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TRIZ Effect Exploitation on Engineering Students Thinking Skills in Product Design

Product design is a creative and multidisciplinary activity that often necessitates the application of analytical and innovative support tools to enhance the concept research phase and solutions development. The TRIZ theory, a highly effective innovation method, has demonstrated its efficacy in supporting innovation across various fields. In this context, our focus has been on integrating TRIZ into the product design process involving engineering designers. This article provides a descriptive and critically assessed evaluation of the operational impact of TRIZ on the design activity, specifically in the development of a "Wastewater Screening and Filtration System" during the preliminary design phases. The objective of this research is to assess the influence of TRIZ utilization on the engineering designers' ability to address a design problem. The ultimate goal is to establish an innovative design support approach based on the use of TRIZ tools that is easily comprehensible and applicable to future designers. Within this article, we present both quantitative and qualitative results of the exploitation of TRIZ tools combined with an energy analysis of the requirement in the product design field.

Keywords: *Product design, innovation, TRIZ, wastewater screening system, preliminary design, energy analysis.*

1. INTRODUCTION

TRIZ (Theory of Inventive Problem Solving) is a prob–lem-solving methodology developed in Russia during the 1940s by Genrikh Altshuller [1]. It is grounded in the notion that innovation is a systematic process that can be taught and effectively applied. [2-3]. In this context, we were interested in presenting the TRIZ theory, which has been successfully integrated into many fields and industrial sectors [4-5], also proving its performance in solving innovation problems and improving creativity and ideation spirit [6]. In recent years, TRIZ has been widely used in the educational field. Different tools of this theory, mainly the contradiction matrix, have been exploited by designers to solve innovative design problems [7-8-9]. Recognizing the challenges of turning theory into practical application when introducing innovation support tools to designers, considerable efforts have been dedicated to the formulation of design approaches that seamlessly incorporate TRIZ tools [10-11-12-13-14]. This initiative has given rise to the development of educational platforms and methodologies designed to facilitate the utilization of key tools within the TRIZ framework [15-16-17-18]. However, some challenges may arise for non-experienced users, such as engineering students, during the use of TRIZ tools [7]. The students usually confound different kinds of technical/physical contradictions [19], and the appli–cation of inventive principles to perform specific solu–tions is also a difficult task for students [20]. The use of TRIZ tools within a structured framework may lead to better outcomes. In this context, our research focuses on the meticulous structuring of a design approach that seamlessly integrates TRIZ tools. The proposed app–roach stands out for its originality. We integrate a pre–liminary design methodology based on energy analysis for the expression of needs with a judicious application of TRIZ tools. We opted for this combination since TRIZ's innovation process predominantly relies on energy analysis across its toolset. In this regard, we present a systematic and innovative design approach comprised of clear and precise steps. This approach enables the designer to articulate the specific need effectively and choose the appropriate TRIZ tool in response to a preliminary energy analysis of the requi–rements. Subsequently, our research delves into evalu–ating the operational outcomes of the proposed app–roach. This assessment covers student performance, the relevance of proposed solutions, and the challenges faced during implementation. This evaluation aims to enhance the proposed approach further. In the first sec–tion of this paper, we introduce the TRIZ theory and its abstraction approach, the fundamental concepts, and tools employed to address innovation challenges. The second section focuses on the presentation of a design project extended to multiple designer groups, where so–lutions are generated using appropriate TRIZ tools. We also present in this section the results of monitoring and evaluation of the design project addressed by the propo–sed approach. Finally, the third section is focused on revealing and evaluating the proposed concepts, accom–

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panied by a thorough examination of the effect of TRIZ utilization on the groups of designers involved in the development of a "Filtration and Screening of Was–tewater" system.

2. TRIZ PRESENTATION

In this section, we present the primary bases of TRIZ theory, beginning from its origin and followed by its general problem-solving approach known as the abs–traction process. Then, we outline the TRIZ essential concepts, and finally, we mention the problem-solving tools proposed by this theory.

2.1 TRIZ Origin

The structuring of TRIZ by Altshuller is at the origin of four main elements:
- Analysis of scientific literature;
- Analysis of patents (more than 200,000);
- Analysis of the psychological behaviors of inventors;
- Analysis of existing methods and tools.

The in-depth analysis of these four main elements allows the TRIZ abstraction process to structure and establish essential notions and problem-solving tools.

2.2 TRIZ Abstraction process

Generally, proceeding directly from a specific problem to specific solutions induces psychological inertia and mental blocks, resulting in a loss of product development time for the designer. In this context, Altshuller structured an abstraction process (figure 1) for problem-solving, avoiding the trial-and-error cycle and overcoming mental blocks.

