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TRAINING THE PARTICIPATORY RENASSAINCE MAN: PAST CREATIVE EXPERIENCES AND COLLABORATIVE DESIGN

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ABSTRACT

Students are frequently trained in a variety of methodologies to assist them in being more creative in the collaborative environment. Some of the training and methods work well, while others have issues. A collaborative stimulation approach is taken to extend creative cognition to collaborative creativity, providing new insights into design methodologies and training. An experiment using retrospective protocol analysis, originally conducted to identify the various types of collaborative stimulation, revealed how diversity of past creative experiences was correlated with collaborative stimulation. This finding aligns with previous research. Unfortunately, many current engineering design teaching programs do not adequately provide opportunities for diverse creative experiences. As this study and other research has found, there is a need to create courses in engineering design programs which encourage participation in diverse creative activities.

INTRODUCTION

Leonardo da Vinci, Galileo, and Michelangelo are known as paragons of the Renaissance man, an individual skilled in many creative pursuits. However, the classical view of the creative genius, working alone on his endeavors, no longer applies. The modern world requires a collaborative approach, in order to be successful in today's complex society [1].

Many tools have been taught to designers, to assist them in being more creative through collaboration. Perhaps the most widely taught and most well known is brainstorming, where individuals generate as many ideas as possible in a short time while suspending judgment to encourage idea generation [2]. More recently, an electronic version of brainstorming has been developed with the advantages of reducing production blocking and participants do not have to be co-located [3]. The 6-3-5 Method, similar to brainstorming, is another popular idea generation technique [4] where six participants generate three ideas on a paper, which is passed to the other participants five times. During each pass, the participants take the ideas they have been given, and develop the concepts further. In addition to electronic brainstorming, there are also many examples of technology being developed to aid in collaboration. In particular, there has been a focus on using electronic devices like tablets, PDA's [5], tabletop screens, wall projections [5,6] and Smart Boards [7] to share information.

In addition to the many methods referenced in research literature, there are a number of popular books on various collaborative and creative methodologies, which are often used as text in classes on creative ideation. They share methods like mind mapping [8], fishbone diagrams, shared design notebooks [9] and many more. Classes teaching students to be creative have been found to both raise creativity test scores [10,11] and also improve the novelty and elegance of engineering designs [12].

The fundamental issue with the various methods taught is that only a handful are based on research findings, especially in popular creativity books. Inventing a method without basing it on research can have adverse effects, as is most evident in one of the most widely taught methods, brainstorming. Studies have found groups participating in brainstorming generate a lower quantity and quality of ideas than if those same individuals worked alone [13,14]. However, more recent studies show brainstorming does have stimulating effects [15,16]. Unfortunately, these effects are usually overruled by social inhibitions and procedural issues [13]. More effective training and methods can be developed when they are established on appropriate research insights, as can be observed in the C-sketch method [17]. The C-sketch method is a modification of the 6-3-5 method, where designers communicate through sketches and has been found to be effective.

Work in creative cognition, established by the Geneplore model [18], has provided new insights into design work. For example, it has revealed more ambiguous and less mature concepts tend to provide the best stimulation [19]. It is believed extending a creative cognition approach to collaborative creativity will provide opportunities for insights on collaborative training and methods.

Creative cognition explores cognitive processes of each designer [18,20], but does not explore the influence of collaborative interactions. On the other hand, collaborative creativity examines team interactions, but treats individuals as "black boxes", not investigating individual cognitive processes [21–23]. While there have been several approaches in merging these two areas, they have not fully extended creative cognition to collaboration. Shalley and Perry-Smith [24], who explore team creative cognition and how individual creative cognition is infused into it, treat individual creative cognition abstractly by not exploring the individual cognitive processes. Similarly, Stempfle and Badke-Schaub [25], who take a cognitive approach to the engineering design process, break down thinking operations into categories but not individual cognitive processes. On the opposite side, Nijstad and Stroebe [26] provide a detailed exploration of collaboration's influence on memory retrieval, but not other cognitive processes relevant to design. Therefore, there is a need for a new approach, which extends creative cognition to collaboration, which may provide new insights into education.

