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IDEA GENERATION TECHNIQUE AND CREATIVITY TOOLS IN ENGINEERING DESIGN COURSE

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ABSTRACT

This study proposes a set of idea generation techniques and creativity tools that can be utilized for the identification of students' perceptions toward generating ideas to produce concept designs. The sample of this study consists of 56 engineering students from the Department of Mechanical and Materials Engineering, Universiti Kebangsaan Malaysia (UKM), who have taken the Mechanical Engineering Design (KKKM 6034), Design Project (KKKM 4955) and Product Design (KKKP 4274) courses. The survey questionnaire instrument was designed based on the theory of the 6 P's of creativity (Person, Process, Product, Place, Pressure and Persuasion). The questionnaire consisted of 32 items, divided by 11 different contexts of people using idea generation techniques: time constraints, differences among members, availability of information, background knowledge of participants, the willingness to perform trial-and-error, democratic leadership, constructive dialogues, vibrant discussions, thoroughness of ideas, elaboration of ideas and diversity of ideas. Statistical analysis revealed that students preferred to use techniques to obtain more ideas by means of reading; observations and interviews; and using integrated creativity tools that combines the problem exploration tools, idea generation tools and concept evaluation tools. The results indicate that, among all creativity tools, Quality Function Deployment (QFD), and Morphology Analysis and Failure Mode Effects Analysis (FMEA), have very high application frequencies in their categories. Students' perception revealed that the creativity tools applied have applicability in all 11 contexts, providing information for the problem solving design process, describing ideas in more detail, as well as generating a wider diversity of ideas and very useful tools in the process of design ideas in group projects.

Keywords: creativity tools, idea generation technique, engineering design.

1. Introduction

Idea generation is a key process in critical and creative thinking. It encourages thinkers to be divergent in their thinking, generate as many potential solutions as possible, and exhibit skills such as fluency of ideas, originality of thought and flexibility in thinking. The objective of the idea generation phase is to use previously acquired knowledge, simple ideas and new information in order to transform this information into something that can be applied on a new situation or problem. The generation of new ideas is a process that is rooted in individual knowledge, in which each person builds from existing situations and uses, regardless of how novel and unexplored the encountered problem is (Gonçalves, Cardoso, and Badke, 2014). According to Girotra et al. (2008), the success of idea generation in innovation usually depends on the quality of the best opportunity identified. Creating an innovative product

requires more than simply understanding the design of an efficient new product development process. Creativity is an essential part of innovation. One of the major concerns among university students is the method used to generate a greater amount of fruitful ideas, and how to become more creative. Liesl et al. (2012) state that many of the problems students encounter in the real world have no pre-determined solutions.

For both the Mechanical Engineering and Manufacturing Engineering programs at Universiti Kebangsaan Malaysia (UKM), there are three compulsory design courses that require students to work in groups in order to improve their creativity, relevant knowledge, theories and methods, as a learning process in creating appropriate ideas and models to develop engineering product designs or systems. Three design-based courses, namely, Mechanical Engineering Design (KKKM 6034), Design Project (KKKM 4955) and Product Design (KKKP 4274), expose students to the appropriate design processes and methodologies to be used. The design engineering process requires a wide range of information, knowledge, experience, judgement of feasibility, and application of engineering scientific analysis. The outcome of these courses aims to provide information about the general process for innovative design engineering, which includes systematic and methodical conceptualizing, creativity, thinking and reasoning, systematic recording and management of design documentation.

In a preliminary study, Johari et al. (2011) claim that the level of creativity of the fourth year students of the Mechanical Engineering and Manufacturing Engineering programs at UKM is low to average, as reflected in their overall inability to generate ideas. After utilizing several creativity techniques, the next student cohort was more creative, as reflected in their ability to propose ideas and think 'out of the box'. According to Heong et al. (2011), most technical students have problems and difficulties in generating ideas to create concrete products and abstracts during their individual assignment courses, mainly due to six factors: running out of ideas, lack of information, lack of specific skills, lack of exercise to generate ideas, lack of time, and emotional disturbance. This shows that it is effective to apply the idea technique and creativity tools in the design process.