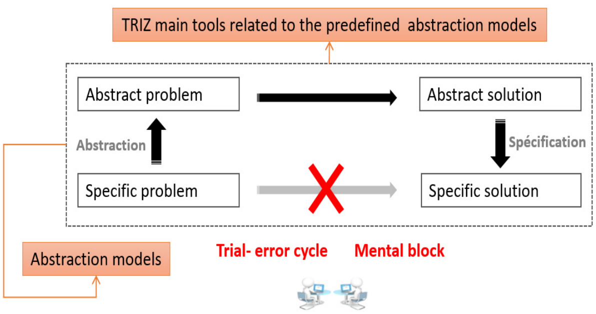


Figure 1: TRIZ Abstraction process

To solve a problem according to TRIZ theory, the designer must carry out an abstraction process, inclu–ding the following steps:
Step 1: The first step is to go from a specific problem formulating to an abstract problem formulating relying on a predefined abstract form of TRIZ,
Step 2: This step consists of transforming the abstract form of the problem into abstract solutions by applying the associated tools,
Step 3: The last step is the specification of concrete solutions from the abstract solutions found previously.

2.3 TRIZ Essential notions

Psychological inertia: it represents the many barriers to creativity and our ability to solve a problem.
Ideal final result: During their evolution, technical systems tend to improve the relationship between the performance of the system and the resources necessary to achieve this performance.
Resources: Resources are the elements that we can use to solve our problems and that exist in our environment.
Contradictions: Altshuller asserts that the origin of any innovation problem is a contradiction. Thus, specifying and defining a problem amounts to knowing and speci–fying the parameters at the origin of this contradiction.
Technical systems evolutionary laws: In the logic of TRIZ, the technological evolution of a technical system is predictable towards well-determined laws of evo–lution.

2.4 TRIZ resolving tools

TRIZ theory can be considered as a toolbox whose choice of use is associated with the context and the model of the abstract problem. Figure 2 shows the different TRIZ innovation problem-solving tools.

Figure 2: TRIZ inventive problems resolving tools

After this brief introduction to TRIZ theory, we will present the educational progress of the TRIZ-based design project for a «Wastewater screen system» in the following section. Mechanical engineering students from ENSAM (National Higher School of Arts and Crafts) led this project.

3. PRODUCT DESIGN BASED ON TRIZ

3.1 Description of the educational framework of the project

Evaluation takes place throughout the execution of the project, at start-up (diagnostic evaluation), during (for–mative evaluation), and then (summative evaluation).

As a result, the supervision and evaluation process for this project will require the following:
Before the project start-up sequence: Diagnostic assessment: This step allows for establishing an initial state of the knowledge held by the engineering students on the subject and the ideas they have about it. It aims to study the representations (conceptions) of the stu–dents regarding the nature of the required work so that the teacher can anticipate the learning obstacles students might encounter during the project. This assessment can be conducted individually or in a collective format.
During the project implementation sequences: For–mative evaluation: It allows the teacher to support student success through:
- ✓ The development, at a given moment during the course of the project, on the order of mastery of knowledge and skills;
- ✓ Detection of gaps, errors, and identification of students in difficulty;

- ✓ Regulation of educational action (correcting choices, differentiating, setting up support activities, providing personalized help, etc.).

For the student, formative assessment allows them to express a judgment on their learning, monitor their acquisitions and their progress, and then self-evaluate using success criteria based on the skills to be acquired.

At the end of the project: Summative evaluation: The aim is to assess the student's skills and knowledge after a sequence or project execution phase and at the end of the project.

The analysis and interpretation of the results must be invested in the planning and implementation of corrective actions as part of a plan to support and remediate student learning.

3.2 Description of the design project and situation assessment

The project aims to develop an innovative and sustainable wastewater cleaning and filtration system capable of treating wastewater at various scales.

The system must be designed to meet several key objectives. Firstly, it will ensure the efficient removal of pollutants through the incorporation of advanced filtration and treatment technologies. These technologies allow the efficient removal of contaminants present in wastewater.

3.3 Presentation of the educational system to support innovative design

Designers: These are engineering students in the 4th year of mechanical engineering who have benefited from significant versatile and technical training integrating specialty multidisciplinary courses focused on:

- Drawing tools;
- Machine elements;
- Transmission systems;
- The product design approach;
- Innovative design with TRIZ.

For this project, designers have to use their own knowledge to design and develop an innovative solution based on the project description and need analysis. In Figure 3, we present a flowchart of the project's progress over a period of 14 weeks.

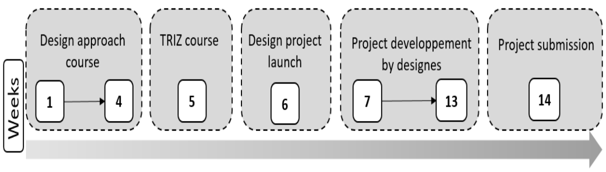


Figure 3: Project progress flowchart

3.4 Student monitoring during the project period

First four weeks: Students are devoted to the course on the design process, and mainly the preliminary design phases (figure 4), namely The conceptual phase, the architectural phase, and the behavioral phase [21].

