How do engineering students perceive the importance of creativity within their own leadership development?

Abstract

Creativity is essential for success in the engineering field at all levels of individual development, from novices to experts and from early career engineers to experienced engineering leaders. Some global technical organizations go to extraordinary lengths to develop working environments that hone the creative skills of their employees, while an increasing number of academic institutions strive to deliver curricula focused on creativity from a variety of perspectives. Despite these efforts, engineering professionals and academics continue to debate the best ways to embed and facilitate creativity in engineering programs. In this exploratory research, we analyzed a sample of graduate-level engineering students' perceptions of the importance of creativity to their professional and leadership development. Then, we explored whether those perceptions could be influenced through activity-based learning. Specifically, we embedded creativity concepts and practices within a masters-level engineering course focused on professional and leadership skills at University X. Creativity was introduced through a dedicated 3-hour lecture session and several activity-based learning sessions throughout the course. We captured the students' awareness and perceptions of creativity at multiple points throughout the course using a combination of assessments, including tailored questionnaires, the Belbin team roles instrument, self-reflection questionnaires, peer feedback questionnaires, and peer reviews. The students' progressive changes in awareness and perceptions of creativity, if any, were then extracted and analyzed using these datasets.

Keywords

Creativity, engineering leadership, leadership development, graduate education

Introduction

We begin with our definition of creativity and its relationship to innovation to set the context for this work. Here, creativity is seen as the ability to generate new ideas, either as new ways of looking at existing problems or of seeing new opportunities, perhaps by exploiting emerging technologies or changes in markets [1-4]; as shown in Figure 1, creativity has two phases. In contrast, innovation is seen as the successful exploitation of new ideas—i.e., it is the process that carries new ideas through to new products, new services, new ways of running the business, or even new ways of doing business [5-7].

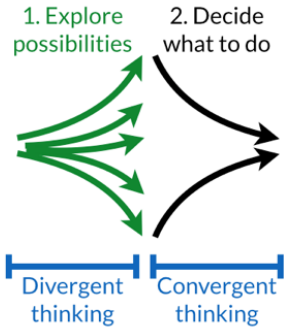


Figure 1: Creativity and Innovation [8].

By the time we reach our university studies, most of us have been trained to move quickly from divergent thinking to convergent thinking, so we can find the best answer or single best plan to whatever problem we face. Interestingly, at an early age, primary school children are masters of divergent thinking, creating a diverse range of ideas without inhibition.

The study of creativity in engineering education is becoming increasingly popular, but it tends to be associated with courses on design (and there, only in idea generation) [9]. Likewise, there are only a few short courses specifically focused on engineering leadership (e.g., Engineering Leadership at MIT [10] and Leadership Development for Engineers at Rice University [11]), and even fewer of these courses make creativity a specific focus (e.g., University X's Leadership skills module). In non-engineering fields, however, such as management, law, and psychology, creativity is often associated with leadership skills and professional development, and we argue that the same should be true in an engineering context. [12-15].

Even in the engineering design courses where creativity is emphasized, several challenges arise when it comes to enhancing student creativity. The issues are mainly due to the instructors' understanding and beliefs about creativity, which influence their teaching approach and what they value in assessment. Tekmen-Araci and Mann [16] identify those challenges to be in four main areas: (1) the instructors' focus on the design product being produced; (2) their educational background and training; (3) the subjective nature of creativity and their beliefs about it; (4) and the performance mindset of the instructors. These findings suggest that enhancing creativity among engineering students may not be possible until engineering educators and practitioners understand and value creativity in practice. Other studies, including those by Jackson [17], identify some serious shortcomings in achieving the goal of fostering creativity in students in areas relating to teaching, assessment and motivation, what the students do, and perceptions. Of all these factors, we believe that if the students' perceptions and actions could be positively influenced by well-designed courses that are delivered through appropriate methodologies, then our job as engineering leadership educators will be accomplished.

Therefore, in order to integrate creativity concepts into engineering leadership study/courses most effectively, it will be important to know how engineering students *perceive* creativity with respect to their leadership development. If they generally recognize its importance, then our job is made easier; however, if they (the engineering students) do not perceive creativity to be important, then we will need to develop this recognition in them. To this end, it will be important to know if and how engineers' perceptions of creativity can be influenced, so that important insights about creativity and leadership development (as recognized in the management field) can be effectively transferred to engineering students as well. To explore these important topics and questions, we explored the perceptions of engineering students about creativity in the context of leadership development.