COLLABORATIVE STIMULATION APPROACH

The collaborative stimulation approach extends the generate-stimulate-produce (GSP) model of creative cognition to collaboration. The GSP model states design operations generate design entities which stimulate cognitive processes, which produce design operations. This cycle continues until a final concept is reached [19]. The collaborative stimulation approach proposes the cognitive-collaborative-stimulation (CCS) model. The core concept the CCS model proposes is that interactions take place through design entities (figure 1).

Cognitive processes are collaboratively stimulated through shared design entities and questions asked by collaborators regarding those design entities. There have been four types of collaborative stimulation identified [27]:

- *Prompting*: a design entity developed by the collaborator stimulates memories in the designer
- *Seeding*: a design entity from a collaborator is infused into the designer's working memory
- *Correcting*: the designer is asked a question or challenged by a collaborator, and then alters the design entity to resolve the raised issue.

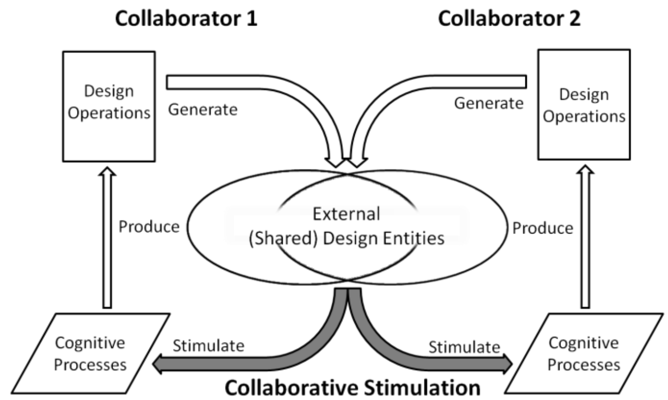

Figure 1:CCS Model

- *Clarifying*: a designer senses a collaborator does not understand a design entity or idea and attempts to clarify which leads to further development of the concept.

The first two types of collaborative stimulation are inspired by the design entities the collaborator produces, and the last two are inspired by the collaborator asking a question. More collaborative stimulation occurring in a design process is better, as it is stimulation which drives cognitive processes to produce new concepts. Without any stimulation, it would be as if the designers were working alone. Collaborative stimulation provides a unique lens to examine how the past creative experiences of students influence their collaborative abilities

EXPERIMENTAL OBSERVATIONS: DESIGN EXERCISE

In order to verify if collaborative stimulation would occur, an experiment was set up, where five teams of two students would collaborate on a design problem. But, beyond just identifying the existence of collaborative stimulation, the experiment has strong relevance to design education regarding past creative experiences of the students.

Experimental Design

The experiment was designed to observe and measure the relationships between collaborative stimulation and cognitive processes.

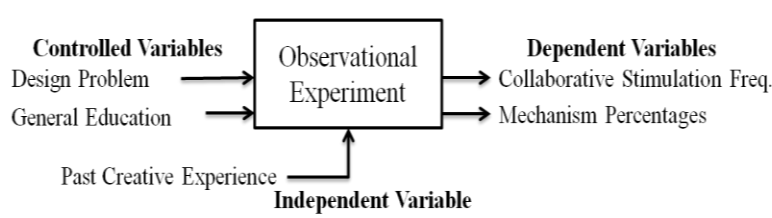

Figure 2: Experimental Design

Control Variables

The control variables in this experiment design were the design problem and general education of the subjects. The design problem given was to develop a device to securely store skateboards (see full problem in appendix). The subjects were all upper level mechanical engineering majors and had exposure to design theory and methodology.

Independent Variable: Measured by the BICB

The independent variable was the past creative experience of each individual. Initially, past creative experience was only tracked to provide additional baseline data. However, implications for education were found when analyzing how the independent variable correlated to the dependent variables.