We also present in this course the energy vision for the need expression (see Figure 5); this vision is taught in this design course in order to facilitate the subsequent use of TRIZ tools.

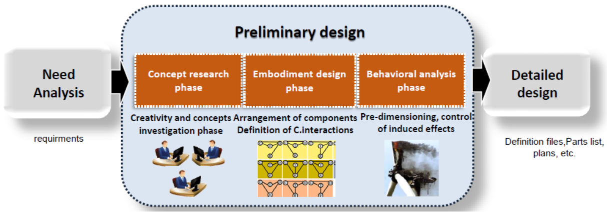


Figure 4: Design process main stages

Generally, a system is considered a black box traversed by a flow of energy, matter, or signal; thus, a function is defined in any system by the transformation of one basic element (energy, material, or signal) into another [22].

In product design, we usually opt for "ENERGY VISION" for system analysis and need formulation [23]. According to Energy Vision, we respect the three following steps:

1. The three flows are summed up in one energy flow;
2. Each element of the system is characterized by its function, its input and output energy;
3. The function is defined by the transformation of a component's local flow into another.

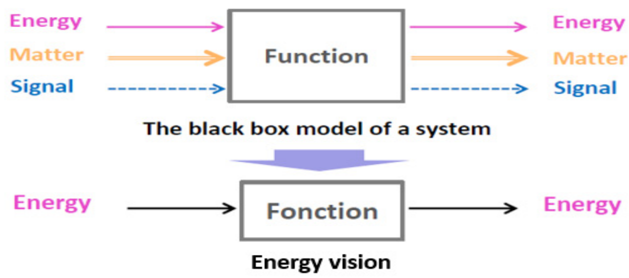


Figure 5: Energy vision for need expression

Week 5: Presentation of the TRIZ course (Origins of TRIZ; the abstraction process; the notions; the tools; energy vision; and examples of designs based on TRIZ tools).

The students followed the course presentation on TRIZ with great interest so that they could subsequently integrate it into their product design processes.

Week 6: Launch of the project: implementation of the specifications.

Week 7-13: Over 7 weeks, we followed the development of the TRIZ-based project by the students while evaluating the following 3 points:

1. Understanding the abstraction process ;
2. Problem analysis and abstraction ;
3. Solution specification and concept proposal.

The majority of inquiries regarding the integration of TRIZ tools in problem-solving arose within the initial three weeks following the project's commencement.

We present the most frequently asked questions by students at this stage.

Questions asked by the students:

Could we use several TRIZ tools for the same problem modeling?

How do you choose the appropriate tool to solve a design problem?

How do we transform a real problem into an abstract problem?

How do we use the TRIZ matrix to solve a problem with several contradictions?

How do we select the most appropriate abstract solutions from the set offered by TRIZ tools?

How can we transition from abstract solutions to specific solutions?

Week 14: finalization of the project followed by a quantitative and qualitative evaluation of the project results.

4. EDUCATIONAL EVALUATION OF THE PROJECT LED BY TRIZ

In order to evaluate the TRIZ exploitation effect on the design process. We established an evaluation sheet, which was submitted with the project report at week 14. We present below the results obtained after analysis of the project reports.

4.1 Result of project progress observation:

- TRIZ abstraction process understanding level

The assessment of the groups revealed that a significant majority had a comprehensive understanding of the TRIZ approach. Particularly the abstraction process, as presented in the initial section. The diagram presented in Figure 6 visually represents the level of compre–hension of the abstraction process, as indicated by the number of students.

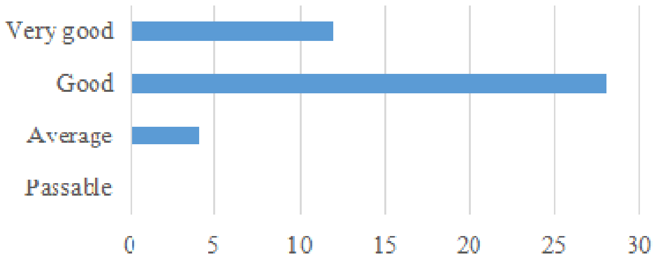


Figure 6: TRIZ Understanding Assessment Chart

- Difficulties encountered with TRIZ implementation

Understanding the theoretical process of abstraction doesn't guarantee the absence of challenges when app–lying it to address a design project. In this context, we sought feedback from designers to identify the phase(s) they encountered difficulties in overcoming.