Related Work / Background

We begin with a brief summary of some leadership studies from the management literature that highlight the importance of creativity in leadership development. Innovation (being comfortable with novel ideas, approaches and new information) is considered to be one of the important personal competence attributes within the emotional competence framework [18]. In his article, "Leadership that gets results" [19], Goleman reviews the characteristics, pros and cons, applicability, and overall impact of leadership styles on the organizational climate. In that review, the Authoritative and Affiliative leadership styles rise to the top in positively impacting the

organizational climate. While the Authoritative leadership style maximizes commitment to the organization's goals and strategy, the motto of this particular leadership style is 'People come first', so it still revolves around people. The common characteristics of these two leadership styles are that they give people freedom to innovate, experiment, and take calculated risks. While considering how leaders could be effective while remaining authentic, Goffee and Jones [20] highlight 'avoiding comfort zones' and 'developing resilience' as two key factors (among others). To avoid one's comfort zones, stepping out of routines, seeking new adventures, and taking some risks are suggested. Similarly, for developing resilience, leaders are advised to prepare themselves by learning and understanding their own values in order to overcome setbacks when they are exposed to new contexts and cultures. These points are in line with the association of creativity as part of one's leadership development and practice.

In the current climate of rapid technological change, global competition, and economic uncertainty, organizations seek to improve creativity and innovation [21]. While early research in organizational creativity has focused on occupations such as scientists and R&D, current thinking is that in any job or occupation, employees can exhibit creativity [22]. Strategy, creativity, and leadership are to a brand what fuel, heat, and oxygen are to a fire [23]. Creativity can and must be applied throughout the entire strategy process from the formulation of a vision for the brand right down to the design and delivery of its products and services—i.e., we must apply what Mauzy and Harriman [24] call systemic creativity. Similarly, Ind and Watt [25] argue that truly creative organizations break down the barriers within the organization and with the outside world to engage all stakeholders in a continuous creative process. Creativity is therefore not something that is limited to brainstorming sessions, but rather a habit that is embedded in the organization. This is a task for the leadership: to encourage ideas to be created throughout the organization. Then the organization's processes and innovations will be built from those ideas.

Next, we move to a brief review of engineering leadership courses and their inclusion of creativity principles. When we explored the available selection of graduate-level Engineering Leadership courses, we were able to find only a few certified professional development type short courses in the USA and Netherlands, and a few graduate-level Engineering and Leadership courses in the UK. The 'Engineering Leadership for Emerging Leaders' by MIT [10] is run over 5 days and is aimed at early career engineers who want to progress into leadership roles. When we examined the program content, we could not find any direct reference to creativity or innovation, though there were references to 'creating a vision' and 'creating a motivating environment'. Similarly, Rice University offers 'Leadership Development for Engineers Specialization' [11] through the Coursera platform; it is promoted as a program that could help advance one's engineering career into leadership and management roles. Rice's specialization comprises three courses (self-awareness and the effective leader, relationship management, and personal leadership development planning and leading high performing teams). Each course is expected to take approximately 13 to 15 hours to complete, over a suggested 4 to 5 week period with 3 to 5 hours/week. Each course covers an extensive range of topics in the areas of leadership and management; however, we did not find any topic related specifically to creativity or innovation, though there was one topic on 'creating a motivating environment'. Delft University of Technology (TU Delft) [26] also offers a 5-week course on 'Leadership for Engineers' via the edX platform; again, we could not find any topic related to creativity in that curriculum.

It was a similar story with the MSc programs in Engineering Leadership and Management from Aston University [27], and Swansea University [28] in the UK. We could not find any topics or courses related directly to creativity, although there was a 10-credit module on 'Enterprise, Innovation and Intellectual Property' in the MSc program at Swansea University. On exploring the syllabus for this module, we found the following two topics: 'Introduction to theory of innovation and enterprise', and 'Introduction to entrepreneurship and entrepreneurial leadership and related concepts (entrepreneurial mindset)'. However, there was no explicit reference to creativity. As an exception, all four MSc programs in the Electronics and Electrical Engineering Department at University X have the module 'Professional and Leadership Skills' as the core. This module has dedicated sessions handling creativity, in addition to having creativity embedded throughout the teaching, learning and assessment processes; it is the focus of our study here.