To determine their past creative experiences, the students were given the Biographical Inventory of Creative Behaviors (BICB) evaluation. The BICB is an inventory of various creative activities on which an individual can score anywhere from zero to thirty-four. There are multiple other tests to measure past creative experiences, such as the Creative Achievement Questionnaire [28] (CAQ) and the Creative Behavior Inventory [29] (CBI). However, the BICB was chosen as it was found to be the quickest of the three tests but still had comparable accuracy [30]. It has also been used in several other studies [31,32]. The main disadvantage to the BICB is that while it measures the number of various activities in which the individual has participated, it does not measure the frequency of those activities. As this study was only interested in recent creative behaviors, the students were only asked to include the creative behavior in the inventory if they had done so in the past twelve months. A copy of the BICB is given in the appendix.

Dependent Variables: Measured by Retrospective Protocol Analysis

The dependent variables were related to collaborative stimulation. While a multitude of results on collaborative stimulation were measured, relevant to this paper were the frequency of collaborative stimulation and the percentages of each mechanism (design entity or question inspired) through which each individual was stimulated.

Retrospective protocol analysis was used to observe the occurrences of collaborative stimulation. The collaborators worked in a natural environment while being videotaped. Following the collaboration, the individuals watched the tape and verbalized what they were thinking at the time. Another method, concurrent protocol analysis, was tested by the authors, but retrospective protocol analysis was found to be more effective [33]. Also, as long as the design session did not last more than 30 minutes, subjects reported they were able to remember 90% or greater of the thoughts which occurred [33].

Methods

Subjects

The subjects consisted of senior and masters students in mechanical engineering from the University of Southern California. All students were in engineering design classes which included group projects; therefore they were familiar with basic engineering design methodologies and had participated in collaborative design. The study was reviewed and approved by the institutional review board.

Procedure

Before coming to the study, the students took the BICB test online, in order to cut down on study time. When arriving at the study, students were first given individual training in verbalizing their thoughts. The training started with verbalizing a simple process, and increased in difficulty until the student was verbalizing their performance on a practice design problem. After training, the students were put in groups of two and provided with pencil, paper, and the design problem statement (given in the appendix) which asked them to develop a device that would securely store skateboards which would prevent students from stacking them up against classroom walls. The students were videoed as they collaboratively worked through the design problem. Immediately after the students completed the design problem, they watched the video of their collaborative work and were asked to retrospectively verbalize their thoughts from the design process. Their verbalizations were recorded in an audio file for later transcription. The experimental procedure is summarized in figure 3.

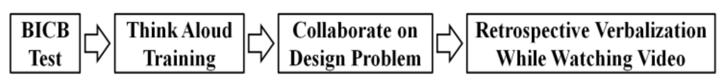

Figure 3: Detailed Experimental Process

Protocol Analysis

The data from each experiment consisted of two audio files and a video file, which were transcribed. A coding scheme was applied to the transcripts to identifying cognitive processes and collaborative stimulation.

The generative cognitive processes were identified before collaborative stimulation. Generative cognitive processes consisted of memory retrieval, association, and transformation. The cognitive processes were then examined to see how they came about, and if they could be attributed to a collaborative stimulation. Collaborative stimulation consisted of prompting, seeding, correcting and clarifying. The coding scheme can be summarized by table 1. Note in the coding scheme DE stands for design entity, or the basic concept on which a cognitive process operates.

Name	Coding Notation	Coding Example
Cognitive Processes (CP)		
Memory Retrieval (MR)	MR(DE(X))	I think a solution would be X
Transformation (TF)	TF(DE(X), expanded)	If X was expanded
Association (AS)	AS(DE(X), DE(Y))	Idea X is like Idea Y
Collaborative Stimulation		
Prompting (Pr)	Pr(DE(X),MR(Y))	X reminded me of Y
Seeding (Se)	Se(DE(X),CP(DE(X));DE(X*))	X, your idea can be altered to create X*
Correcting (Co)	Co(DE(X), CP(S(X), DE(X*)))	X can be modified to X*, which solves the issue you brought up
Clarifying (Cl)	Cl(DE(X), CP(X);DE(X*))	this is how X works but wait, it can be changed to X*

Table 1: Coding scheme for the CCS model

The coding scheme was checked by conducting inter-coder reliability which gave a proportional coefficient of 0.86 and kappa of 0.53 for collaborative stimulation, and a proportional coefficient of 0.87 and kappa of 0.68 for generative cognitive processes.