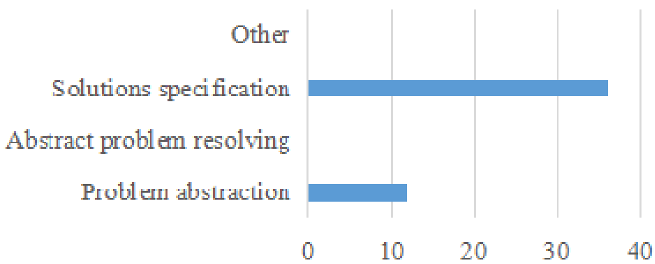


Figure 7: Diagram of the most encountered problems

The diagram presented in Figure 7 illustrates that the most challenging phase was the solution specification, followed by a few groups struggling with formulating the abstract problem;

- Use and mastery of TRIZ tools

Throughout this evaluation, our focus extended to identify the most frequently used TRIZ tools in this design project. Certainly, the contradiction matrix emerged as the predominant problem-solving tool employed by designers in developing their products. It was followed by scientific effects and, finally, innovation principles, as illustrated in the diagram (see Figure 8).

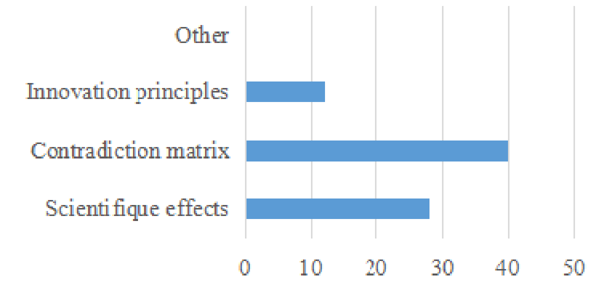


Figure 8: TRIZ used tools diagram

- Phase(s) of the design process concerned by the use of TRIZ tools

The diagram featured in Figure 9 illustrates, in per–centage, the various phases of the design process influ–enced by the exploitation of TRIZ tools among the project's designers.

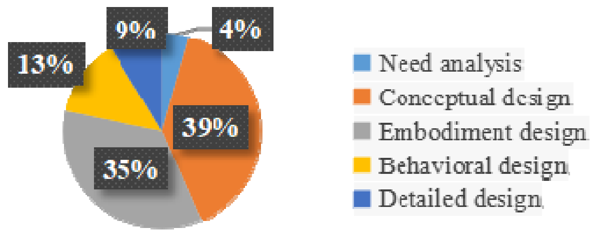


Figure 9: Design phases integration TRIZ

- **Frequency of TRIZ tools exploitation during the design**

As seen in Figure 10, the majority of designers utilized TRIZ tools multiple times during their project development.