What is still missing from this picture? Why do so many engineers still consider creativity to be a minor topic, both in general and in terms of management/leadership? Could their perceptions of creativity be part of the problem? Considering the above leadership development education scenario for engineers across the globe, we arrive at the following conclusions: first, there is generally a lack of emphasis on fostering creativity in engineering education, even when people recognize its importance. Engineering curricula are becoming so full of technical topics, that many instructors feel there is no room for focused creativity instruction. Second, both engineering instructors and students have differing perceptions on what creativity means and whether it could be developed at all; this confusion is not uncommon, even in the social and behavioral sciences [32]. Third, both engineering instructors and students seem unaware of the importance of creativity for leadership development, possibly because (once again) they are so focused on the technical requirements of an engineering education. Next, there are no standardized teaching methodologies or techniques available to teach creativity within the engineering leadership curriculum, despite a wealth of general creativity techniques focused on specific creative activities, such as idea generation. And finally, there has been little acknowledgement or push from either the professional institutions or industries of the role of creativity in leadership development for engineers; without this external recognition of its importance, it will be more difficult to persuade academic institutions to invest in creativity instruction within their engineering curricula.

Exploratory Research Methods

Study Participants and Course Structure

The participants in our exploratory study included students enrolled in a module at University X called Professional and Leadership Skills (7341 ELEM). This module, which is taught by the first author and her team, is a core module for students enrolled across all the MSc Electrical Engineering programs in the Department of Electronics and Electrical Engineering at University X. During the period when this study was conducted, there were 13 students enrolled in this module, all of whom were males; they all had an engineering bachelor's degree in Electrical/Electronics Engineering. The cohort's age range was 23 to 28 years, and at least 11 of the students had work experience in their field. Full participation in this pedagogical study was encouraged (but not required) for the students enrolled in 7341 ELEM; appropriate processes were followed to obtain ethical (IRB) approval from University X before the study began. We have grouped the participants into 5 categories (G1, G2, G3, G4 and G5) based on their background to answer our research questions.

The Professional and Leadership Skills module contains a 3-hour creativity lecture session composed of two parts: (1) entrepreneurship and (2) creativity. The entrepreneurship portion focuses on the definition of entrepreneurship, the characteristics and competencies of entrepreneurs, and examples of local entrepreneurs. The creativity portion of the session (the portion of greatest interest here) focuses on creativity identity ('are you creative?'), divergent and convergent thinking, growth vs. fixed mindsets, creativity and innovation in the public and private sectors, ideation techniques, and a selection of creativity exercises to illustrate these topics. Other creativity exercises were also interspersed within the course, including a simple creative building exercise ('the marshmallow challenge'). The creativity session and these exercises comprise the instructional activities we examined for their influence on students' perceptions of creativity and its importance in their leadership development.

Research Questions

The goal of our exploratory study was to document how we could effectively embed creativity within an engineering leadership curriculum and to gather evidence on students' perceptions about the importance of creativity within their own leadership development. We considered the following research questions to help us develop this understanding:

- RQ1: How do engineering students perceive the importance of creativity in their leadership development before and after creativity instruction?
- RQ2: How do they perceive their own personal creativity level before and after creativity instruction?
- RQ3: Which types of activities were most/least effective in changing their perceptions of creativity and its importance in leadership development?
- RQ4: What assessment methodologies could be effective in elucidating the students' perceptions?

Data Collection

This study is part of a wider pedagogical study on leadership skills for engineers. The focus for the type and components of the questionnaires used was to capture a range of personal and social competencies and skills, of which creativity was one component. For the purpose of pedagogy, a range of instruments was designed, including tailor-made questionnaires, self-reflection questionnaires, Belbin tests, and peer reviews. Both point-based questions as well as narrative elements were used to capture data. The data captured from the students covered their personal perspectives as individuals, peer observers, and team leaders.

