AC 2010-1812: SYSTEMATIC IDEATION CURRICULUM EFFECTIVENESS INVESTIGATION & DEPLOYMENT TO ENHANCE DESIGN LEARNING

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Abstract

This paper presents our current research on the effectiveness of TRIZ, emphasis on sketching and technology enabled sketching in improving the ideation performance of undergraduate engineering students in classroom settings. This research also investigates the impact of TRIZ and two other conditions, emphasis on sketching and the Pulse Smartpen, for their impact on the ideation performance and provide understanding into the mechanisms by which they operate to this end. Our objective is to test our hypotheses that TRIZ, sketching, or the pulse Smartpen improve design ideation alone or in some combination. To this end, we defined experimental design and protocols to study design and ideation tools, and thereby, provide a standard way to benchmark tool effectiveness. This research work involves rigorous experimental designs to collect quantitative and qualitative data to answer the following three research questions.
1. Can TRIZ improve the ideation performance of engineering students?
2. Can sketching improve the ideation performance of engineering students?
3. Can technology enabled journaling (via Pulse Smartpen) improve the ideation performance of engineering students?
The treatment conditions are applied to classes of engineering students from different backgrounds and different institutions. Partial results are presented for this work in progress supported by NSF (0920446 and 0920707).

1 Introduction

Design learning and the related design ability have a three-pronged foundation: 1) design process knowledge, 2) design analysis knowledge, and 3) creative processing ability (ideation). Design process knowledge, in general, is taught in first year design courses, and then practiced throughout the engineering curriculum culminating in the capstone design course. During second and third year courses, the engineering curriculum focuses on analytical concepts and techniques ultimately intended to support design analysis ability. Given the overcrowded traditional engineering curriculum, it is not surprising that students do not improve their creative processing skills. The proliferation of assistive software for design has an impact on student training as well. For example, sketching was a critical skill in traditional engineering design but the practice has become less important to students as computer-aided drawing tools have become available to them.

Industrial and academic leaders long expressed concerns about the impact of traditional engineering education on the creative potential of future engineers. A lack of creativity is viewed as problematic in a rapidly changing technology-oriented world where generating new ideas is essential to survival[1,2]. Industry has also perceived new BS engineering graduates as lacking design capability or creativity, as well as an appreciation for considering alternatives. In the past several years, universities have responded to these challenges by adding more design content and introducing more open-ended design problems into their engineering curricula. Improving creativity is difficult because researchers are limited to studying the process of design ideation through observation and measurement of the external representations of artifacts talked about, written down, or sketched out. We can, however, attempt to impact the process by identifying methods and tools to improve all aspects of the design ideation process.

The authors adopt the motto by Stouffer et al [3]: "*Choosing to embrace creativity is never a zero-sum commitment that will make technical concerns secondary. Rather, creativity can be a powerful tool to enhance technical efforts to solve engineering problems of all kinds*." We hypothesize that by carefully crafting a strategic curriculum that can be seamlessly integrated to design courses, we can help enhance our students' creative processing outcomes. As part of this curriculum, we propose to integrate TRIZ (a systematic problem solving approach) and sketching, and support the ideation process with technology enabled journaling (using Pulse Smartpen). In this integration, TRIZ will provide the systematic innovative problem solving method, sketching will externalize and enhance the design ideation, and Pulse Smartpen will capture the ideation outcomes seamlessly, and might decrease the cognitive load. Below first we explain our rationale for choosing these curriculum content and technology along with relevant literature review. Then, we provide our plans for experimentation and project management.

This research work proposed in this paper involves conducting research on undergraduate engineering education, assessing student achievement, and refining learning materials and teaching strategies, and is undertaken by four faculty members with complementary expertise and students from four institutions with diverse populations.

