AC 2008-1195: IN-CLASS CREATIVITY EXERCISES FOR ENGINEERING STUDENTS

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Abstract

The flattening of the world is rejuvenating the call for engineering educators to better develop students that are creative and innovative so that they can have a clear advantage in a very competitive global economy. Much has been written and many exercises developed in response to this calling. Unfortunately, while many such exercises are fun and engaging and serve many useful purposes, the authors find the majority of them failing to provide the participants with a toolset or thinking process change that can be easily applied to creatively and innovatively solve the day-to-day engineering problems which the students will routinely encounter upon graduation. The authors have reviewed a large amount of literature and many books relating to creativity exercises and have adopted several (some with minor changes) that are particularly effective in providing very distinct teaching points that can result in a student’s future ability to directly and consciously apply a particular technique to generate more creative concepts. This paper will describe three such exercises and summarize some of the results typically obtained when they are run with students.

Introduction

By now, most engineering educators have read or heard about Thomas Friedman’s book\(^1\) describing how the lowering of trade and political barriers coupled with the digital revolution have made it possible for anyone to do business anywhere, anytime. Innovation is no longer being dominated by large corporations; increasingly, individual entrepreneurs and small start-ups are competing not just for labor/manufacturing but also in high-tech and R&D capacities. As engineering educators, the authors’ take on all of this is that in order to maintain competitive advantage as a nation, we need to revitalize how we educate our future engineers. It clearly no longer suffices to develop engineers who will merely outnumber those in competing nations and out compute those in developing countries; what is needed, in our opinion, is an engineering workforce able to out innovate the rest of the world and create so much value that our nation will be able to compete – and win – in the 21\(^{st}\) century.

In preparation for understanding how we as engineering educators might adjust our curricula to respond to these changing times, the first author has read numerous books\(^1, 3, 12-15\) on the subject of innovation and creativity. Simultaneously, the College of Engineering of Science at the University of Detroit Mercy had identified Innovation and Creativity as one of four critical areas vital to the future success of our engineering students. This UDM priority coupled with generous support from Ford Motor Company, the Kern Family Foundation, the Lemelson Foundation, and the Jesuit 100 has led to an explosion of curricular developments in the areas of innovation, creativity and entrepreneurship. These activities have included four new university courses, a new pre-college program course, three technical entrepreneurship case studies, the creativity exercises about which this paper will focus, and plans to roll out a minor in entrepreneurship aimed at both technical and non-technical students. The authors also believe that the key competitive advantage boils down to company culture and process, and while the culture of external large corporations may be largely out of our hands, we have been developing and teaching courses on the product development process for more than a dozen years. A key aspect
of our product development courses is that they are project based\textsuperscript{9-11}. It has become clear to the authors that additional focus on tools/processes related to innovation and creativity is warranted.

Over time, the authors have been exposed to a variety of creativity exercises through conference workshops or industrial training sessions. Though inspiring in many ways, the authors felt that there was room for exercises with more distinct ‘morals’ or ‘teaching points’ which would provide a deeper understanding of typical roadblocks to creative thinking and provide concrete, conscious ways in which an engineer looking to innovate can break down some of these barriers and create more and less obvious concepts. The authors set out to identify/develop a series of creativity and innovation exercises that can be used in the classroom, each having a distinct ‘teaching point’ that can be made in a wrap-up discussion.

The authors began by reviewing available literature and texts on creativity exercises for education and training. The texts found most useful include\textsuperscript{12-14}. The academic literature search turned up nothing directly of interest; there were many papers on how innovation/creativity have been emphasized/integrated into courses and projects, but the authors did not directly find any exercises described which meet their objectives/intentions.

Based on this review, the authors selected three in-class creativity exercises which they have used (slightly tweaked) and had great classroom success with. The authors don’t claim to have invented or developed any of these exercises. However, the work done to identify these particular exercises as potentially valuable classroom experiences for engineers, combined with the authors’ past successes in using these exercises motivated the authors to prepare this paper to spread the word. These exercises are described in the subsequent sections of this paper.

These exercises have been run four times at UDM, once as an NCIIA Conference workshop, once as a guest lecture for Bizdom U, and once as a guest lecture for faculty at Lawrence Technological University. The UDM classes involved have been the Interdisciplinary Design, Entrepreneurship, and Service course, the Innovation and Creativity course, and the Product Planning and Development course. The second author also plans to integrate these into product development courses at his institution.

