creativity could not be enhanced. In codifying these answers, we used another conceptual framework. Instead of categorizing based on conceptual keywords, we applied our proposed conceptual framework [2] in which creativity is hypothesized to be a combination of personality traits, behavioral states, and a set of skills.

Figure 10: Why can creativity not be enhanced?

Not surprisingly, if you felt you couldn’t do anything to increase or decrease your creativity, you strongly tended to regard creativity as a trait. Engineers answering this question tended to blame the situation (state) more than non-engineers, while non-engineers blamed personality traits slightly more often than engineers.

4. DISCUSSION

The principal axis factoring was reassuring both in its effectiveness and in its correlation with the three-index theory of creativity that focuses on flexibility, originality, and fluency. These factors can now be used to score respondents along these axes.

Question 1 responses, defining creativity, were noteworthy in many regards. Overall, there was a great diversity of responses. However, certain themes were dominant. The ideas of novelty and originality were the most common. Seeing creativity as an ability was also extremely common. This is not that insightful, however, as it is not specific to a skill or trait. Indeed, it does not preclude creativity as a state, either. Of interest, was the great number of respondents who felt that creativity was only valid if manifested i.e. it couldn’t just be a novel idea. It had to be realized in some fashion. Also of note was the dominance of the notion of divergent thinking. Some did regard convergent thinking as important, but relatively few respondents expressed that idea.

This brings up a likely limitation of this data gathering approach. It is quite possible, in the heat of the moment that they were being typed in, that these unbiased definitions were incomplete, even by the standards of the respondents. If this question had been posed at the end of the survey, or if respondents were instead faced with a list of potential elements or qualities of creativity to check off, we might have put together quite a different picture.

It was encouraging to see that most people regard creativity as a positive behavior, generally. It was interesting to see that many felt that creativity is a positive agent of change, and that it has positive mental health benefits! Including indirect reasoning, it also appears that post-secondary education is not necessarily diminishing creativity. However, this result may vary by discipline, which will be a focus of upcoming analyses.

Q10 and Q11, looking at when one should and should not be creative, yielded few surprises. Interestingly, the characteristics of most universities (lots of rules and regulations) would seem to stifle creativity, at least for students. This needs to be looked at more closely. These questions would also benefit from a change in format similar to Q1 i.e. a checklist approach to answering the questions, to capture all of the situations one might agree or disagree with.

In the case of Q12 and Q13, it was curious that the percentages of those who felt creativity could be enhanced and diminished were not more similar. For an unknown reason, some people think creativity levels can go up but not down. Practice, or the lack thereof, is identified by many as being important, and more so by engineers. On the other hand, engineers seem to feel less influenced by communication in this regard, which might be a reflection on how much they value communication. We will soon be

able to dive into the data to see whether there are gender differences on this point, too.

5. CONCLUSIONS AND FUTURE WORK

The coding process for the open-ended, qualitative questions in our survey yielded valuable insights which can carry forward to future versions of this survey. They also present a compelling picture of views on creativity at the University of Saskatchewan, in 2015. There was, in fact, a lot of creativity shown in answering these questions. Developing themes around concepts arising in the various answers to the questions, was challenging. At this point, it is impossible to draw conclusions around causal factors as they relate to opinions around creativity. However, results were consistent with our hypothesis that creativity is a mix of trait, state, and skill, much like familiar athletic and artistic abilities.

Our factor analysis results correspond nicely with the three-index theory of creativity involving the factors of flexibility, originality, and fluency. Indeed, further work on Q1 may reinforce this. And further work can now proceed in using the factor analysis to score respondents on the three factors that we isolated.

In terms of further work, more coding will take place with Q1, our largest and most complex data set. After that, we will have quantified all of our data such that cross-tabs between questions will be relatively straight-forward. Of particular interest to us will be the comparisons of engineering responses versus non-engineering responses. However, we will be able to cross with any demographic factor, and tie any factor to our rCAB scores. This is sure to generate some interesting results.

In terms of data collection, we will soon be ready to deploy a second version of our 2015 survey at any campus. This survey will take less time to complete and results will be more valid, as we close some of the open-ended questions which should help significantly with data quality.

While we still aspire to assess and measure creativity levels, this is a ways off yet, as we focus for now on getting the most out of our current data set, and expanding it with input from other institutions.

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