2 Background

Creativity in engineering design is mostly predicated on (1) desire and fulfillment; (2) knowledge of objects and principles possessed or available (knowing how to obtain the needed knowledge and how to use it) that includes tacit knowledge gained in experiences, heuristics, and instinct ("gut" feeling); (3) openness (i.e., a willingness to accept criticisms and ideas from others); and (4) knowledge of process, especially design and problem solving processes [1,4,5]. While (1) and (3) are personality traits, (2) and (4) must be learned. Traditional idea generation methods such as brainstorming rely heavily on (2). Accordingly, these methods fall short when used as the main vehicle for creativity. Traditional approaches to creativity, which advocates using brainstorming, C-sketch [6], SCAMPER [7], etc., call upon designers to look inward for inspiration, and then communicate their ideas to others to create a synergetic and shared experience. ***Our research work will test the effectiveness of TRIZ and sketching supported by technology enabled journaling (Smartpen) during ideation and subsequently develop a strategic curriculum integrating these in a manner to enhance creative processing ability of our engineering students across all disciplines.***

TRIZ is a systematic approach to the generation of innovative designs to seemingly intractable problems. It was first developed in Russia by Genrich Altshuller [8] after World War II and grew in prominence there in the early sixties and seventies. TRIZ's has been used for many years in Europe and Asia and it the method's popularity continues to grow. TRIZ is based on the analysis of hundreds of thousands of patents. These original analyses articulated numerous solution patterns from diverse disciplines. The patterns and the tools are continually being updated by researchers worldwide. TRIZ has been recognized as a concept generation process that can develop clever solutions to problems by using the condensed knowledge of thousands of past inventors. It provides steps that allow design teams to avoid the “psychological inertia” that tends to draw them to common, comfortable solutions when better, non-traditional ones may exist. The TRIZ problem solving process starts with analyzing the system and resources, developing Energy-Material-Signal models, and the formulation of technical contradictions using the contradiction matrix. After this the ideal final result is defined; this is a statement that defines the desired solution for the design problem which removes the original system’s deficiencies while preserving its strengths, does not increase original system’s complexity, and does not introduce new efficiencies. The physical contradictions are formulated and the contradiction matrix provides suggestions on how other designs have solved the contradiction. The designer has to translate these suggestions to the current design problem.

The act of sketching is a both physical and mental process. A well used description of sketching is that a sketch is a designer’s ‘conversation with themselves’. What happens physically during sketching is easy to see and understand. The cognitive processes involved in sketching have been explored by many researchers in various concentration areas, including: engineering, architecture, art, education, and psychology. Much work has been done using protocol studies and the reader is referred to analysis of work on that topic by Purcell and Gero [9].

To study the sketching behavior by students during ideation, work by some students will be captured using a new technology – Pulse Smartpen. The Smartpen is an exciting new pen with simultaneous digital and audio capture capabilities. The Smartpen was introduced in June of 2008 as a tool for note taking in classes or meetings. The Livescribe website (http://www.livescribe.com/smartpen/index.html) provides excellent demonstrations and video on how the Smartpen operates. The simultaneous recording of the audio is useful in two ways: (1) it links what the student is hearing to what the student is writing or sketching; and (2) the digitized journal pages can be uploaded to a website, enabling access by approved researchers and storage. Think-aloud protocols, which are typically used for design thinking research, may not be naturally fitting to the actual design setting, and hence might introduce bias. The Smartpen is a well-fitting data collection instrument in the disguise of a designer’s pen that can minimize the bias introduced to data.

3 Research Questions

This research work involves rigorous experimental designs to collect quantitative and qualitative data to answer the following three research questions to formulate an effective curriculum for integration to design focused courses.

Research Question 1: Can TRIZ improve the ideation performance of engineering students? It is hypothesized that the training of students in the TRIZ ideation method will improve students’ ability to generate a variety of innovative concepts.

Research Question 2: Can sketching improve the ideation performance of engineering students? It is hypothesized that the requirement for sketching will stimulate the creativity of students in design ideation. Planned work involves rigorous testing in the context of engineering students doing typical design course projects.

