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Application of TRIZ Method in a Product Design and Development Tertiary Technical Education Course

Muhammad Firdhaus Che Hassan[1], Nurul Nazirah Mohd Imam Ma'arof[1], Suhaimi Shahrin[2], Norsyahadah Yeop Wasir[2], Siti Fatimah Hashim

[1]Faculty of Technical and Vocational, Universiti Pendidikan Sultan Idris, Malaysia, mfirdhaus@ftv.upsi.edu.my
[2]Faculty of Engineering Technology, Universiti Malaysia Perlis, Malaysia

ABSTRACT

Theory of Inventive Problem Solving or TRIZ method can be applied in assisting students undertaking a product design and development tertiary technical education course, especially during the conceptual design stage of their learning process. Students without the background of arts during their secondary or early tertiary (certificate or diploma level) education studies as well as the art skills needed to excel in this course tend to have problems in completing the conceptual design stage. By applying the TRIZ method during this stage, there will be guided creative thinking to sketch out something new out of contradictions surveyed from existing products. To proof that TRIZ is applicable, the design and development of a portable road debris collector was taken into account for this application. Data was taken from ethnography and questionnaires from operation staff of a local cleaning company. From here, the usage of TRIZ method assisted the student in hand to put forth direct result of the aftermath of guided creative thinking in sketches which are scoped on the main attributes and problems identified with existing product, without ever jeopardizing the need to complete the conceptual design stage. As an example, data from one of the most chosen answer for improving parameters and worsening parameters are for volume of moving object and shape, respectively. So, the suggested inventive principles for this contradiction are application of segmentation, asymmetry, dynamization, and pneumatic and hydraulics. From these inventive principles suggested, students can sketch out their conceptual design according to only these options. Significant implication from the application of TRIZ method during the conceptual design stage of this course will withheld any forced creative thinking for students in order to create an innovative new product from scratch, as the inventive principles suggested guides the amount of sketches needed to complete this stage.

Key words: Theory of Inventive Problem Solving, Product Design and Development, Conceptual Design; Guided Creative Thinking, Inventive Principles

1. INTRODUCTION

Students with all sort of secondary or early tertiary (certificate or diploma level) education background can undertake a product design and development tertiary education course. The focus on this type of course is based on practical work after enduring the knowledge beforehand, and it tends to be extremely thorough and repetitive in nature as to generate the desired effects of creativity gained [2]. This creates a level of uncertainty in their feelings when trying out for the first time a certain topic in this type of course, thus becoming hesitant in expressing it out during the conceptual design stage [6]. To dispel this notion, TRIZ can be applied during this stage as it assist the students by guiding their creativity towards the focused solutions and its possibilities, predictable or not [5]. In this study, the chosen case study was done during the conceptual design stage of a design and development of a portable road debris collector which in turn to complete this course.

1.1 Problem Statement

The TRIZ method was founded by Genrich Altshuller, a patent engineer from Russia, in 1946, with which he discovered that solutions to innovations were repeated based on around 200,000 patents later narrowed down to 40,000. This method is mainly based on solving contradictions of existing products or systems across all industries [13] [9]. Some examples of its application are the conceptual design and improvements of automotive parts such as engine rubber mounting composite [1] and utility compartment [12], integration with AHP method in an automotive door panel design [11], innovation towards a hoverboard [5], and even to improve the service design in a zoo [7]. This interactive way of providing a guided creative thinking can also be related to an experiment using a modified game of snakes and ladders for a guided prediction of students' future careers, which is basically more or less like game playing [22].

Conceptual design stage considers an array of constraints and ranks them from most important to the least. This creates an opening to identify the problems in existing products and assist the designer to explore within these boundaries [8]. Sometimes pointed out as creative ideation, this stage commonly operates on quantity based rather than quality of the outcomes from tasks given in a given time, thus resulting in a variety of results that does not solely focus on the problems to be resolved [3]. Fundamentally, this stage can be carried out through sketches of ideas created through images from within, though can also be inspired by shapes and outlines from nature [10]. Sketches can also be done based on customers' needs, whereby information was collected via interviews of users, and in turn can be used to establish target specification [15].