Regarding the audience for the exercises, students involved have ranged from sophomore level through graduate level; the authors feel the exercises are very well suited to that entire range (and, while we have not used them at the freshman or K-12 levels, we expect they would work equally well with that audience). During the Lawrence Tech workshop for faculty and the NCIIA workshop, the attending faculty members played the role of students; the results were very similar to those we have seen with students.
The Spelling Test: The Exercise

This exercise is a slightly tweaked version of the exercise entitled ‘ABC’s of Creativity’ which can be found in the book by Epstein.13

Materials needed to execute this exercise include:
- A set of plain wooden blocks with no markings.
- A set of kids’ alphabet blocks with all blocks having a T on them removed. These should ideally have letters on all sides with no pictures and not the same letter on each side. Due to surprising difficulty finding these sorts of blocks in these days, the ones used by the authors have letters only on two of the six faces with the other faces blank.
- A stopwatch.

The exercise is best described by explaining how it is run. The basic steps of this exercise can be summarized as follows (note that it can be done simultaneously for any number of groups, but for simplicity sake it will be described as if it is being done for one small group of about 8 students):

1. Two volunteers are asked to wait outside until called upon. They can be given the classic none dots puzzle or some other puzzle to work on while waiting to be called upon.
2. One of the remaining students is selected as the first subject. He/she will be referred to as Subject 1 hereafter. Another student is selected as a timer and given a stopwatch. The timer is asked to record the time it takes each subject to spell each word.
3. Subject 1 is given instructions as follows as the set of blank wooden blocks is dumped on the table in front of the subject: “Please use these blocks to spell the word lit as in I lit a candle as quickly as you can. You will be timed.” Subject 1 generally produces the solution shown in Figure 1 within 10 or 20 seconds, most of which was time it took to execute the solution – not decide how to solve the problem. The timer records the time it took to complete the task.

![Figure 1. LIT Using Plain Blocks](image)

4. Subject 2 is brought in and given instructions as follows as the set of alphabet blocks (with the T’s removed – unbeknownst to the subject) is dumped on the table in front of the subject: “Please use these blocks to spell the word lit as in I lit a candle as quickly as
you can. You will be timed.” Subject 2 typically finds an L and then an I fairly quickly, then struggles a while looking for a T, but relatively quickly rules out that there are any T’s. With a little thought, Subject 2 generally abandons the expectation of finding a T and ultimately produces one of the two solutions shown in the top portion of Figure 2. The timer records how long this took. Two of the more unique past solutions are shown in Figure 3 and Figure 4.

Figure 2. The Three Most Common Solutions to LIT with no T’s

Figure 3. Missing Letters Spell LIT
5. Subject 3 is brought in and handled in a fashion very similar to how Subject 2 was handled with one extremely critical difference. In this case, Subject 3 is asked to spell three easy words (we used dog, ear, and mob because the letter complexities would make spelling the words by laying out the blocks in the shapes of the letters unattractive) before being asked to spell lit. Subject 3 always eventually produces a solution but the time to spell lit is typically far higher than it was for the prior subjects.

The Spelling Test: The Past Results

Though there is a lot of inherent variability in any such exercises involving human subjects, past results running this exercise (four times at UDM, once as an NCIIA Conference workshop, once as a guest lecture for faculty at Lawrence Technological University, and once as a guest lecture for students at Bizdom U), the general trend is as expected and is similar to the sample data from the January 2007 UDM results shown in Figure 5. Time to execute this exercise varies a bit, but generally can be done and discussed in about 30 minutes.

Figure 5. Spelling Test Sample Results. Time to Spell LIT. (Each bar represents a different student; there were two students given blank blocks, three given blocks missing all T’s who where only asked to spell LIT, and three given blocks missing all T’s who were first asked to spell three words requiring no T’s before being asked to spell LIT)
The predominant tweak over the exercise as laid out in \textsuperscript{13} is the part involving beginning with a set of blank blocks. The authors would like to thank Doug Tougaw at Valparaiso for providing the suggestion to do so.

**The Spelling Test: Discussion/Teaching Points**

This exercise illustrates how past successes – and expectations of certain solution approaches – often hinders ones consideration of other alternatives. This is poignantly evident in the fact that those asked only to spell \textit{lit} typically migrate to a solution other than spelling it using the letters on the blocks much more quickly than those who previously spelled three words successfully using that paradigm. As part of the class discussion, we proceed to discuss the concept of anchoring and how it can inhibit one’s ability to think creatively. By anchoring, we are referring to the tendency of most individuals to remain fixed on one particular approach to solving a problem, even when other solutions may potentially be better. This psychological inertia is one of the fundamental premises behind Altschuller’s Theory of Inventing Problem Solving (TRIZ)\textsuperscript{12}. We also point out that not all subjects ultimately came to the same solution, and that in practice this means that one really needs to be thorough and rigorous in concept generation to avoid potentially proceeding with an inherently weak (or less strong than was possible) concept. Another interesting note relates to the fact that the task is very easy using the blank blocks; the blocks with letters clearly provide more information, yet that additional information does not necessarily lead to an easier time solving the problem. A final talk point relates to the partial integration of promising – but incomplete – solutions (note how some students trying to spell \textit{lit} when there are not T’s ultimately scrap using the L and I blocks and ‘make’ an L and an I just like they make a T while others simply use the L and I blocks and ‘make’ only the T).