***Research Question 3*: *Can technology enabled journaling improve the ideation performance of engineering students*?** Keeping a design journal enables a student to refer back to previous sketches and descriptions to facilitate deep processing strategies such as iteration, analogizing, and re-representation of the problem. It is hypothesized that the novelty of using the Pulse Smartpen as well as reduction in the cognitive load will engage students in the journaling process.

To analyze the impact of the study variables (and interaction effects) we started collecting data from students with an Ideation Assignment (IA). The IA requires each individual student to develop and document a number of concepts (at least 5) for their in class design task. This assignment is repeated under a number of different treatment conditions and design scenarios defined by the nature of the course in which the students are participating.

4 Research Approach

The diagram in Figure 1 shows the methodology to be followed in this research. The first step is the definition of hypotheses followed by the experimental design. The overall experimentation is distributed among the participating universities as well as the assessment of the ideas generated. ANOVA will provide the statistical information to generate the conclusions.

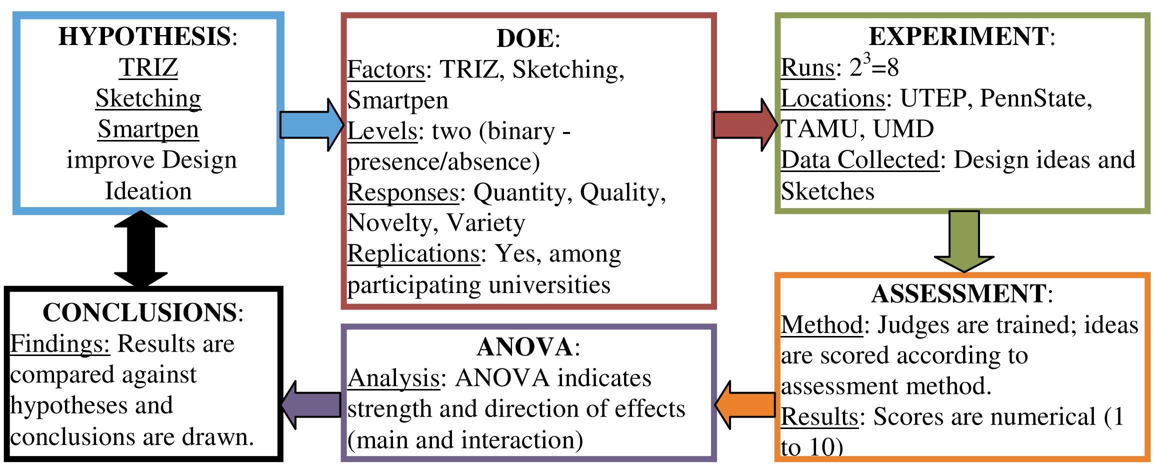

Figure 1. Methodology

5 Design of Experiments (DOE)

The DOE structure follows Montgomery's [10] approach. The subsections below explain each step in detail.

5.1 Recognition of and Statement of the Problem

Design ideation continues to be a mysterious and yet a very important part of the design process. In the past, there have been studies related to how people generate ideas, why some are more productive in idea generation than others, etc.[11,12,13,14]. However, the mystery remains because not being able to directly reach a designer's mind limits our comprehension of the process. This DOE involves rigorous experimental designs to collect quantitative and qualitative data. The objective of the experiment is to confirm our hypothesis that *TRIZ, sketching, or the Pulse Smartpen improve design ideation alone or in some combination.*

5.2 Selection of the Response Variables

There are two fundamental values used in judging the worth of a design ideation method: how effective it is in expanding the design space and how well it explores this space. Based on that, four independent effectiveness measures are proposed for this research: quantity, quality, novelty, and variety of the ideas generated[15].