There are numerous techniques that can be exploited to obtain new ideas. According to Hamid (2006), ideas could be obtained through seven different techniques: impersonation, interviews, exploration, reading, observation, experimentation and experience. Moreover, there are many creativity tools that have been invented, but only a few of them are applied often. Applying creativity tools is a method to assist in the generative process. It enhances the quantity of responses (fluency), ideas that are distinct from each other (flexibility) and the level of uniqueness of the ideas generated (originality). In a problem solving process, creativity tools can be classified into three main categories: problem exploration, idea generation and concept evaluation (Childs, 2014). Effective problem solvers are able to recognize the existence of a challenge and identify potential solutions (Liesl, Phyllis, Teri and Katherine, 2012). Idea generation tools involve a mixture of external research, creative problem solving and systematic exploration (Johnson, Gibson and Andrew, 2014). These tools have been broadly categorized into two main groups: intuitive and logical. Intuitive approaches like brainstorming include systematic procedures (based on ideal possibilities and solutions) that help an individual to break routines and overcome mental blocks; while logical approaches such as TRIZ include existing available sources, and more scientific and engineering principles, aimed at thoroughly decomposing and analyzing problems (Sefertzi 2000; Gonçalves et al., 2014). Concept evaluation comprises the process of selecting

concepts that satisfy design goals and give an impact on the direction of the final design (Toh and Miller 2015).

Therefore, the research questions formulated in the present study are stated as follows:
a) What are the techniques that students use to obtain new ideas?
b) What are the creativity tools that students use during the problem solving process?
c) What are students' perceptions toward the applicability of creativity tools during the problem solving process?

2. Method

Quantitative designs are used to determine the techniques and creativity tools students use for ideation in the problem solving process, as well as for understanding the perception of the applicability of the creativity tools in the problem solving process. Questionnaires were distributed to the Mechanical Engineering students during academic semester 1 (session 2014/2015), at the Faculty of Engineering and Built Environment (FKAB), UKM. A total number of 56 students were selected to participate in this study. Thirteen of them were Master's degree students, 32 were Bachelor's degree students in the Mechanical Engineering Department, and 11 were in the Manufacturing Department. All of the students engaged in idea generating methods and design processes, and were enrolled in the following design courses: Mechanical Engineering Design (KKKM 6034), Design Project (KKKM 4955) and Product Design (KKKP 4274).

This work takes a descriptive approach. The questionnaire was divided into three main sections, and all question types were closed-ended. Sections A and B consist of the multiple choice questions category, where respondents were restricted to choose among any of the predefined multiple choice answers in order to identify the application frequency of the selected technique and creativity tools they use for ideation in the problem solving process. Section C comprises a Likert-scale question category based on a 4-point Likert scale that ranges from *strongly disagree* to *strongly agree* in order to assess the perception about the creativity tools' applicability in the six categories of creativity. During the process of developing the questionnaire, the researcher considered theories regarding idea generation based on the six P's of creativity proposed by Lin et al. (2006): person, process, product, place, pressure and persuasion. The frequency analysis of this study is based on the frequency of selection and percentage of the agreed statement.

3. Results and Discussion

3.1 Application Frequencies of Selected Idea Generation Technique

Students' technique selection for idea generation was evaluated. The reason for this attribute is to ensure that the previously mentioned assumptions towards students are true. The researchers assume that students obtain their ideas from impersonation of previous project designs. Idea generation requires students' skills in using any source to search for, and formulate, novel ideas. The findings indicate that the assumptions are not true; only five students used the impersonation approach, as depicted in Figure 1.

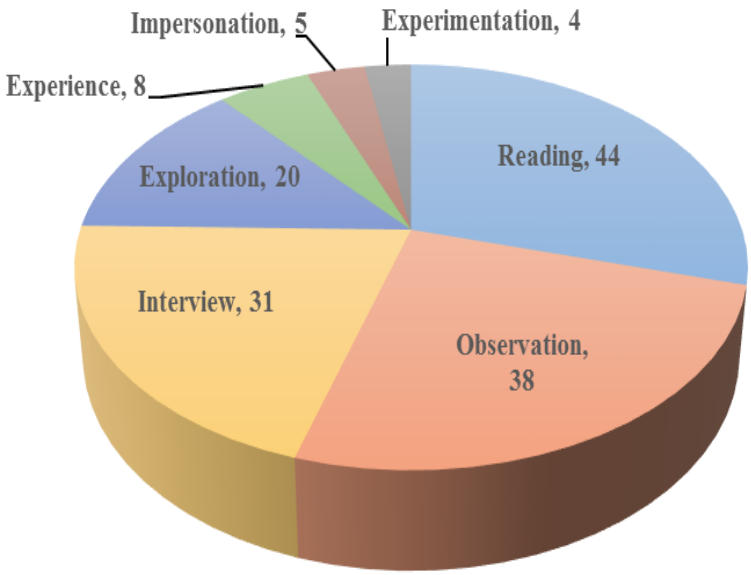

Figure 1: Application frequency of selected idea generation technique.