**The Parts Handling Operation: The Exercise**

This exercise is based off of the one entitled \textit{Keys to Creativity} in \textsuperscript{13}. Materials required for this exercise include:

- A broom with a screw-off handle – but not one where the threaded connection is obvious at a glance.
- A key ring with a number of keys on it such that the broom handle cannot fit into the key ring unless the handle is disconnected; then the threaded end of the handle just fits into the key ring opening.
- A typical stool.
- Duct tape.
- A variety of miscellaneous stuff; this stuff should be mainly as useless as possible for the task at hand (the reason for this will become clear later).

These materials are shown in Figure 6 and Figure 7.
To setup for the exercise, the stool is placed in the room with the keys on top in a position similar to that shown in Figure 7 – namely with the opening of the ring posed invitingly towards where the subject will stand. Within broom handle range of the stool, lay a piece of duct tape down as the ‘stand here’ marker.

Once again, the exercise is best described by explaining how it is run. The basic steps of this exercise can be summarized as follows:

1. One volunteer is asked to leave the room.
2. Another volunteer from the class is selected. He/She will be referred to as Subject 1 hereafter.
3. Subject 1 is given instructions along these lines: “You are working in an assembly plant and need to come up with a process to retrieve that part [point to key ring] to you without having the part touch the floor and without you crossing the line [duct tape]. You have only the broom as a tool.” [The other ‘tools’ aren’t in play yet and should be out of sight to avoid distraction.]
4. The class observes as Subject 1 looks for ways to meet the stated objective. Usually, within a few minutes, the following solutions are tried:
   a. The subject hooks the broom on the rungs of the stool and drags the stool close enough to grab the key ring. This works fine but the subject is told that a foreign competitor has a patent on the method and that he/she must search for another method (i.e., the subject is ‘given the excuse’).
   b. The subject tries to insert the upper end of the broom handle into the key ring. It does not fit.
   c. The subject knocks the key ring off the stool, catches them on the broom, and carries them over. This method usually fails, but in any case the subject is again given the excuse (or another excuse about reliability) and asked to find another method.
   d. The subject tries to bat the key ring over the line. Again he/she is given ‘the excuse.’
5. Eventually the subject more closely examines the broom, realizes the handle comes off, unscrews the handle, and easily snares and retrieves the keys. This is the solution sought and Subject 1 is done. One student just after this ‘ah ha’ moment is shown in Figure 8.

![Figure 8. Student About to Retrieve Keys](image_url)

6. The above steps are repeated for Subject 2 with one major difference; this subject is invited to use the broom plus all the miscellaneous stuff shown earlier.
7. Subject 2 then proceeds as long as it takes (highly variable) to find the sought-after solution, and is given the excuse for any different solutions found (sometimes a creative use for some of the miscellaneous stuff is found).

**The Parts Handling Operation: Past Results**

Past experience with this exercise has shown that the subjects given only the broom to work with more quickly converge on the sought-after solution than those given the multiplicity of mainly
useless tools. In addition, there seems to be a general tendency of those given only the broom to focus intently on the stool and key ring, tending to ignore a closer look at the tool for some time. As might be expected, those given all the tools tend to focus intensely on the tools more so than on the problem – yet it typically takes them much longer to consider taking the broom apart. Based on the authors’ experiences, time to complete the exercise is highly variable (roughly 3 to 15 minutes per subject).

The Parts Handling Operation: Teaching Points

Following the exercise, the authors like to discuss several points:

- Having multiple tools in one’s toolbox (i.e., multiple possible approaches to a problem) tends to result in trying to apply them in a breadth-first approach, whereas having few or a single tool forces a more thorough depth-first approach.
- Sometimes having more possible approaches results in finding one that’s marginally acceptable and sticking with it, when there may be a better approach that’s left unexplored (except perhaps by the competition).
- Having tools in one’s toolbox is not enough; an innovator must fully understand them and be able to apply them in non-obvious ways.
- When several potential solutions for a problem can be identified in a relatively short period of time, it is important to avoid jumping to selecting one right away. It is always important to study the problem in more detail and from different perspectives to see if any new and better ideas can emerge.
- An innovator always tries to envision possible solutions that are not obvious at first glance.
- When many possible solutions are generated, a structured methodology is required to select the most promising one.

Bisociation: The Exercise

Bisociation is a term coined by author Arthur Koestler in his book The Act of Creation\textsuperscript{16}. Bisociation, also referred to as forced association, involves connecting of two things seemingly unrelated. It can be an effective entrepreneurial approach in product creation. Many of the references refer to this technique – though sometimes by a different name. A quick web search also turns up numerous references.