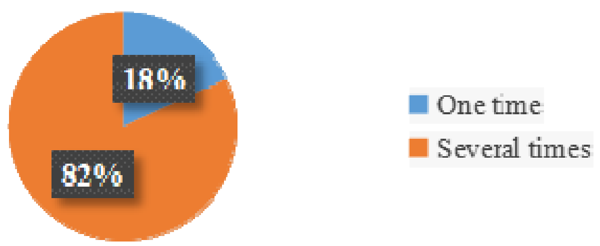
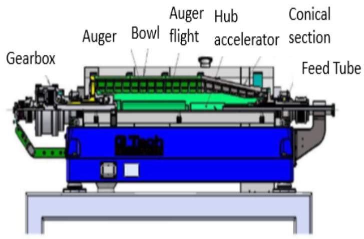
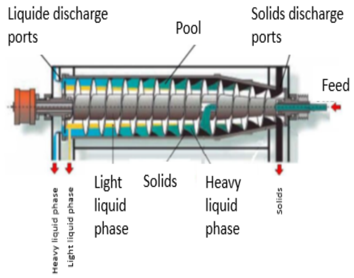
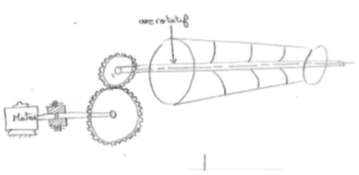
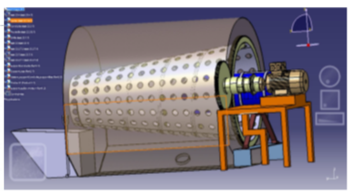
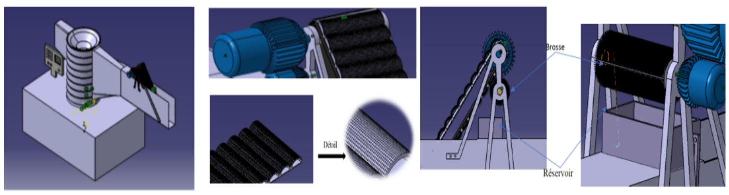
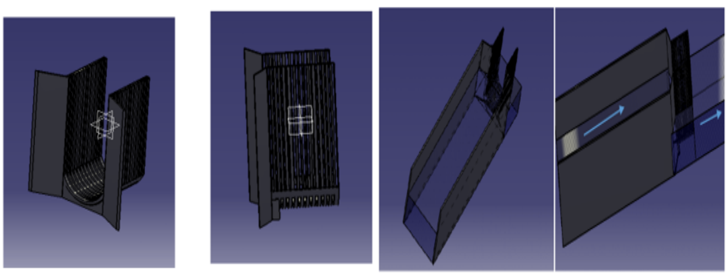
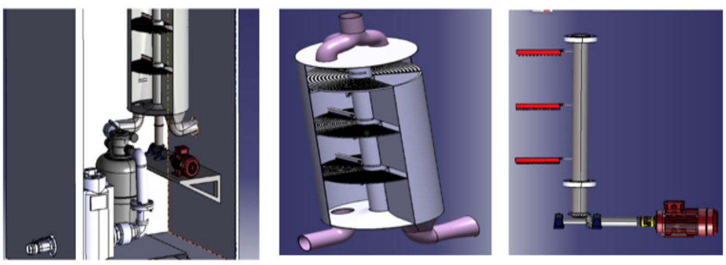
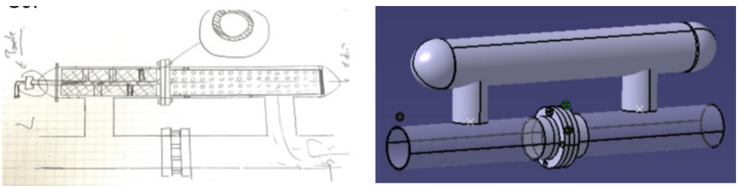
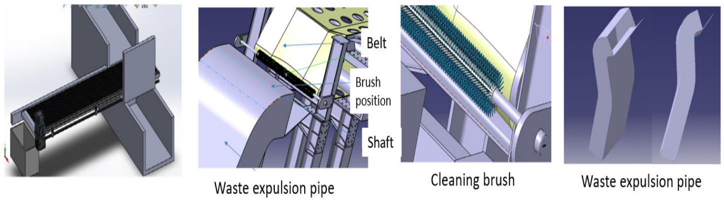
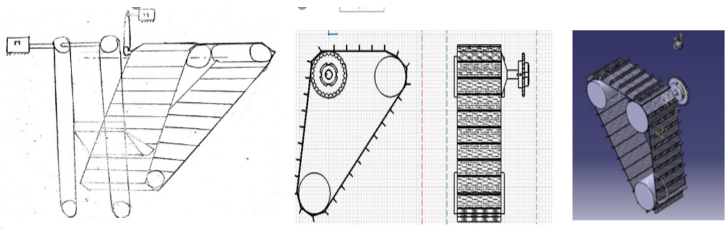
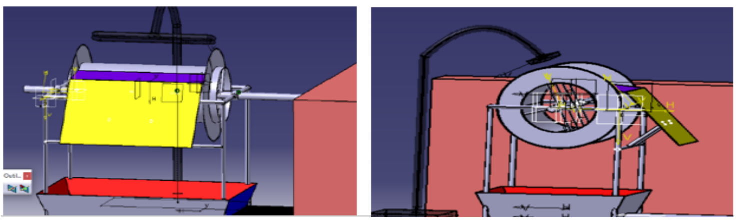
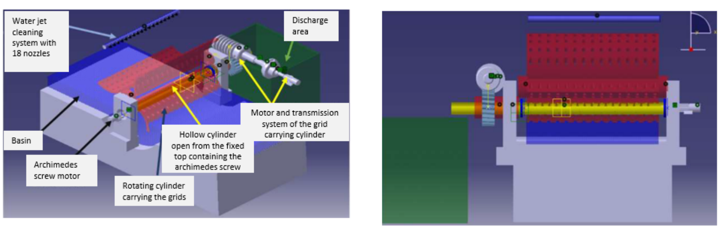
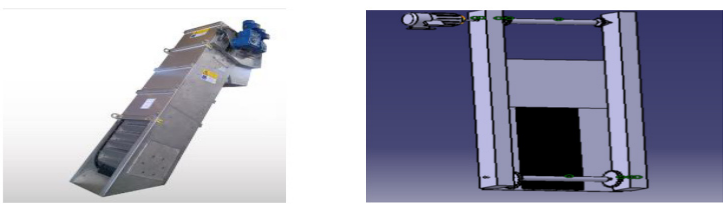


Figure 10: TRIZ tools exploitation frequency

In Table 1, we present the proposed concepts, each developed through the utilization of various TRIZ tools, as informed in prior results. It is important to highlight that the solution concepts are presented in the table below exactly as provided by the design groups.