Among all the techniques, students preferred to read text, pictures, documents, articles, journals, magazines or reference books for finding new ideas to solve the problem at hand. It has been proven by Shewfelt (2012) that reading widely can formulate a well-prepared mind for idea generation. Observations and interviews also have high application frequencies, since ideas can be found in one's daily life. This great technique of data collection assists students to identify needs, and in turn they are able to suggest methods to overcome these needs because this method is a user-based design, and astute observers tend to produce ideas as a result of their observations (Childs, 2014). Observations and semi-structured interviews can yield a rich set of data in a relatively short period of time, providing the information necessary for subsequent design and evaluation phases (Shneiderman, Ben, Gerhard, Mary and Brad. 2005). Students also use the exploration approach to obtain ideas. This is proven by Figure 2, which shows that students generally apply four problem exploration tools to generate ideas.

3.2 Application Frequency of Selected Creativity Tools.

As illustrated in Figure 2, 17 creativity tools has been used by students in the problem solving process to develop engineering product designs. This reveals that students feel it is very important to use integrated creativity tools that combine problem exploration tools, idea generation tools and concept evaluation tools. As proven by Lee, Walsh, and Wang (2015), it is important for identifying, evaluating and selecting the best novel ideas by using integration process that combine the divergent process of idea generation and the convergent process of idea evaluation.

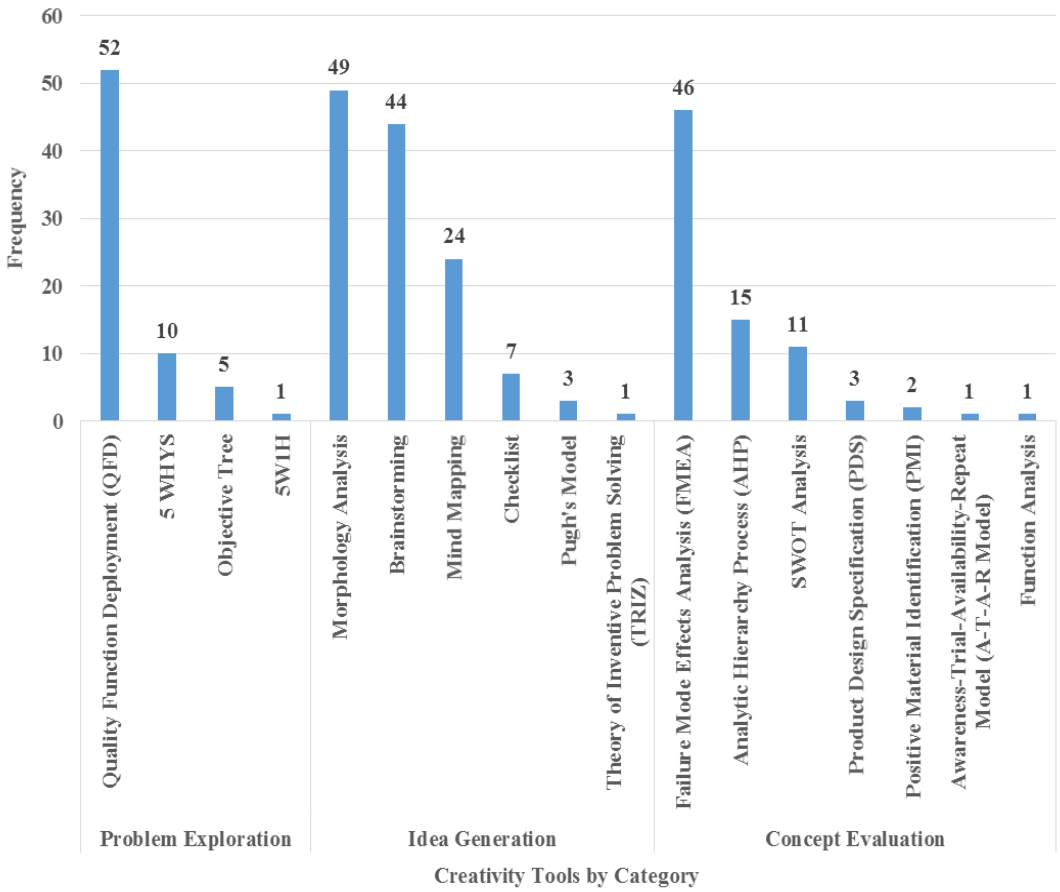

Figure 2: Application frequency of creativity tools by category.