When the authors run this exercise, they begin by asking each student to take three minutes to write down as many ideas as possible for new earrings. A tally of each student and the number of ideas is logged.

Next, the authors present a number of PowerPoint slides illustrating examples of successful products that illustrate bisociation. These examples are summarized in Error! Reference source not found. The slides used begin by revealing two inputs (mail order and computers for instance) and ask if anyone knows the resulting product and the mind behind the idea (Dell Computers and Michael Dell in this case).
### Table 1. Bisociation Examples

<table>
<thead>
<tr>
<th>Things Associated</th>
<th>Resulting Product (person behind the idea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computers + mail order</td>
<td>Dell Computers (Michael Dell)</td>
</tr>
<tr>
<td>Auction + web</td>
<td>Ebay (Pierre Omidyar)</td>
</tr>
<tr>
<td>Bookstore + web</td>
<td>Amazon.com (Jeff Bezos)</td>
</tr>
<tr>
<td>Horse carriage + steam engine</td>
<td>Car/train (debatable as to who was first)</td>
</tr>
<tr>
<td>Wine press + coin punch</td>
<td>Printing press (Gutenberg)</td>
</tr>
<tr>
<td>Icebox + rail car</td>
<td>Refrigerated rail car (Gustavus Swift)</td>
</tr>
<tr>
<td>Rubber + waffle iron</td>
<td>Sole for Nike shoe (Bill Bowerman)</td>
</tr>
<tr>
<td>Tablet PC + cell phone</td>
<td>iPhone (Steve Jobs)</td>
</tr>
<tr>
<td>Floating Soap + Distortion in Glass</td>
<td>Float glass [distortion free] (Alastair Pilkinson)</td>
</tr>
<tr>
<td>Stuffed animal + web game</td>
<td>Webkinz (Ganz; individual unknown)</td>
</tr>
<tr>
<td>Skipping stones + Frisbee</td>
<td>SkipDisc (Whamo; individual unknown)</td>
</tr>
</tbody>
</table>

Following these examples, the students are again given three minutes, but this time they are asked to write down as many ideas for new earrings by thinking about the North Pole. The number of ideas per student is logged in a data sheet on a student-by-student basis next to their original number of ideas. Students are asked to share some of their new ideas.

**Bisociation: Past Results**

The reason the instructors log the number of ideas with and without bisociation on a student by student basis is to enable a quick two sample t-test to be conducted to determine if more ideas (based on statistical significance) can be shown to result using bisociation. Unfortunately the authors’ past results have not resulted in a clear indicator as such. This may be because the time limit allotted of three minutes per idea generating session (without and then with bisociation) is too short. In any case, the results have uniformly shown that the vast majority of ideas (nearly all) that result during the bisociation portion of the exercise are in fact new ideas that were not on the student’s original list (hence a flaw in the original data analysis). This provides strong evidence that the technique was successful in generating numerous new ideas, and most of the students acknowledged that most of the ideas they came up with during the bisociation portion of the exercise would never have resulted (given unlimited time) from the pure brainstorming activity. Perhaps to gather statistically significant data, a class could be subdivided and only half
given the bisociation half of the talk with the others simply given three more minutes to log ideas. Then the numbers of ideas could be compared between the groups. The authors have conjectured about doing this but have stopped short due to small class sizes and a concern that the variability person to person would most likely statistically mask the general trend without a very large sample size.

**Bisociation: Teaching Points**

The authors like to ask the students to reflect on how their thinking changed during the bisociation portion of this exercise. All students who have participated in this clearly acknowledged that their thinking changed. The authors go on to discuss how thinking about odd topics may in fact result in new ideas. Another teaching point is that breadth of knowledge outside one’s principle domain is often the key to having a great idea (for example, if someone knows very little about the North Pole, then the bisociation example is less useful).

A question typically arises as to what words to use. Some of the literature suggests random word searches, while others (14 for example) provide lists of recommended words to use. Reference 14 also devotes an entire chapter (entitled *Brutethink*) to random stimulation.

**Assessment**

The authors find creativity enhancement a very difficult thing to assess. The only real assessment instrument available so far has been student feedback – either direct or via course evaluations. That feedback has been overwhelmingly positive.

**Conclusions**

The authors believe that innovation and creativity are the cornerstones of this country’s technical future competitiveness. The in-class creativity exercises outlined in this paper each provide distinct teaching points which the authors believe result in students having a better understanding of some of the typical roadblocks to creative thoughts during the product creation process. This understanding should enable the students to ultimately be more creative and innovative engineers. The fact that students report feeling the way their thought processes change is encouraging to the authors that when faced with a new problem, they will remember these exercises and the lessons they bear regarding inhibitors to their creative processes.

**References**