5.2.1 Novelty

Novelty is a measure of how unusual an idea is as compared to other ideas. There are two approaches to measuring Novelty: a priori and posteriori. Novelty a priori requires the predefinition of what is expected to be novel before actually analyzing the ideas. The ideas generated can be analyzed based on the functions the problem requires it to fulfill. The evaluator predefines each function at different levels (e.g. high, medium and low) based on the type of the ideas expected. The ideas falling in the corresponding level for each function receives a novelty score (e.g., High-10, Medium-5, Low-1). A novelty score for each idea can be calculated by assigning weights for each function and aggregating for an overall value. Novelty a posteriori can be calculated by counting the number of occurrences for the same idea for each function. The novelty score (S) for each function's idea can be calculated using the formula:

$$S_{Novelty} = \frac{T \quad - C}{T} \times 10$$

Where:
T = total number of ideas for given function
C = number of ocurrences of a particular solution for the given function

The higher the occurrence of a particular solution, the lower the novelty score. A novelty score for the whole idea can be calculated by assigning a weight for each function and multiplying the novelty scores for each to obtain an overall novelty score. The expression for S is multiplied by 10 in order to normalize it (i.e., 0 is lowest while 10 is highest).

5.2.2 Variety

Variety measures the explored solution space during the idea generation process. The uniqueness of concepts is reflected by the variety index. When calculating the variety index, concepts are rearranged into a hierarchy structure. Within a function category, all the concepts are further differentiated by their working principles. The number of working principles in a function category greatly affects the value of the relative variety index. Similar to the novelty index, the higher the value of the variety index is, the better it is. A set of ideas is analyzed for each of its functions to generate a "genealogy tree" that has at its top the function to solve, then at the next level, the physical principles (or physical effects) used. For each physical principal one or more working principles are identified, and for each working principle one or more embodiments can exist. The tree is used to calculate a Variety score for the set of ideas. More branches at higher levels of the tree means a higher variety score, while more branches at lower levels of the tree means lower variety score. Figure 2 depicts a set of ideas in two genealogy trees (one for each function).

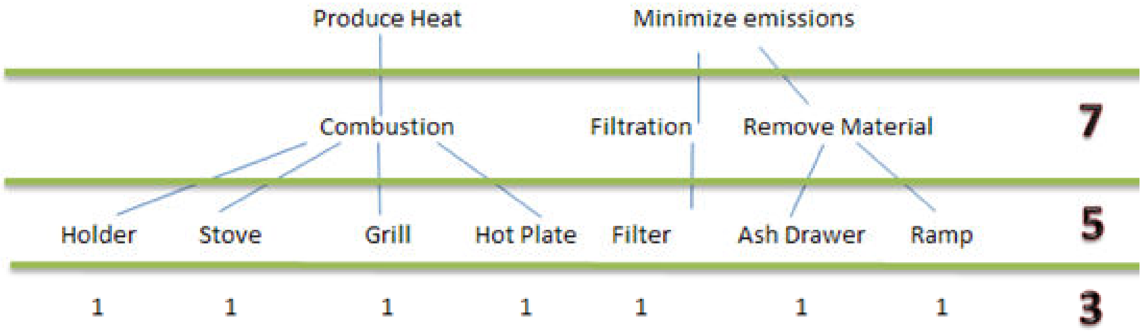

Figure 2. Sample Genealogy Trees

The following formula calculates a score for variety:

$$\text{Variety Score for each function: } M_{Variety} = 10 \times \sum_{k=1}^{l} \frac{S_k b_k}{n}$$

Where:
l = number of levels of abstraction used to describe ideas (i.e. physical principle, working priciple, embodiment)
S_k = rating score for level k
b_k = number of branches at level k where each branch represents a different component type
n = number of total ideas generated in the set

Shah et al.[15] suggest using 10, 6, 3 and 1 as S_k for the four levels structure from top. However, Nelson et al.[16] considered setting S_k to be 10, 5, 2 and 1 for a four levels structure can provide a more differentiable result. The formula for Variety is multiplied by 10 for normalization purposes. The overall variety score is calculated by assigning weights for each function and multiplying the variety score to obtain an overall score for the set of ideas (i.e. each idea in the set has the same variety score).