The application of TRIZ in conceptual design for this certain case study was done for a technical based bachelor degree program student in a technical university whereby around thirty percent of the content of this degree is of arts based. By applying TRIZ, automatically the solution is focused, thus eliminate the need to do comparison testing between proposed product and current ones in the know how [18]. The product design and development course includes research on current products, conceptual design of improvised current products, and development of the improvised products. During this conceptual design stage, material selection can also be identified beforehand, sometimes using an Elimination and Choice Expressing Reality or ELECTRE, as in the case for the material selection of a badminton racket frame in a sustainable manner [17]. This form of multi-criteria decision making (MCDM) method is rather useful in terms of making selections, as currently as in this pandemic outbreak season of coronavirus disease-2019 (COVID-19), whereby the selection of applicable immediate patients contracted with this virus to be allowed convalescent plasma (CP) transfusion [19]. The product chosen for current research was a portable road debris collector. Road debris collectors sweep road debris or street dust through three main street sweeping technologies which are the mechanical broom sweepers, vacuum sweepers and regenerative air sweepers. By sweeping these road debris, the public health at most will be protected [4].

2. METHODOLOGY AND DATA COLLECTION

To comprehend the conceptual design stage, design research was done through the ethnography, interview and questionnaire surveys. The ethnography was done with the help of a local cleaning company whereby the process of sweeping and the mechanism used was observed. Interview was done with the service unit manager of this company to know the operational background of the company itself. Finally the main data to be compiled from are from the results of questionnaires handed out to operation staff of this company. A total of fifteen (15) operation staff participated in this survey, which consists of Section A: Demographic Data of Respondents, Section B: Respondents' Opinions and Section C: New Design of Product. Section A consists data of the respondents' name, gender, age, occupation experience, while Section B asks the respondents on the problem faced using current products and opinions in improving them, and lastly Section C needs the respondents to give opinion on the suitable mechanisms to be inducted into the new design of the current products.

By collecting the data from Section B and C of the questionnaires, the conceptual design stage can be done with application of TRIZ method. The TRIZ process flow in Figure 1 shows the basic application by recognizing the problems to be solved, identifying function analysis, cause and effect chain analysis, and engineering contradiction, applying the system parameters from the engineering contradictions into the contradiction matrix, and from there specific inventive principles will be determined.

After choosing the appropriate specific inventive principles, sketches will be done to generate creative ideation for a new product. This will also be assisted by suggestions in Section C of the questionnaires.

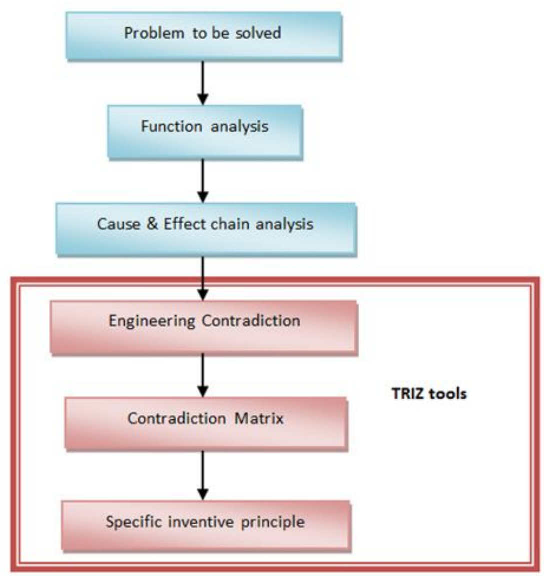

Figure 1: The TRIZ process flow [14].

3. RESULTS

3.1 Design Research

From the ethnography process, there are three ways the local cleaning company does the sweeping process which are by using a road sweeper truck, manual road sweeping, and using blowers. These mechanisms have its own advantages and disadvantages as shown in Figure 2. The sweeping process was identified as to determine the types of mechanisms to choose from in order to create an improved product.