RESULTS

Observations relevant to design education were made when comparing the BICB scores, or the variety of past creative activity, to the collaborative stimulation results. The average BICB score of the participants was 8.90 with a standard deviation of 5.84.

The frequency of collaborative stimulation was the first result compared to the BICB scores. The average time between two consecutive collaborative stimulations was 1 minute and 7 seconds, with a standard deviation of 35 seconds. This created an average frequency of 0.89 collaborative stimulations per minute.

On the team level the team average BICB score and frequency of collaborative stimulation had a correlation of 0.94 (figure 4).

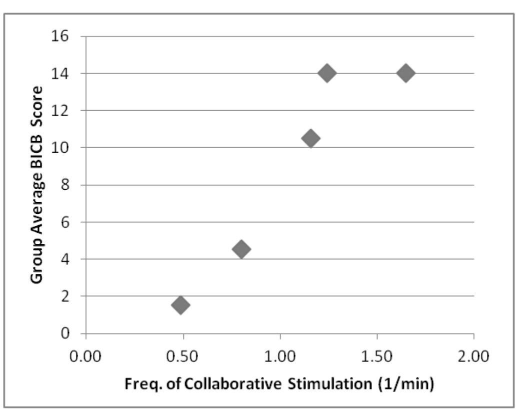

Figure 4: Group Average Results

Similar results were also observed on the individual level. Each individual's BICB and frequency of collaborative stimulation had a correlation of 0.89 (figure 5).

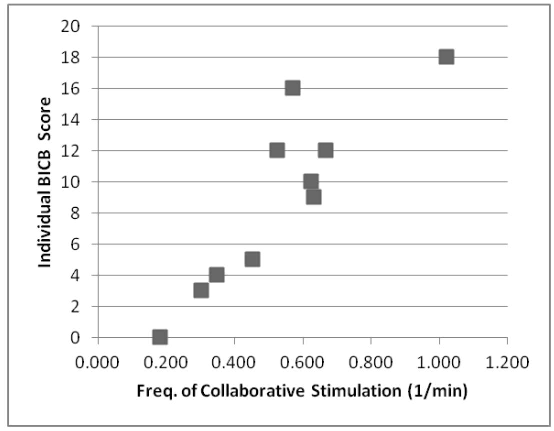

Figure 5: Individual Results

As mentioned earlier, collaborative stimulation occurs because of shared design entities or questions. In each individual the percentage of stimulation by a design entity (prompting and seeding) versus a question (clarifying and correcting) was an average of 55% with a standard deviation of 26%. This ratio, or the percent of time a student was stimulated by a design entity was compared to each designer's BICB score and a correlation of 0.31 was found (figure 6).

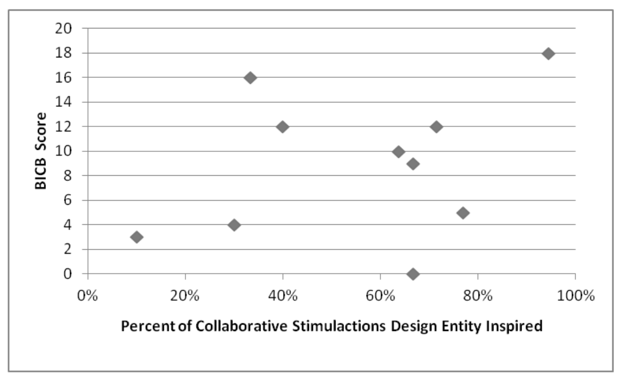

Figure 6: Percent Design Entity Inspired

DISCUSSION

The results found that high BICB scores (a broad variety of past creative experiences) had a strong positive correlation with stimulation frequency. While correlation is not necessarily causation, this result was expected as research has revealed individuals with diverse, creative backgrounds are more effective in collaboration [22,24].

A weak positive correlation was found between BICB scores and the percent of time a student was stimulated by the design entities their collaborator invented. While a positive correlation should be expected, it was weaker than the investigators would have predicted when comparing the result to past research.