There are four tools that exist in problem exploration: QFD, 5WHYS, Objective Tree and 5W1H; while six tools exist in idea generation: morphology analysis, brainstorming, checklists, mind mapping, Pugh's Model and TRIZ. In the concept evaluation technique, students commonly use seven tools: FMEA, AHP, SWOT analysis, PDS, the A-T-A-R Model and Function Analysis. Among all the tools, QFD (52), Morphology Analysis (49) and FMEA (46) have very high application frequencies in their corresponding categories. This analysis has shown that students use these tools more compared to others because all three of these techniques apply systematic methods of functional analysis, namely, design requirements, parts characteristics and need assessment to identify new combinations of invention elements in creating new products, which are suitable for the engineering design field. As proven by Lo et al. (2010), using the integrated technique (QFD and Morphological Analysis) promotes quick generation of innovative concepts. Also, Goncalves et. al (2014) state that using morphological analysis at the beginning of the idea generation phase can create new solutions to the problem at hand. Brainstorming also has a high application frequency, mainly because it is the best-known technique by far. According to Aichouni et al. (2015) state that the use of creative thinking techniques such brainstorming, lateral thinking, mind-mapping, six thinking hats technique, morphological analysis, can improve substantially the existing levels of creativity and innovation among individuals in organizations.

3.3 Perception about the Applicability of the Creativity Tools in Problem Solving Process.

In section C of the questionnaire, students were asked to indicate their perceptions about the applicability of the creativity tools that have been selected and used. Figure 3 shows that all creativity tools are very applicable tools in different contexts in category of product, process and person.

Based on the responses in the product category, they agreed that creativity tools can help them to generate new ideas (95%) and new creative solutions (93%) (diversity of ideas), more depth of an idea (elaboration of ideas) and to obtain a higher quantity of innovative ideas (thoroughness of ideas). This in turn would help them to obtain design specifications (82%) for achieving feasibility of ideas (85%), to analyze detailed idea designs (97%), and to identify suitable methods (80%) and materials (82%). This finding is supported by Herring et al. (2009), who claim that using idea generation tools may help to stimulate creative thought, generate more ideas and expand on the solution space. According to Sefertzi (2000), the use of proven tools can enhance and stimulate creative abilities, ideas and creative results.

In the process category, students indicated that using creativity tools gave them the opportunity to plan and present an opinion (93%), project (97%) and design project (98%) (democratic leadership), and provide more information in the process of decision making and analyses due to time constraints (availability of information). In availability of information contexts, using creativity tools can help students to facilitate the process of decision making (87%), analyze the results (91%), identify the problems (93%) and needs (93%), and select a final idea (88%), in order to ensure the design meets the required specifications, achieves the desired goals and helps to make rational decisions (95%). This finding is supported by Toh and Miller (2015), who state that ideation tools can help designers generate a large quantity of effective solutions and explore a larger solution space.

In the person category, more than 80% of students agreed that creativity tools are useful in the process of idea design in groups or team members that have different backgrounds (91%), knowledge (81%), experiences (93%), ages (87%) and genders (82%). This finding is supported by Lee et al. (2015), who state that increasing team size adds people from distinct knowledge domains, the chance of more novel outputs increases.