Table 1: Concepts of proposed and improved solutions retained by each group

Proposed concepts	Solution principle
Group 1: Decanting centrifugal  	The separation takes place in a horizontal cylindrical-conical bowl equipped with a conveyor (endless screw). The sludge enters the centrifugal decanter through the feed rod (on the right side in the sketch) and is then gradually accelerated in the feeding zone. Centrifugal force causes the solids to settle on the wall of the bowl. The conveyor (endless screw) rotates in the same direction as the bowl but at a different speed. The solids are thus conveyed towards the conical end of the bowl, and the hydraulic pressure inside the bowl enhances the conveying. Only the driest fraction of the sludge leaves the bowl through the "solids" outlet towards the casing. The separation occurs along the entire length of the cylindrical part of the bowl, and the clarified liquid is discharged by gravity through adjustable weirs.
Group 2: Physical filter  	A physical filter is a mechanical device that utilizes a membrane or filtering material to trap suspended par–ticles in a liquid or gas. This type of filter is capable of capturing particles of varying sizes depending on the mesh size of the filtering material. The advantages of a physical filter include its ability to retain a broad range of particle sizes, ease of use, and reusability. However, it can be expensive to clean and maintain, especially when used with high-viscosity liquids.
Group 3: Centrifugal separator 	Our solution primarily includes a centrifugal sepa–rator that operates with centrifugal force. This force allows for the separation of fine particles from the water based on the principle of density. The removal of sediment adhered to the inner wall of the separator bowl is ensured by the rotation of fins located at the bottom, generated by the rotation of the output shaft. At the inlet of our system's pipeline, we have added an inclined bar screen designed to eliminate coarse particles. It is equipped with an automated system that detects water overflow outside the open pipeline.
Group 4: Hole pump and gravity 	For the solutions to be adopted, three options were considered: pump, holes, and gravity. We will utilize a porous material (such as grids or perforated plates) onto which we will inject the liquid-solid mixture using a pump with a precise flow rate. The solid particles will settle on the porous material, allowing the liquid to continue its path through the holes. This way, we can separate the solid from the liquid. However, a problem may arise due to the holes becoming clogged by the solid, causing a blockage in the passage of the liquid, especially with the high flow rate of the pump. Therefore, it is necessary to remove the solid debris periodically.
Group 5: Tiered filtration system 	The system is a large cylinder containing circular grids inside, supported from below by bars attached to the outer cylinder to prevent any potential bending of the grids. The system consists of three levels, with the spacing of the grids decreasing from one level to the next. The first level is designed to separate coarse waste with a size greater than 6 mm. The second level aims to eliminate waste ranging in size from 6 mm to 3 mm. The final level is designed to remove fine waste with a size between 3 mm and 1 mm. The waste collected by the grids is scraped on each level by a scraper attached to a rod connected to a shaft. This shaft is driven by an electric motor and controlled by an automatic switch that allows for changing the shaft rotation direction.

Group 6: Perforated membrane screening system 	The use of perforated pipes or membranes can be an effective method of water filtration. Multi-stage filtration is a water filtration approach that uses multiple filtration processes to remove contaminants more efficiently and completely. The principle of multi-stage filtration is to combine different types of filtration processes to remove different types of contaminants at different filtration levels.
Group 7: Rotary belt screening system  	• Rotating belt • Pipeline adaptation We combined the two previous concepts to perform both functions simultaneously: system drainage and waste capture. The key elements of our solution include: • A pipeline adapted at two levels • A rotating belt
Group 8: Rake screen and water jet 	Initially, our team decided to incorporate a cleaning system in the form of a rake driven by a chain. This rake would be specifically designed to remove large debris that might not get caught in the perforations. As for particles inside the perforations, we planned to eliminate them using water jets. These water jets would then be collected through a pipeline, effectively removing undesirable particles while maintaining system performance. However, due to the complexity of the rake's drive system and energy efficiency considerations, we decided to modify the cleaning system. We eliminated the rake and replaced it with small plates perpendicular to the perforated sheets forming the belt. These plates would carry bulky debris to the upper part of the system, which would feature a brush to clear them from the system. Additionally, we chose to add small perforations with a diameter of 0.4mm to the plates embedded in the sheets. This not only lightens the plates, saving energy, but also allows water to pass through, carried by the cleaning system.
Group 9: Rotary drum screener 	We have innovated a new system that receives, filters and separates solid particles from water. The water from the main pipeline passes through the pumping system to a spraying unit, which applies it to a section of the lateral surface of the rotating grid mounted on the support. The water passes through the grid and falls by gravity into the tank, while the solid particles accumulate on the lateral surface of the rotating filtering grid. This grid rotates periodically to make contact between the layer of solid particles and the blade, removing them and transferring them to a conveyor that transports these wastes to a storage unit.
Group 10: shafts with rotating filters  	The principle of this solution involves placing a hollow cylinder with a fixed groove (1) inside another cylinder containing filters (2). Both cylinders have the same axis of revolution; however, (2) rotates while (1) remains stationary. When (2) rotates, it displaces the floating waste on the sea surface towards the groove in the cylinder. Evacuation System: When the waste accumulates inside the cylinder (1), an Archimedean screw compresses and moves them towards the discharge area.
Group 11: Chain screener 	Chain bar screens are designed for the filtration of urban and industrial water, the protection of pumping stations, water intakes, etc. They enable the removal of suspended matter from wastewater. Chain bar screens are intended for the filtration of large-sized waste. A floating waste discharge device using a vortex effect has been added to the pipeline outlet to address this.