Others have found concepts produced by collaborators will stimulate new ideas [26]. A team's diversity in background results in one team member being stimulated differently by a concept than their collaborator would [22]. This would lead to an entirely new set of ideas produced through collaborative stimulation. The same theory has been proposed from a network perspective, that a team's creative potential comes from the member's diverse connections outside the team [24]. Therefore, this research would imply that as diversity of past creative experience increases (higher BICB scores), there should be a shift to more design entity inspired stimulation.

However, the results seem to suggest it is not only design entity inspired stimulation which is correlated with past creative experiences. Past creative experiences appear to increase the frequency of *both question* and *design entity* inspired collaborative stimulation, as there is an increased frequency of collaborative stimulation but only a weak increase in the percentage of design entity inspired stimulation correlated with BICB scores. Work by the authors has found question inspired collaborative stimulation to be highly impactful, but the influence of questioning on collaboration is under explored [27]. Studies from interpersonal congruence provide theories which may explain why both question and design entity inspired stimulation increased about equally.

Work in the area of interpersonal congruence, shows diversity encourages creative collaboration as long as interpersonal congruence (how well group members can understand each other's perspectives) is high [34]. Since the engineering students had similar educational backgrounds and were working on technical projects in their area of expertise, it was expected interpersonal congruence would be high. This would result in greater creativity (or more stimulation) for teams with greater diversity in creative experiences (and also higher BICB scores). Another consideration is that team members with diverse creative backgrounds may actually have the ability to have higher interpersonal congruence levels. A diverse creative background provides more areas for team members to relate to their collaborator's perspective, whether it is a design entity being proposed or a question being asked, which would lead to greater collaborative stimulation.

From the current findings as well as previous research, it is evident that diverse past creative experiences increase the ability to be stimulated within a group, regardless of the type of collaborative stimulation.

Unfortunately, often times current engineering design education does not provide or encourage rich and diverse creative experiences. While there are many design classes which having a component training engineers in the creative thinking process [12,35], there is a lack of classes encouraging students to explore diverse areas of creative activity [36]. If a student participated in only the activities most engineering design programs provide and encourage, their creative activity would only be represented as a seven or eight on the BICB. But those who were stimulated most frequently had scores of more than double this number. From a collaborative stimulation perspective, there is a dire need for engineering design education to provide a greater diversity of creative experiences. Other research has identified the same need.

One of the first lessons others have noted is that educating engineering students to be creative, especially in areas of psychology and the studio arts, broadens the student's perspectives [36]. Focusing on only a single area in education can lead to low interpersonal congruence, which results in poor team performance [34]. While expertise in their area of training is a requirement, focusing on just a single expertise can lead to arrogance and the false belief that a purely engineering perspective is most important. It is helpful to accompany training in diverse creative experiences by having engineering students work on multi-disciplinary teams, which includes students from outside the field of engineering [36]. This can assist in understanding the value of perspectives from different disciplines.

Incorporating diverse creative experiences into engineering education is also advantageous, as it would teach students in new ways that would pertain to their specific learning style. Many engineering students learn well through visual, sensing and active learning styles, while traditional engineering education caters to auditory, abstract and passive learners [37]. Combining current engineer education with opportunities to participate in various creative activities, like the studio arts, would provide education which teaches both types of students in the ways they learn best.

The need to modify engineering design education by incorporating diverse creative experiences can be summed up by Stouffer, Russell, and Oliva. In exploring the future of engineering education, they identify the need for it to *"usher in a new generation of adaptable, flexible, well-rounded, and innovative professionals* [35]*."*

However, training engineering students in a diverse set of creative experiences is not without its challenges. While it would be advantageous to design new or modify current classes to incorporate training in diverse creative experiences, often there is a lack of resources. Finding the right faculty to design and teach such a course is a challenge the authors have found from personal experience. Additionally, getting current faculty within the engineering department to accept the new courses can be even more challenging, as student's course loads are already full of technical courses and many faculty do not see the value in exercises of creativity for engineers. Solving this challenge requires persistence and the education of faculty to the importance of creative diversity.