Figure 2: Comparison of cleaning process mechanisms.

From the questionnaires, the results for Section B consists of two parts which are the aspect of the products that should be improved and the problems faced by existing products. The first part will be used as the Improving Parameters and the latter as the Worsening Parameters, as to be applied in the Contradiction Matrix later.

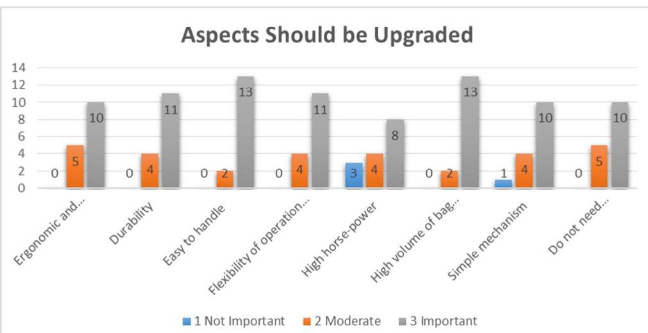

Figure 3: Improving parameters according to aspects should be upgraded in current products.

In Figure 3, shows the result of the first part of Section B. According to this, 86.7% of respondents give emphasis on the “Easy to handle” and “High volume of bag storage” answers, presumably so as this is a survey on the design and development of a portable road debris collector. Next answers in line are the “Durability” and “Flexibility of operation or use” answers with 73.3%, and third with 66.7% are the “Ergonomic and function design” and “Do not need maintenance regularly” answers.

As for the Worsening Parameters data of Section B of this survey, Figure 4 shows obvious highest answer is “Too expensive” with 73.3% of respondents giving it of upmost importance. Then with 60% choose the answer of “Cannot adjust height”. Finally, there are three answers tied at 46.7% which are “Needs more spaces for storing”, “Difficult to handle”, and “Not ergonomics”.

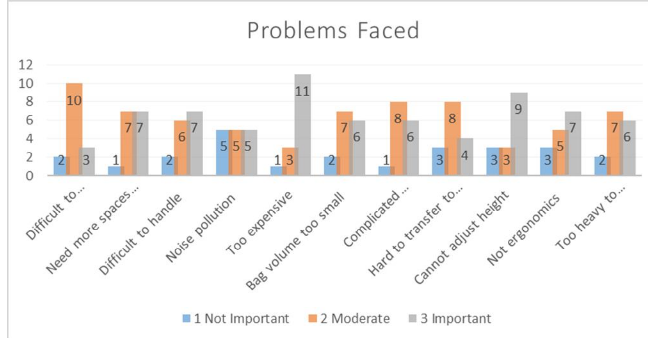

Figure 4: Worsening parameters according to problem faced in current products.

In Section C of the questionnaires refer to the opinion of respondents on the proposed new design of the product. 46% of the respondents prefer a combination of mechanism, such as a vacuum and a roller brush (sweep), while none really prefer the current product of blower. Figure 5 shows the percentage of preferred mechanism for the new product. The preference towards the combined mechanism is mainly due to the similarity in design and function with a road sweeper truck.

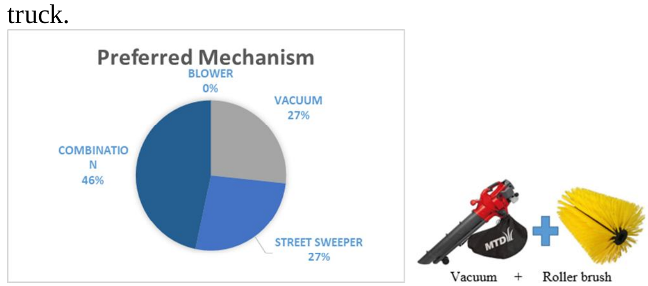

Figure 5: Preferred mechanism for new product.