The data were collected using questionnaires filled in by the students and their peer reviewers at regular periods. In addition, data in the form of self-reflections from the individual students, narrative feedback from the assessors, and narrative feedback from student peer reviewers at the end of the course were included in the analysis. All the datasets for an individual student were linked before anonymizing them. The questionnaire and Belbin test analyses were applied to pre-course, post-activity, and post-course (with peer and instructor review) datasets; the narrative self-reflections, peer feedback, and instructor feedback were collected at the end of the course.

Using the pre-course questionnaire, students were primed to think of creativity as part of their professional development and role. In interpreting the Belbin test results, we considered a student's creativity level as *high* if Plant (PL) is in their preferred roles, *medium* if PL is in their manageable

roles, and *low* if it does not appear or is in the least preferred roles. To address RQ1, data from the pre-course questionnaire and self-reflections were used. To answer RQ2, we collated data from the pre- and post-course Belbin tests from both the individuals and their peers, the post-activity Belbin, self-reflection narratives, and the post-course questionnaire from both the individuals and their peers. Next, RQ3 was addressed through data from the pre- and post-course questionnaires, along with the self-reflections. Finally, RQ4 was answered using data from the pre- and post-course questionnaires and peer reviews.

Data Analysis and Key Findings

The data collected during this study were both qualitative and quantitative, making this a mixed methods study. The data we collected to extract creativity were mainly qualitative. Though there were 11 instruments in total that we could use to extract data, and 13 graduate engineering students participating in the study (in 5 groups: G1 to G5), we had only nine complete sets for all 11 instruments. As a result, we used a critical case study approach for our analysis.

RQ1: *How do engineering students perceive the importance of creativity in their leadership development before and after creativity instruction?*

To answer our first research question, we examined the pre-course questionnaire and compared the participants' ratings and reasons with their post-course self-reflection. The pre-course questionnaire had the following two sections on creativity:

Creativity:

On a scale of 1 to 5, how important do you think it is to have creativity in your field of work (1 being lowest, 5 being highest)?

Reflection (write 2 or 3 lines on each of the questions below):

1. Where do you think you will need to use creativity in your field of work?
2. How confident are you in being able to apply creativity techniques to your work?
3. Name/describe the creativity techniques you have used before.

For these two questions, Groups 1, 3, 4 and 5 rated the importance of creativity as high (4 or 5), whereas Group 2 rated its importance as low. The rationale provided by Group 2 was that the industry where the students had worked formerly required heavy regulatory documentation and processes in the industry, thus resulting in very limited requirements for creativity. These two students demonstrated creativity, but their perceptions of their creativity seemed to be low. Perhaps they interpreted creativity as only 'unstructured' thinking or risky behavior, whereas the students from the other groups (G1, G3-G5), who had worked in healthcare, music, design and management, perceived creativity more broadly and as an important skill to pursue.

These results were then compared to the students' post-course reflections on the creativity session and activities within the course. In this self-reflective narrative, all the students from all the Groups positively endorsed the importance of the creativity session and acknowledged the usefulness of such teaching sessions to their personal skills enhancement. This suggests that the creativity session and activities did influence at least one group's perceptions. The results are summarized in Figure 1.

		what they thought of the importance			What they thought during their reflection			Answers for the narrative questions from the pre-course questionnaire	
	Student	pre-course Ques			self-reflection				
Participant group		H	M	L	H	M	L	Where do you need Creativity?	How confident are you in using creative techniques for work?
G5	CdaS		x		x			N/C	N/C
	CBY		x				x	problem solving; managing an organisation	Not at all; creativity not part of the national and work culture.
G4	BD		x			x		N/C	N/C
	FM	x					x	presentation; communication	quite sufficient
G3	HRD		x				x	N/C	N/C
	JVBF	x			x			Design; analysis; deriving conclusions from the analysis.	more confident when the work is within the subject expertise.
G2	SF			x	x			heavy regulatory documentation and processes in the industry I work for - resulted in very limited requirement	creativity is one of my weaknesses
	MUK			x	x			needed for planning; concisely summarising information; and presentation	somewhat confident
G1	TM	x			x			dealing with patients with dementia at work in a care home.	very confident
	DT		x				x	N/C	N/C