Even when such classes are successfully created, a key challenge will be creating long lasting change in the students. Current studies caution courses on creativity may only produce short term semester results, and not the long lasting results in the student's career [12]. To accomplish the goal of training students in diverse creative activities, there is a need to make broad participation in the arts a habit.

Despite these challenges, there are classes on creativity which focus on giving students diverse creative experiences. In the Marshall School of Business, at the University of Southern California, a course "Strategies for Fostering Creativity in Business" exposes students to a diverse set of creativity related experiences including improvisation, Tai-Chi, painting, yoga, and trapeze. To complete the course, each student must also undertake a semester project, where they learn a new creative skill they do not have past experience. Having students pursue a new creative activity in an area of their choosing increases the opportunity for long time participation in diverse creative experiences. There is a need for engineering design to follow suit.

SUMMARY AND CONCLUSION

In summary, a collaborative stimulation approach was taken to extend creative cognition to collaborative creativity, providing new insights into design methodologies and training. The CCS model, based on creative cognition, proposed that interactions take place through design entities by the concepts themselves and questions about the concepts. These interactions lead to collaborative stimulation, of which there are four types: the design entity inspired *prompting* and *seeding*, and the question inspired *clarifying* and *correcting*. An experiment using retrospective protocol analysis was conducted to identify the various types of collaborative stimulation. However, this experiment also revealed additional findings on how diversity of past creative experiences was correlated with collaborative stimulation.

Taking a collaborative stimulation approach revealed diverse creative experiences (or high BICB scores) is correlated with being frequently collaboratively stimulated, in both the areas of design entity inspired and question inspired stimulation. These findings were also supported by previous research. Therefore, it is important for engineering students to be encouraged to pursue diverse creative experiences outside of their area of expertise. Unfortunately, many current engineering design programs do not adequately provide these opportunities. There is a need to add opportunities to become involved in diverse creative activities to current programs. However, this need is met with the challenges of finding the right educators, getting general faculty acceptance, and creating long lasting changes. There are some courses which already accomplish this; however, there is a need to create additional courses like this in engineering design programs across the nation, to educate the next generation of engineer.

While the Renaissance man, skilled in engineering, sciences, and the arts, working alone is not effective in today's complex society, there is still a necessity for a diverse skill set. There is a need for a new breed of participatory Renaissance man, an engineer who is skilled in their specialty, but also has exposure to a broad variety of creative activities in order to be an effective collaborator. As design educators, we have the distinguished opportunity of training future engineers to be participatory Renaissance men and women.

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APPENDIX

Design problem statement: Skateboards are one of the most popular forms of transportation at USC. Unfortunately though, when students come to class, the only current method for skateboard storage is to line them up against the wall. However, this has the potential to mark up the wall and skateboards can fall over in a domino effect if one is accidently bumped. A larger problem is that in large lecture halls, where there are often 2-3 rows of skateboards stacked up against the back wall. With so many boards, it can be hard to find yours, or even worse, it provides the opportunity for someone to steal one unnoticed. Design a device which will safely and securely hold skateboards while students are in class. This device could either be located in the hallway or outside the building, but not in the class room due to space constraints.

BICB Test: Please type a “yes” by the following items that you have participated in the past 12 months.

1. Wrote a short story	18. Invented a game
2. Wrote a novel	19. Chosen to lead
3. Organized an event	20. Made a presentation
4. Produced a script	21. Wrote a poem

5. Designed a textile
6. Decorated a room
7. Invented a product
8. Drew a cartoon
9. Started a club
10. Made a picture
11. Published an article
12. Made a sculpture
13. Criticized a scientific theory
14. Made recipes
15. Produced a short film
16. Made a webpage
17. Created a theory
22. Adapted an object
23. Published research
24. Choreographed a dance
25. Designed a garden
26. Made a photography portfolio
27. Acted
28. Gave a speech
29. Mentored others
30. Designed an experiment
31. Wrote jokes
32. Served as a leader
33. Composed music
34. Made a collage