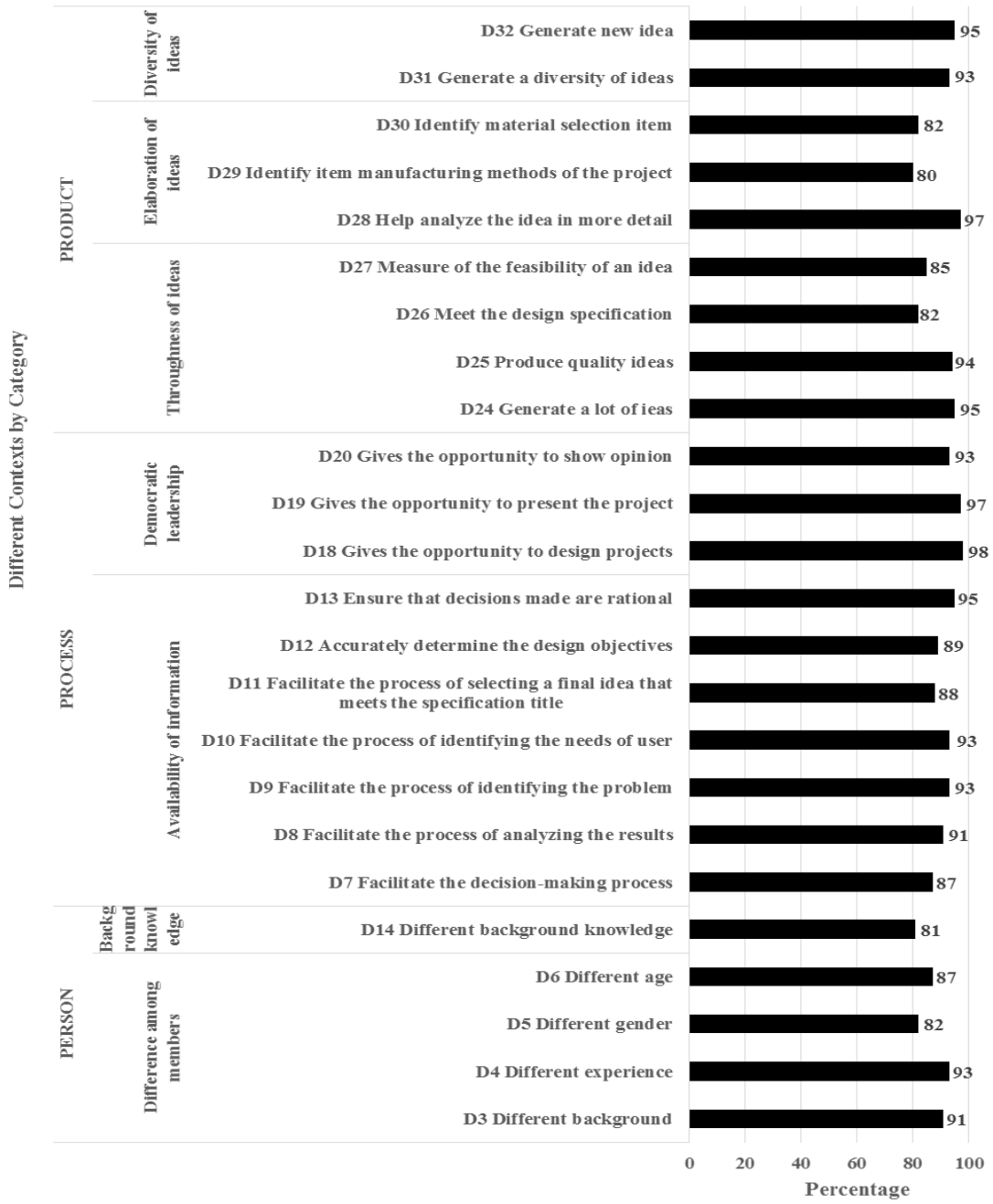

Figure 3: Student's perception about the creativity tools in different contexts in category of product, process and person.

Figure 4 depicts that all creativity tools that have been selected and used are considered as very applicable tools in all different contexts in the categories of persuasion, pressure and place. In the persuasion category, student indicated that creativity tools are very applicable tools in the context of constructive dialogue that shows them positive comments (95%) and suggestions of improvement (93%). In the pressure category, creativity tools allow team members to sketch ideas (93%) and try or experiment methods and techniques (93%) (the willingness to try and error context). On the other hand, they agreed that creativity tools can generate (86%) and accelerate the process (84%) of idea generation under time constraints. This finding is supported by Shneiderman et al. (2005), who state that creativity support tools can promote, accelerate and facilitate creativity. In the place category, students indicated that

the use of creativity tools gave each member the chance to speak up during the discussion (91%) in the problem solving process (vibrant discussion contexts).