5.2.3 Quantity

Quantity is the total number of ideas generated in a specified amount of time. The premise of this measure is that generating more ideas increases the chance of better ideas. This score is directly assigned by counting the number of ideas each subject records during an experiment.

5.2.4 Quality

Quality is the measure of the feasibility of an idea and how close it comes to meeting the design specifications. The quality of an idea is an independent measure since it can be based on a physical property or ratio related to the performance of the artifact (e.g., time, weight, energy). At the conceptual stage, quality can usually be adequately estimated even though there is not enough quantitative information to do a formal analysis. At the embodiment stage, it may be possible to do some quantitative analysis perhaps in ratios of expected attribute values to the desired ones. These could be computed to quantify quality. Table 1 shows an example for 3 quality characteristics of an idea (notice that functions are not evaluated but characteristics). Each characteristic (cost, emission and operation) can be fulfilled at 3 levels, each obtaining a different score. The total quality score for an idea is calculated multiplying each characteristic score by its assigned weight (0.3, 0.3 and 0.4 in the example)

Table 1. Quality Score Table

		Score		
Wt		3	5	7
0.4	Cost	Too costly, only very few can have it	Approx. 50% of household can afford it	Most household will be able to afford it
0.3	Emissions	Serious healthy proles, when using it	Mild but perssistent healt issues appear	People can work continuosly without affect their health or their family
0.3	Operation	Very difficult to opearate, requires too much attention	People are divided, some says is ok, some don't like it, requires some supervision	very easy, doesn't require much to get used to it

The feasibility and/or desired characteristics of each design can be evaluated qualitatively or quantitatively and normalized on a scale of 1 – 10 to get the quality rating $M_{Quality}$.

$$M_{Quality} = \sum_{i=1}^{c} w_i S_i$$

where $M_{Quality}$ is the overall score for the idea, S_i is the score for the i^{th} quality characteristic and w is the corresponding weight. The total number of quality characteristics is c.

5.3 Choice of Factors, Levels and Ranges

Factors are classified as design factors (variables of interest) and nuisance factors, variables that need to be blocked or ignored. Once the design factors are selected a range or levels (i.e., treatments) will be set. The hypotheses outlined yield three variables of interest; TRIZ, Smartpen and sketching. These main variables are the design factors with potential influence on the performance of the design process. Table 2 summarizes the factors and their levels. Besides the variables of interest (i.e., design factors), other variables exist that need to be identified some of which may need to be addressed (i.e., controlled or blocked) and others will be ignored. We summarize these below.

The design problem to be used (the ideation task) opens a whole set of variables (domains involved, complexity level, known/unknown variables, level of detail in the solution requested, etc.). Accordingly, we need to control for it. Study subjects, engineering students, bring a complete set of variables such as knowledge background, domain knowledge, design experience, personality, technical skills, motivation, GPA, etc. We plan to control (and document) some of these, especially the most relevant ones (e.g., personality and general background through questionnaires) with tests like IPIP neo based and Big-Five. Inherent divergent thinking ability (a measure of creative processing) of students will be measured using unusual uses test (a sub-test of Torrance test of creativity)[11,12]. This test measures the originality, flexibility and fluency of idea generation. Originality evaluates participants' creativity against a list of common responses to the same problem. Creativity is often understood to provide answers that are outside common social experience. Flexibility measures the ability to develop a wide range of different answers. Creativity is expected to encourage answers that will go beyond slight differences and produce responses that are quite distinct from those previously developed. Finally, fluency is the ability to develop a large number of relevant responses to a given stimulus.