Figure 1: Students' perceptions before and after the creativity session (RQ1)

RQ2: *How do students perceive their own personal creativity level before and after creativity instruction?*

To answer our second research question, we examined data taken from the pre-course questionnaire, the pre- and post-course Belbin tests (from both the students and their peers), and the self-reflection narratives. We evaluated the progress made in the participants' level of creativity from each of these exercises from pre-course stage to post-course stage. The pre-course questionnaire and Belbin tests were completed at the beginning of the course, before teaching started. The self-reflections were the consolidation of all the students' learning; these were written after all the teaching activities were completed. The post-course questionnaire, Belbin tests, and peer reviews were conducted at the final feedback stage, where the instructors gave their feedback on the students' self-reflections.

The consolidated data, summarized in the bar chart of Figure 2, were obtained by averaging the results for each instrument/assessment within each group (G1 to G5). Linear trend lines have been added to the G1 to G4 datasets, as G5 had a missing data point. Overall, it is interesting to see that the students' perceptions of their creativity level show an increasing trend over the duration of the course. The percentage change is different for different groups, which is understandable, as this could depend on various factors, such as differences in their backgrounds, personality types, current positions in life (and thus differing needs), etc. For example, G4 seems to have had the highest percentage of positive change in their perceptions; we know from our experience with the students, that the students in G4 were relatively younger, with less experience in industry.

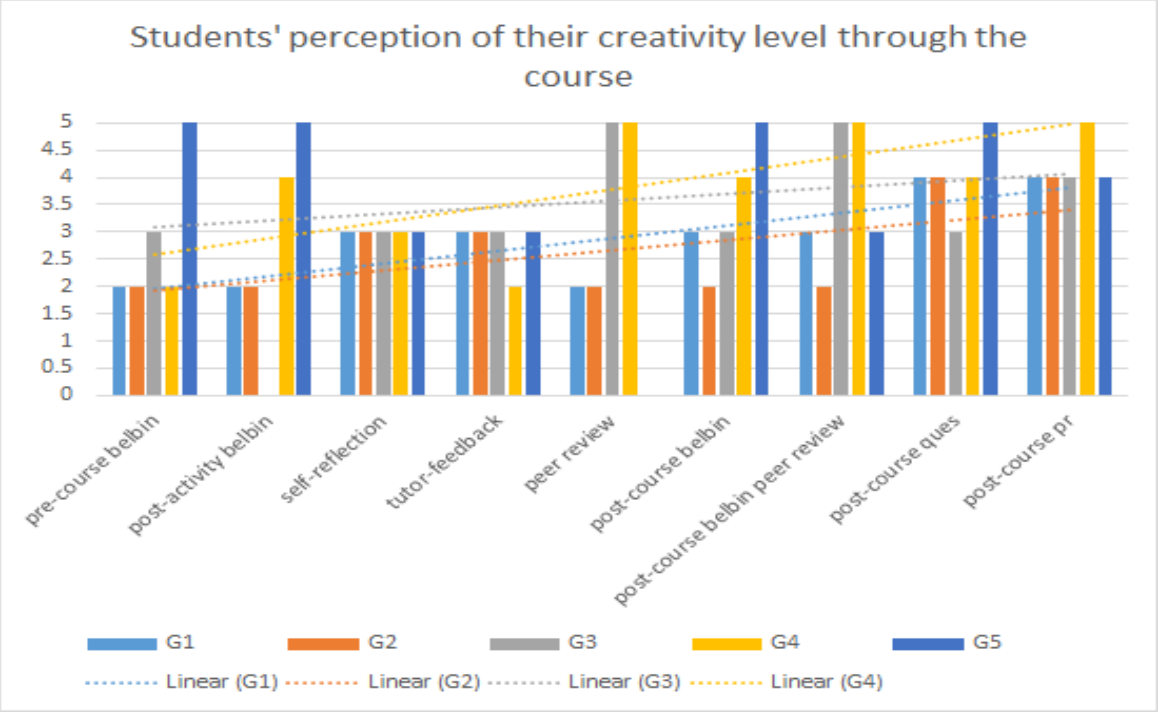


Figure 2: Progression of the students' perceptions of their creativity through the course