4.2 Results analysis

From this case study, we observed that all groups utilized TRIZ tools to generate solution concepts for the wastewater screening system. The use of TRIZ tools varied among groups, depending on the needs identified and the design challenges encountered by each. These differences are reflected in the diagrams presented earlier, illustrating variations in TRIZ tool utilization, the design phases addressed, and the frequency of tool application among the groups. It is notable that the TRIZ integration approaches adopted by project groups were grounded in the TRIZ abst–raction model, which was well understood by the ma–jority of students. This comprehension is considered a crucial step for effectively incorporating TRIZ tools into the design project. The use of TRIZ in this project enabled students to enhance the innovation aspect thro–ughout the design process in various ways, primarily:

- ✓ Proposal of new concepts;
- ✓ Improvement of an existing solution;
- ✓ Selection of the relevant solution;

The identification of abstract problems through the TRIZ models has contributed to enhancing the spirit of creativity and innovation in seeking solution concepts.

Consequently, it is our contention that the majority of the proposed concepts in this project are relevant and possess a significant innovative aspect.

Designers feedback regarding the TRIZ tools exploitation in the project:

TRIZ was very helpful throughout the study process, providing a structured and innovative approach to solving technical problems. Below, we present the main contributions noted by the project groups through the use of TRIZ:

- ✓ Providing a systematic approach for solving com–plex problems and stimulating creativity by propo–sing innovative solutions;
- ✓ Reducing design and production costs by offering more efficient and simpler solutions;
- ✓ Encouraging collaboration among members of our project group and providing avenues for exchan–ging ideas and solutions;
- ✓ Assisting in resolving problems faster and more efficiently;
- ✓ Anticipating potential problems through the ana–lysis of development trends in technical systems;
- ✓ Investigating solutions in areas that are completely different from what we are accustomed to doing;
- ✓ Integrating various disciplines beyond mechanics to design the system;
- ✓ Enriching the technical background by offering a wider range of potential solutions to problem-sol–ving.

In summary, the implementation of TRIZ in this design project sparked creativity within the groups, offering a robust methodology for problem-solving.

TRIZ prompted students to think innovatively, encouraging them to venture "outside the box" and enhancing their ability to devise effective and original solutions.

5. CONCLUSION ET PERSPECTIVES

Through this study, we identified diverse and effective approaches employed by designers using TRIZ in formulating, analyzing, and resolving problems.

TRIZ's systematic approach to addressing design problems with students brought clarity to the design process, enhanced ideation, and elevated creativity.

Comparing the outcomes with previous design projects involving engineering students, the application of TRIZ demonstrated its efficacy, particularly in the concept research phase (Exploiting scientific effects and innovation principles) and in resolving innovative problems encountered during the design process, rely–ing on the contradiction matrix and separation principles.

Students demonstrated a keen interest in reasoning in terms of contradictions and induced effects to enhance existing solutions or develop innovative ones.

The integration of TRIZ into design education is now essential, and efforts should be directed towards identifying educational and practical methods that facilitate the learning of the abstraction process and the use of TRIZ tools adapted to specific needs.

Our research project is strategically structured to achieve this objective, aiming to cultivate a creative mindset among future engineering designers.

REFERENCES

[1] Al-tshuller, G. S. (1996). And suddenly the inventor appeared: TRIZ, the theory of inventive problem solving. Technical Innovation Center, Inc..

[2] San, Y. T. (2014). TRIZ-Systematic innovation in business & management. First Fruits Sdn. Bhd..

[3] Kamarudin, K. M. (2017). Development of Integrated Systematic Approach Conceptual Design and TRIZ Using Safety Principles in Embodiment Design for Complex Products (Doctoral dissertation, University of Sheffield).

[4] Hmina, K., Sallaou, M., Taleb, A. A., & Lasri, L. (2019, April). TRIZ The Theory of Inventive Problem Solving is State of the art. In 2019, the 5th International Conference on Optimization and Applications (ICOA) (pp. 1-7). IEEE.

[5] Buzuku, S., & Shnai, I. (2017). A systematic literature review of TRIZ used in Eco-Design. Journal of the European TRIZ Association, 4, 20-31.

[6] Yehya, M. I., Coulibaly, A., Chibane, H., & Houssin, R. (2023). Framework for evaluating solution concepts in TRIZ-based inventive designs using a functional, behavioral, and structural modeling approach. *FME Transactions*, *51*(4).

[7] Belski, I. (2011). TRIZ course enhances the thinking and problem-solving skills of engineering students. Procedia Engineering, 9, 450-460.