The second part of Section C refers to the preferred concept design of the new product, according to similar shape and functions of a sweeper. In Figure 6, Concept A shows a vacuum connected to a separate debris container, Concept B is a lawn sweeper with roller brush with container at the handles, Concept C replicates a lawn mower with a vacuum mechanism, and Concept D shapes as a portable vacuum cleaner. Concept C was chosen the most with 50% of respondents agree to this concept design. This concept again resembles the design that can function well similar to a road sweeper truck, with debris captured and contained in a specific enclosure.

Figure 6: Preferred concept design for new product.

3.2 Conceptual Design

In this section, the student involved will be applying the TRIZ method with guided solutions as opposed to do a great number of sketches without end, usually taught in a conventional product design method of teaching. To use the TRIZ method, data from Section B of the questionnaires will be used. The Improving Parameters and Worsening Parameters must be identified from the answers chosen. The top three answers for both set of data will be used according to popularity.

For the Improving Parameters, they are identified from “Easy to handle” as #33 Ease of operation (Manufacturability); “High volume of bag storage”: #7 Volume of moving object; “Durability” and “Do not need maintenance regularly”: #27 Reliability (Robustness); “Flexibility of operation or use”: #35 Adaptability or versatility; and “Ergonomic and function design”: #12 Shape.

As for the Worsening Parameters, they are identified from “Cannot adjust height” as #35 Adaptability or versatility; “Need more spaces for storing”: #8 Volume of stationary object; “Difficult to handle”: #36 Device complexity: and “Not ergonomics”: #12 Shape. Note that there is no system parameter for value of money in the TRIZ method. For both parameters, it is simplified in Table 1.

Table 1: System parameters identifications

	Data	**System Parameter**
Improving Parameters	Easy to handle	#33 - Ease of operation (Manufacturability)
	High volume of bag storage	#7 - Volume of moving object
	Durability	#27 - Reliability (Robustness)
	Do not need maintenance regularly	
	Flexibility of operation or use	#35 - Adaptability or versatility
	Ergonomic and function design	#12 - Shape
Worsening Parameters	**Data**	**System Parameter**
	Too expensive	Not applicable
	Cannot adjust height	#35 - Adaptability or versatility
	Need more spaces for storing	#8 - Volume of stationary object
	Difficult to handle	#36 - Device complexity
	Not ergonomics	#12 - Shape

As an example to determine the specific inventive principles by using the Contradiction Matrix, as shown in the extract of identified system parameters for this case study in Fig 7, the chosen Improving Parameters and Worsening Parameters are #7 Volume of moving object and #12 Shape respectively. So, the Specific Inventive Principles recommended are Principle #1: Segmentation, #4: Asymmetry, #15: Dynamization, and #29: Pneumatics and hydraulics. In Table 2 are the explanation of each specific inventive principles for this example.

From the explanation in Table 2, a conceptual design can be created through sketches with guided creativity due to the application of TRIZ. This enabled the student to do a certain number of sketches and focused on the recommended specific inventive principles that is applicable for the new design of a portable road debris collector.

	Worsening Parameters / Improving Parameters	Volume of stationary object	Shape	Adaptability or versatility	Device complexity
#		8	12	35	36
7	Volume of moving object		1, 15, 29, 4	15, 29	26, 1
12	Shape	7, 2, 35	+	1, 15, 29	16, 29, 1, 28
27	Reliability (Robustness)	2, 35, 24	35, 1, 16, 11	13, 35, 8, 24	13, 35, 1
33	Ease of operation (Manufacturability)	4, 18, 39, 31	15, 34, 29, 28	15, 1, 34, 16	32, 26, 12, 17
35	Adaptability or versatility		15, 37, 1, 8	+	15, 29, 27, 28

Figure 7: Extract of identified system parameters from the contradiction matrix with its specific inventive principles.