RQ3: *Which types of activities were most/least effective in changing their perceptions of creativity and its importance in leadership development?*

To answer our third research question, we examined the results shown in Figure 2, along with the pre- and post-course questionnaires and self-reflections. From these contributions, we believe that the course session on creativity helped greatly in students' understanding of the theory, types, and value of creativity in their development; this was captured in their self-reflection narratives, as illustrated in several quotes from the students' self-reflections about this specific session (see Figure 3). To set the scene, the students were first primed to think of creativity as part of their professional development and role; second, at each learning session, they were reminded of the need to be creative, either by having to use the skill in an activity or having to consider its role while answering a questionnaire or assessing their preferred roles using the Belbin test; and finally, they had to put their creative skills to use when they wrote their self-reflections and gave constructive peer feedback.

Participant 1:

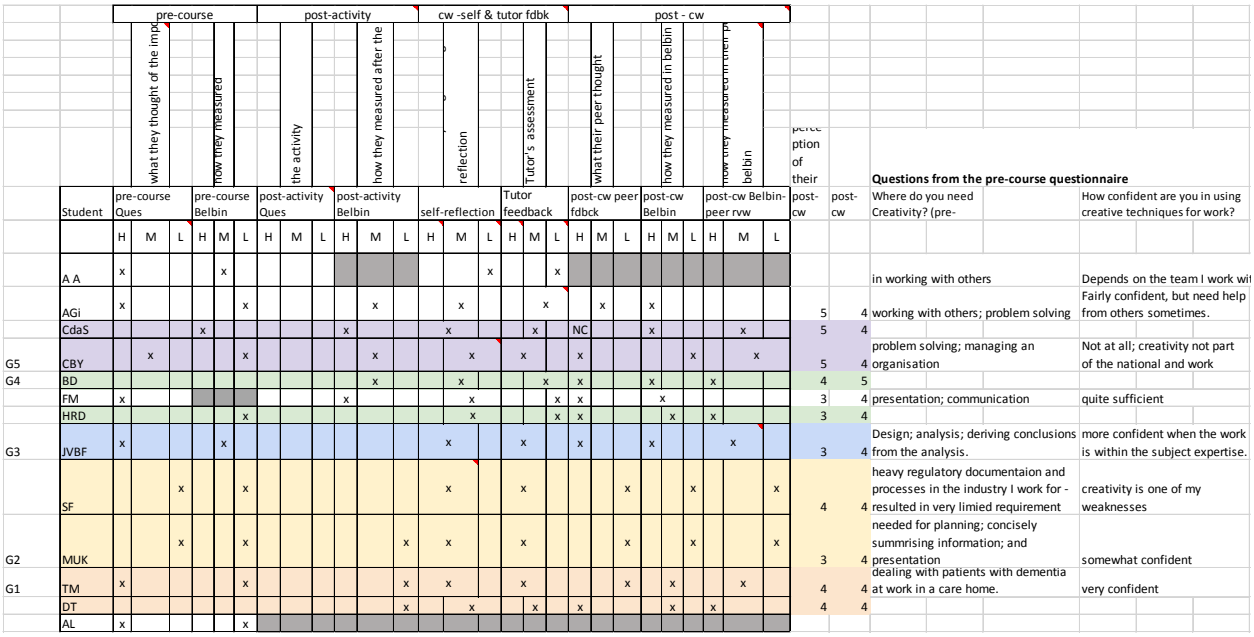
We were engaged in interesting activities on this day which focused on one of the generally weakest link of engineers which is being creative and innovative. I have always been of the view that I was the least creative person but I did manage to surprise myself during the course of an activity where I was able to successfully draw the most number of shapes from a piece of a circle.

We ended the session with an interesting activity where we were provided with a fixed number of spaghetti pieces (20), some thread (3ft), some scotch tape (3ft), one marshmallow, and some rope and were given the task to build the highest possible structure utilising these resources only. We were divided into groups of three and we quickly made the decision to take a course of action. The leader of our team delegated tasks and suggested a course of action to which we readily agreed. We has started making good progress but failed to achieve a free standing structure at the end. However, it was a very interesting exercise in that the winning team made very good use of their resource namely the marshmallow as a stable support on which they had built their structure. This shows the importance of creativity and thinking outside the box to find ingenious solutions to problems.