Table 2. Factors and Levels

	TRIZ	**Sketching**	**Smart Pen**
Level A	Training	Emphasis	Pen + Use Training
Level B	No Training	No Emphasis	No Pen or Training

5.4 Choice of Experimental Design

Since there is an interest in the main effects and interactions, a full-factorial experiment was chosen; the corresponding runs are shown in Table 3. Sample size is important in any experiment or study. In order to determine an accurate sample size, the problem must be carefully defined and randomized correctly in order to assure a size that meet the goals of the experiment. The sample size must be big enough in order to be scientifically significant but not too big where some of the effects are of little scientific significance. In other words, under-sized studies do not produce useful results, and oversize studies produce results that are not necessary. In this experiment, the Power Approach will be taken in order to determine the correct sample size. Using the Power approach the confidence interval is determined by obtaining a desired width of the experiment. In order to determine a correct sample size that satisfies the goals of the experiment certain parameters must be first established such as, a hypothesis test, significance level, and an effective size must be specified. These values can be obtained by using historical data or conducting a pilot study. A pilot study can also provide us with the right variance.

Table 3. Full Factorial Arrangement 2^3

Run	TRIZ (training)	Smartpen (training)	Sketching (emphasis)
1	0*	0	0
2	1*	0	0
3	0	1	0
4	0	0	1
5	1	1	0
6	1	0	0
7	0	1	1
8	1	1	1

*: 1 shows the variable is present, and 0 shows it is not.

There are certain limitations of the planned experiments, one being the class size. Experiments will be conducted primarily in engineering classes which are limited to a maximum number of students. Sample size is only one characteristic of several determinants, therefore it can be held constant and the effective size can be studied to determine whether the experiment is under-powered or over-powered. In turn by knowing if the experiment is under-powered or over-powered, recommendations can be made in order to increase or decrease the variance of the experiment by changing other factors, for example, these factors can be held constant.

5.5 Performing the Experiment

The treatment conditions will be applied to classes of engineering students from different backgrounds and different institutions. The conditions will also be applied to different types of designing tasks. The courses listed in Table 4 are within the investigators' teaching portfolios and will be used to draw student/subjects for the controlled experiments. These courses are ideal given the fact they have inherent design focus, and thus design assignments are natural components of the course content. These courses include first-year students through senior students, and some graduate students. The courses are from a variety of related engineering curricula including mechanical engineering, industrial engineering, business and information science and technology (IST).

Table 4. Ideation Assignment Data Collection Conditions

University	Subject Courses	Exp Runs	Outcome	Analysis
University of Texas at El Paso	MECH 4466 (25 students) MECH 4364 (25 students)	Runs will be randomly assigned including repeated measures	Quality, Quantity, Novelty, Variety (same outcomes used)	MANOVA (same analysis used)
Penn State	EDSGN 100 (4 sections, ~120 students) QMM 492 (27 students)			
Texas A&M	MEEN 601 (20-35 students)			
University of Maryland	ENME600 (15-20 students)			

Table 4 also outlines the specific numbers of students in each treatment conditions and identifies the chief analytical method for each set of results. The primary method will be a repeated measures factorial design augmented by multiple regression analyses to determine the degree of variance accounted for in each dependent variable conditions. Repeated measures MANOVA is used when the same subject takes the same tests more than once and those outcomes tests have multiple measures or more than one dependent variable.

The research questions directly identify the effect of three independent variables in this study on improving design ideation: (1) TRIZ training; (2) Sketching emphasis during ideation; and (3) Journaling with the Smartpen. To analyze the impact of the study variables (and interaction effects) we will collect data from students with an Ideation Assignment (IA). This assignment will require each individual student to develop and document a number of concepts (at least 5) for their in class design task. Assignment will be repeated under a number of different treatment conditions and design scenarios defined by the nature of the course in which the students are participating. Table 5 briefly describes the treatment conditions. Data collection will be done at the team level as well. The differences in the selected courses and number of students in treatment groups require slight alterations in the experimental design for each population. The chart below outlines the design used in this study from the point of view of treatment conditions (experimental treatments).