Table 2: The example's specific inventive principles explanations

Specific Inventive Principles	Explanation
#1 - Segmentation	Divide an object into independent parts and make an object easy to disassemble
#4 - Asymmetry	Change the shape of an object from symmetrical to asymmetrical
#15 - Dynamization	Divide an object into parts capable of movement relative to each other
#29 - Pneumatics and hydraulics	Use gas and liquid parts of an object instead of solid parts

As can be seen in Figure 8, the sketch refers to Principle #1 which refers to Segmentation. This sketch shows the debris container and roller brush can be disassembled.

As for Principle #15 Dynamization, the sketch in Figure 9 shows that handles of the proposed new product can be folded.

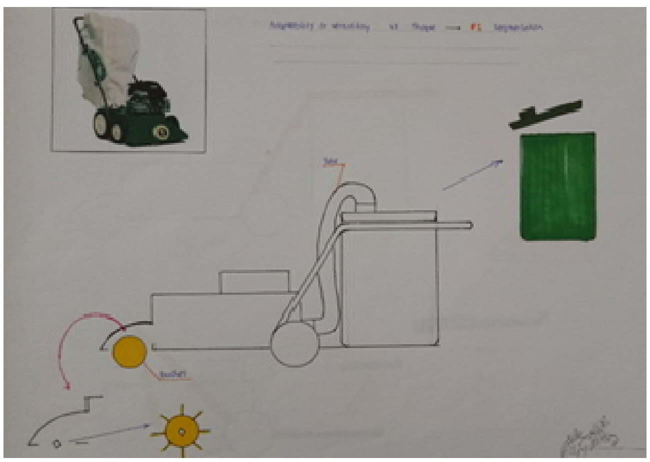

Figure 8: Sketches of principle #1 Segmentation

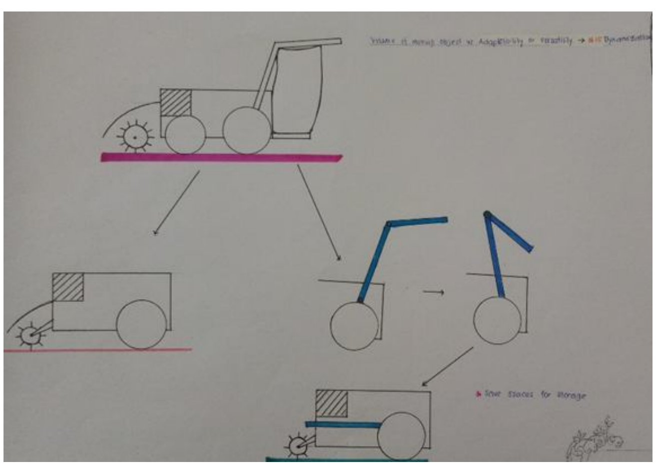

Figure 9: Sketches of principle #15 Dynamization

The chosen specific inventive principles were appropriate to be applied towards the proposed new product accordingly. It is not a matter of choosing all the principles given. This in turn will make the sketches produced more focused oriented and can be improved. As stated by [16], students will gain more through a guided process, without the hassle of anxiety and believing in one selves, especially during self-directed learning.

3. CONCLUSION

With the application of the TRIZ method in the conceptual design stage in a product design and development tertiary course, students from all types of secondary and lower tertiary education background can definitely not stress out on being creative especially in creating sketches for an improvised product. The TRIZ method can assist students in identifying the problems and its parameters as to generate possible solutions from a contradiction matrix, and limiting the number of sketches needed to be done during this stage. With this guided creativity, a product design and development tertiary course would not be inclusive to the arts minded students, but for all to enjoy by applying the TRIZ method in the conceptual design stage. Further research application can also be done towards early stage tertiary technical courses in polytechnics and community colleges, especially in Malaysia, as there was substantial findings that the students in these institutions lack in creativity and non-preference towards complex module guidance is high such as in a Project-Based Learning environment [20]. Also, this research can be applied as far as in schools, as in Malaysia, the TRIZ method is currently applied in the subject of Design and Technology. Teachers admit that this method is important but most haven't grasp the procedures in implementing this method in the subject said [21].

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