Participant 2:

started to work on it, teammates provide a lot of ideas and support to make this happen. After this activity, I felt that creativity is the act of turning new and imaginative ideas into reality. It is essentially an ability to perceive the world in different or new way, to make connections between unrelated things and to generate solutions. From my perspective, adults tend to be more restricted with experience and knowledge, the ideas generated will be more "inside a box". While children believe everything and think everything is possible, so the ideas generated tend to be more creative than adults. Many jobs around the world require creative thinking nowadays, including positions in business and science because creativity is used to generate or recognize ideas, alternatives or possibilities that may be useful in solving problems,

Figure 3: Self-reflection excerpts from two participants on the usefulness of the creativity session



		pre-course						post-activity						cw -self & tor fdbk						post - cw											
		what they thought of the impc			how they measured			the activity			how they measured after the			reflection			Tutor's assessment			what their peer thought			how they measured in belbin			how they measured in their pi			perce ption of their	
	Student	pre-course Ques			pre-course Belbin			post-activity Ques			post-activity Belbin			self-reflection			Tutor feedback			post-cw peer fdbck			post-cw Belbin			post-cw Belbin-peer rvw			post-cw	post-cw	Questions from the pre-course questionnaire: Where do you need Creativity? (pre-	How confident are you in using creative techniques for work?
		H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L				
	A A	x				x										x			x													
	AGi	x					x					x			x				x			x								5	4	working with others; problem solving	Fairly confident, but need help from others sometimes.
	CdaS				x						x			x			x			NC			x					x		5	4		
G5	CBY		x				x					x			x			x			x					x			x		5	4	problem solving; managing an organisation	Not at all; creativity not part of the national and work
G4	BD											x			x				x					x			x			4	5		
	FM	x									x				x				x					x						3	4	presentation; communication	quite sufficient
	HRD						x								x				x						x			x			3	4		
G3	JVBF	x				x								x			x			x				x				x			3	4	Design; analysis; deriving conclusions from the analysis.	more confident when the work is within the subject expertise.
	SF			x			x							x			x				x			x					x		4	4	heavy regulatory documentaion and processes in the industry I work for - resulted in very limied requirement	creativity is one of my weaknesses
G2	MUK			x			x						x	x			x				x			x					x		3	4	needed for planning; concisely summrising information; and presentation	somewhat confident
G1	TM	x					x						x	x			x				x			x				x			4	4	dealing with patients with dementia at work in a care home.	very confident
	DT												x		x			x		x				x			x				4	4		
	AL	x					x																										

Figure 4: A snapshot of the various data collection points through the course

RQ4: *What assessment methodologies could be effective in elucidating the students' perceptions?*

Figure 4 shows a snapshot of the types of data collected through the course, along with their chronological order. It is very important to achieve a good balance between collecting data frequently enough to be able to derive useful information and not overdoing it to the point of losing the buy-in from the stakeholders (i.e., the students and instructors). Therefore, we tried to time our data collection with those activities for which the students may want to get feedback related to their participation. Table 1 provides details on the data collected, along with the approximate time taken to fill in the questionnaire during each collection point over the 12-week teaching period.

Based on the pre- and post-course questionnaires and peer reviews, we believe we have more or less identified the optimum points at which to make the assessments we useed. We may have to rethink the type and number of questions, so as to enable a more complete picture of the students' experience and perceptions, as noted under RQ2. We agree that the questionnaires, Belbin tests, self-reflections, and peer reviews have certainly helped capture these learning moments. So, we believe, managing the points at which these assessments are carried out is also very important in helping them to assimilate/consolidate this learning process.