Table 5. Proposed Experimental Treatments Based on Independent Variables

	Treatment Application	Treatment Control Group
TRIZ Training	Two 50-minute TRIZ lectures will be given • Training materials on TRIZ and the specialized inventive principles and cataloged examples (developed by Kremer under the CCLI Grant DUE 0445944). The effectiveness of these materials have been shown by others as well [2]. • The same set of study materials, examples, and will be available to students in an online module through course management software.	No TRIZ training material and software will be provided.
Sketching Emphasis	Ideation Assignment will require submission of sketches from each individual student. All other wording will be identical to the Ideation Assignment given to students without this treatment. • The Ideation Assignment will be accompanied by a two-page handout on the importance of sketching. This treatment was piloted by Grenier[17] and found to have an impact. It is important to note that this is not an treatment to alter the sketching skills of students. It is intended to encourage students to use their skills.	No sketching emphasis will be provided.
Smartpen for Journaling	Each student will receive the Pulse Smartpen and accessories to use over the period of data collection. This will be the time required for the Ideation Assignment. • The Smartpen and companion journal include a guided hands-on exercise for users that is sufficient to acquaint them with the technology. Students will be required to upload their design journal notes to the Livescribe website. This will give project personnel access to the journal material. The data will be downloaded as .pdf files and coded with a subject number.	No smart pen training and hardware will be provided.

The sequence of activities in the Ideation Assignment is as follows: First the ideation task is assigned to all students, so all can get familiar with the problem. They have 20 minutes to generate as many complete concepts as they can individually. In the second phase a treatment is given that could be one of the 8 possible runs described previously in Table 3. In phase 3, four days are provided to continue on the same problem.

5.6 Scoring of the Experimental Data

In general, the scoring of experimental data follows the next three steps, shown in Figure 3.

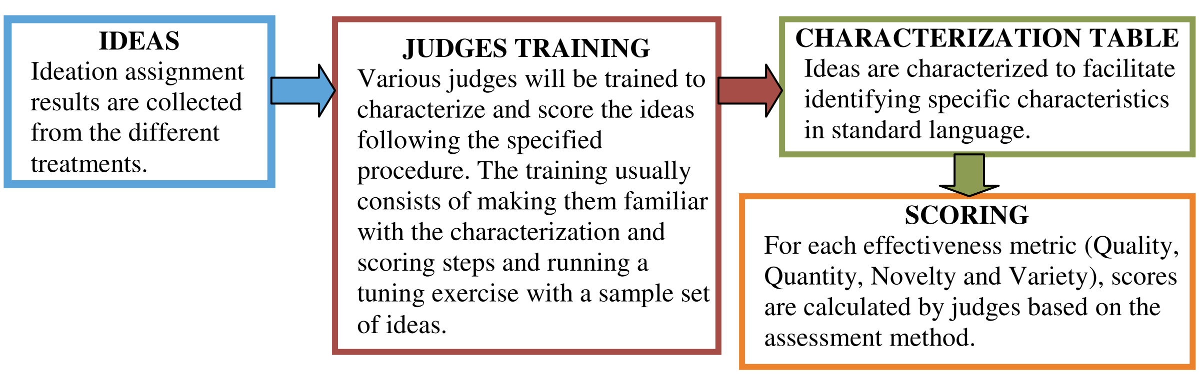

Figure 3. Scoring Assessment

The first step is characterization of ideas making the scoring process easier by identifying specific characteristics in each idea in a standard language. Second step involves the creation of scoring aids such as trees and tables to help calculate the scores. And third step, the actual calculation and assignment of scores. These scores will be used to perform MANOVA. The training usually consists in making them familiar with the characterization and scoring steps and running a tuning exercise with a sample set of ideas. In general, it is expected that the scores assigned independently by each judge will be similar to those of other judges evaluating the same groups. Future research may evaluate between and within judges reliability in more detail.

6 Current and Future work

Since the start of this research project, the participating institutions have been conducting pilot studies to learn more about the variables of the DOE. This is a summary of the knowledge gained.