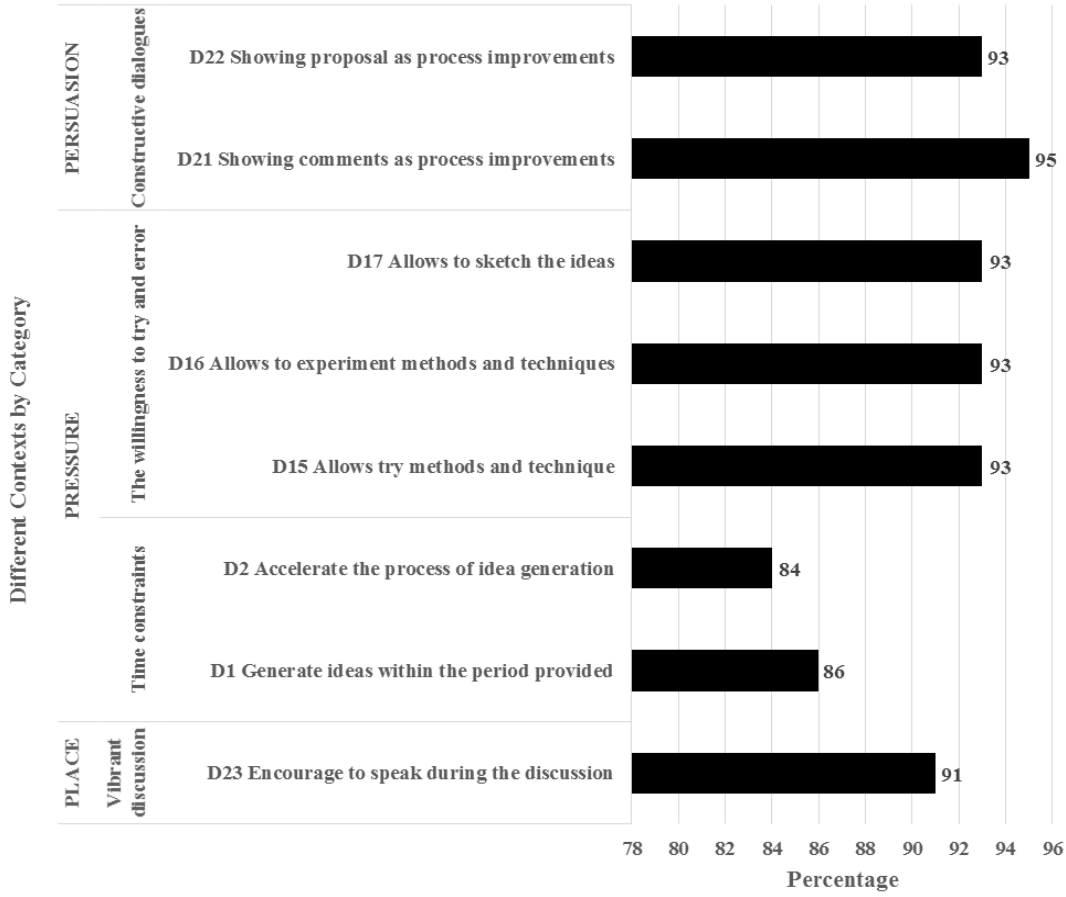

Figure 4: Student's perception about the creativity tools in different contexts in category of persuasion, pressure and place.

4. Conclusion

This study aimed to identify the techniques and creativity tools that students use to obtain an idea in the problem solving process, and to indicate their perceptions about the applicability of the creativity tools that have been selected and used. To meet this goal, a quantitative analysis of data acquired from 56 students enrolled in design course was performed. In the analyses carried out at the end of the study, all of the student candidates declared that ideas can be obtained through reading, observations and interviews. This study also revealed that the most frequent creativity tools applied for the problem solving process have a systematic approach, which consists of functions analysis such as Quality Function Deployment (QFD), Morphology Analysis, Failure Mode Effect Analysis (FMEA), Analytic Hierarchy Process (AHP) and SWOT Analysis. The results of this study reveal that students feel that it is very important to use integrated creativity tools that combine problem exploration, idea generation and concept evaluation. Our results indicate that three creativity tools that fall in the upper rank according to category are: Quality Function Deployment (QFD) (problem exploration), Morphology Analysis (idea generation), and Failure Mode Effect Analysis (FMEA) (concept evaluation). Lastly, the results of students' perception revealed that the creativity tools applied have applicability in all 11 contexts providing information for the problem solving design process, describing ideas in more detail, as well as generating a wider diversity of

ideas and very useful tools in the process of design ideas in group projects. Our results are used to provide directions for future research, as well as evidence for the need to develop instructional methods that encourage creativity throughout the design process.

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