Table 1: Details of data collection through the 12-week course

Type of instrument	*Number of tick box type questions*	*Number of narrative type questions*	*Significance of the sampling time*	*Average time taken for completion*
Pre-course questionnaire	3	8	Pre-course: to assess their initial knowledge and perception	15 minutes
Pre-course Belbin test	N/A	N/A	Pre-course: to assess their personality profiling-to identify their preferred, manageable and least preferred roles	20 minutes
Post-activity questionnaire	15	1	To assess their perception of level of various skills used in the activity	15 minutes
Post-activity Belbin test	N/A	N/A	To capture any change in their most preferred/manageable/least preferred roles after the learning sessions and the activity	18 minutes
Coursework: Self-reflection	N/A	Reflective writing (up to 15 pages)	Final course assessment: To capture their leadership journey through the course.	15 days
Post-coursework peer feedback	2	6	Peer review: to capture peer feedback and the ability to give constructive feedback.	10 minutes
Post-coursework Belbin test	N/A	N/A	To capture any change in their most preferred/manageable/least preferred roles at the end of the course	15 minutes
Post-activity Belbin test (peer review)	N/A	N/A	To capture the peer's perception of the participants' most preferred/manageable/least preferred roles at the end of the course	18 minutes

Limitations and Future Work

The clearest limitation of this work is the small sample size. This could not be avoided, as we had to rely on the number of students enrolled in the four MSc programs in the Electronics and Electrical Engineering Department at University X. As student numbers are expected to increase in the next academic year, we hope to have a bigger sample size to work with in the future and will continue to grow our dataset. We are building a case for this module for students in the engineering and related programs at University X. If the pilot study proves successful in terms of increased demonstrable creativity skills, we may be able to extend the module to other engineering and computing science related MSc programs.

The lack of a complete dataset for each student (i.e., not all students completed all instruments) was another limitation of this study. The data were collected at specific weeks of the teaching semester, mostly before and after an activity. This meant that if a student was absent for that

particular class/activity, then his/her dataset was incomplete. In our future work, we will explore alternative ways of collecting data from students when they miss a data collection activity.

We also faced some challenges associated with asking people questions about creativity when they have not studied it formally (e.g., how is creativity defined?). For example, Group 2 consistently rated their creative skills to be somewhat low to medium, although there was evident progress in their creative ability (post-activity, post-creativity session, post-reflection), which was captured in the peer evaluations, Belbin tests, and instructor evaluations as medium-high. It seems that when some students refer to their lack of creative ability, they are referring to only the 'unstructured' type of creativity, a bias often found in today's society due to inaccurate representations of creativity [32]. A study by Kazerounian and Foley [29] concluded that, across fields, engineering has the most room for improvement in supporting creative skill development; in engineering, the word 'creativity' may evoke discomfort, because it seems subjective and ambiguous [30]. This has helped us to rethink the design of our questionnaires to enable us to capture the most appropriate data. In fact, based on this experience, we have already redesigned our pre-course questionnaire for this semester.

The students' original perceptions of creativity almost certainly influenced their answers, which may be another limitation in this study (e.g., if the students thought of creativity as only structured or unstructured thinking). This issue is supported by the study by [30], which notes: "While some engineers believe they are not creative people [29], this belief does not mean that they cannot be taught to act creatively [31]. Creativity is not an attribute or ability that one either has or does not have [32]; rather, all individuals are capable of exhibiting it in different ways, at different levels, and in differing times and circumstances [33-36]. Students' creative skills can be developed and fostered, just as practice in any specialized domain can lead to improvements in skills [37]. A university course can improve students' creative skills by aligning course content, instruction, assessments, and the environment towards creativity-focused learning goals". This has shown us the need to rethink the design of assessment methodologies and questions to help give the students an unambiguous picture of what we are asking for and to extract the correct information.

Implications and Conclusions

The implications of this exploratory study for engineering educators are two-fold: first, our work here suggests that students' perceptions of creativity can be influenced by creativity instruction, although considerable additional work will be needed to determine which instructional methods are the most effective and practical. This small exploratory study utilized fairly typical creativity lecture topics and exercises, which have the benefit of being easily accessible; but many others remain, and these should be considered as well. Our work also suggests that the definition of creativity may be a significant factor in helping engineering students understand and appreciate the importance of creativity in their leadership development. If they see creativity as a 'special topic' that is only relevant in other disciplines (e.g., the arts and humanities) or specific industries (e.g., design), or they perceive creativity to be limited to a particular type of thinking (e.g., divergent thinking), then convincing them to 'take creativity seriously' will be an uphill battle. Fortunately, the rigorous study of creativity in engineering education is becoming more prevalent [38-39], and those results can be leveraged to show engineering students the relevance of creativity in their own studies and leadership development.

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