6.1 Penn State Pilot Study

At Penn State, data collection plan provided in Figure 1 has been implemented in two different courses: EDGSN 100, and QMM492. Four sections of the EDSG 100 course was involved in data collection yielding over 120 individual data sets and 32 team level data sets. Out of these sections, three of them were taught by the same instructor. In two sections (where TRIZ training was provided), instructors were different, and the level of the bias introduced due to having different instructors was intended to be measured. In QMM492, a senior course for non-engineering students, data was collected to be compared to senior engineering students to understand the importance of the background knowledge of students. Data collected is currently under study.

6.2 UTEP Pilot Study

Through a pilot study performed in the fall semester of 2009, it was found that the treatment for TRIZ and Smartpen can be complex. Students were trained on the use of TRIZ, and they were required to first produce a functional diagram, define the technical contradictions and produce concepts as part of their ideation assignment. We found that the students were interested in the method, but it does require more than the 2 hours originally allocated for the training and initial ideation session. With respect to the Smartpen, students were excited to learn about this new technology, but it was clear that the immediate benefit was the eagerness to use it. The pen has relevant memory storage functionality, but this is better exploited for bigger design tasks on longer periods of time, when students have the necessity to revisit their ideation sessions. In this pilot study, sketching was the easiest variable to manipulate.

6.3 Texas A&M Pilot Study

As a pilot evaluation of the Biomass design problem, TAMU mechanical engineering students were asked to spend 45 minutes on this design problem. The goal of this activity was to verify that the design problem is clearly written, is appropriate for the group being evaluated and that a wide range of solutions is produced. For this initial evaluation of the design problem, the participants were not provided with the TRIZ method nor the EMS model. Results from this activity showed that students were able to produce a range of solutions unassisted and many students were unclear what exactly biomass was. To remedy this, a definition of biomass was added to the problem.

6.4 University of Maryland Pilot Study

A group of 17 University of Maryland graduate students participated in a pilot study of the TRIZ treatment. The course was “Engineering Design Methods” (ENME 600), an introduction to different conceptual design methods for mechanical engineering. Seven of the students were also working engineers. Fourteen class members had never heard of TRIZ before the experiment. The other three (two professionals and one student) were more familiar with TRIZ (i.e., they rated their understanding of TRIZ at a level of “3” out of 5.

The 17 class members were in the TRIZ training condition; the class members were not given the sketching emphasis lecture nor did the use Smartpens. For the ideation assignment, students were asked to take the assignment home and complete the TRIZ application through to the development of one or two good solutions. It is obvious from the results that 20 minutes is not an adequate time period for students to follow the TRIZ method and develop good designs. During the 20 minutes most of the class was able to identify proper contradictions and suggested inventive principles for application to the design task.

7 Preliminary Conclusions

The main goal of this research is to measure and assess the effectiveness of TRIZ, sketching emphasis and technology enabled journaling in improving the ideation performance of undergraduate engineering students. To achieve this goal, an experimental approach was presented that includes hypothesis definition and Design of Experiment. The experiment factors are TRIZ, Sketching Emphasis and Smartpen, each with two levels (treatment: presence/no presence). The experiment will be run in a 2^3 full-factorial. The generated ideas will be assessed and scored applying the response variables Quantity, Quality, Novelty and Variety. Pilot studies have been conducted at the four participating institutions. In Penn State University the data collection plan was implemented in two courses, the data collected is currently under study. In the University of Texas at El Paso a pilot study was performed in the fall semester 2009, students were given treatment in TRIZ, sketching and Smartpen then asked to produce a functional diagram then produce concepts. A group of 17 University of Maryland graduate students participated in a pilot study of the TRIZ treatment. At Texas A&M the pilot study is underway. The pilot studies will help fine tune the experimental approach. After the experiments are completed, the data will be analyzed statistically. This data will then be validated with real life design (with questionnaires and interviews to experienced designers for example) and then explained from the point of view of cognitive psychology (relating to memory, structuring, and other mental processes). After validating and explaining, the results will be applied to curricular strategy in order to achieve the main goal of improving the ideation performance of undergraduate engineering students.

8 Acknowledgements

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