[8] Hmina, K., Sallaou, M., Arbaoui, A., Lasri, L. (2018). A preliminary design innovation aid met–hodology based on energy analysis and TRIZ tools

exploitation. International Journal on Interactive Design and Manufacturing (IJIDeM), 12, 919-928.

[9] Hmina, K., Arbaoui, A., Sallaou, M., & Lasri, L. (2014, October). On the use of small wind turbine in design and innovation education. In 2014 International Renewable and Sustainable Energy Conference (IRSEC) (pp. 281-286). IEEE.

[10] Rajic, D. S. (2020). Compatibility Between TRIZ Contradiction Matrix and LT-Units System. *FME Transactions*, *48*(2).

[11] [Rajić, D. (2021). LT-contradiction matrix. *Fme Transactions*, *49*(1), 95-102.

[12] Delgado-Maciel, J., Cortés-Robles, G., Sánchez-Ramírez, C., García-Alcaraz, J., Méndez-Contreras, J. M. (2020). The evaluation of conceptual design through dynamic simulation: A proposal based on TRIZ and system Dynamics. Computers & Industrial Engineering, 149, 106785.

[13] Donnici, G., Frizziero, L., Liverani, A., Leon-Cardenas, C. (2022). Design for Six Sigma and TRIZ for Inventive Design Applied to Recycle Cigarette Butts. Designs, 6(6), 122.

[14] Hmina, K., El, A. M., Lasri, L., & Sallaou, M. (2020). Preferences-based approach for TRIZ contradiction matrix exploitation in preliminary design. Fme Transactions, 48(3), 588-599.

[15] Petrović, M., Miljković, Z., & Babić, B. (2013). Integration of process planning, scheduling, and mobile robot navigation based on TRIZ and multi-agent methodology. *FME Transactions*, *41*(2), 120-129.

[16] Construction of a Blended TRIZ Creative Learning Platform. 2015.

[17] Ke, J. (2018). Research on Application-oriented Innovation and entrepreneurship Training Platform Construction Based on TRIZ Theory.

[18] Otavă, E., Brad, S. (2020). TRIZ-based approach for improving the adoption of open innovation 2.0. In Systematic Complex Problem Solving in the Age of Digitalization and Open Innovation: 20th International TRIZ Future Conference, TFC 2020, Cluj-Napoca, Romania, October 14–16, 2020, Proceedings 20 (pp. 452-464). Springer International Publishing.

[19] Priven, A., Danilovsky, Y., & Ikovenko, S. (2014). Teaching Disadvantage as an Appearance of Contradiction in basic TRIZ education. *International Journal of Systematic Innovation*, *3*(2).

[20] Chang, Y. S., Chien, Y. H., Yu, K. C., Chu, Y. H., & Chen, M. Y. C. (2016). Effect of TRIZ on the creativity of engineering students. *Thinking skills and creativity*, *19*, 112-122.

[21] Pahl, G., Beitz, W.: Engineering Design: A Systematic Approach. Springer, New York (2013)

[22] Savransky, S.D.: Engineering of Creativity: Introduction to TRIZ Methodology of Inventive Problem Solving. CRC Press, Boca Raton (2000)

[23] Pailhès, J., Sallaou, M., Nadeau, J.P., Fadel, G.M.: Energy based functional decomposition in preliminary design. J. Mech. Des. 133(5), 051011 (2011)

ЕКСПЛОАТАЦИЈА ТРИЗ ЕФЕКТА НА ВЕШТИНЕ РАЗМИШЉАЊА СТУДЕНАТА ИНЖЕЊЕРИНГА У ДИЗАЈНУ ПРОИЗВОДА

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Дизајн производа је креативна и мултидисциплинарна активност која често захтева примену аналитичких и иновативних алата за подршку како би се побољшала фаза истраживања концепта и развој решења. ТРИЗ теорија, веома ефикасан метод иновације, показала је своју ефикасност у подршци иновацијама у различитим областима. У овом контексту, наш фокус је био на интеграцији ТРИЗ-а у процес дизајна производа који укључује инжењерске дизајнере. Овај чланак даје дескриптивну и критички процењену процену оперативног утицаја ТРИЗ-а на пројектну активност, посебно у развоју „Система за филтрирање и филтрирање отпадних вода“ током фаза прелиминарног пројектовања. Циљ овог истраживања је да се процени утицај коришћења ТРИЗ-а на способност инжењерских дизајнера да реше пројектни проблем. Крајњи циљ је успостављање иновативног приступа подршке дизајну заснованог на употреби ТРИЗ алата који је лако разумљив и применљив будућим дизајнерима. У оквиру овог чланка представљамо и квантитативне и квалитативне резултате експлоатације ТРИЗ алата у комбинацији са енергетском анализом потреба у области дизајна производа.