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# LearnAIing: Generative Artificial Intelligence to boost teaching and training in technical field

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## Abstract

Generative Artificial Intelligence is revolutionizing the field of education, offering innovative tools to support students in the learning process and teachers in their activities. This paper presents an AI-powered software developed to support the teaching of systematic innovation courses, following TRIZ methodology, through the integration of Large Language Models (LLMs), Retrieval Augmented Generation (RAG) techniques and the access to patent source. The article describes the methodology implemented and the results of an experimental phase conducted on a large sample of students. The analysis shows how the use of AI in technical Problem-Solving enhances a more structured approach but at the same time is more effective in stimulating creativity and lateral thinking, reducing psychological inertia and boosting Technology Transfer. The findings highlight significant improvements over traditional didactics methods, both in learning effectiveness and instructional support.

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## 1. Introduction

Artificial Intelligence, for several years now, has been disrupting the way human beings used to see things and perform more or less complex tasks in everyday life, including the work sphere. However, one context in which it has been slow to establish itself as firmly is that of education, partly because of the initial limitations of these tools that made them not entirely reliable, such as hallucinations and the impossibility of checking the accuracy of answers or access to up-to-date information, but also partly because of the fear associated with the improper use that students

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might have made of them, stigmatizing such tools as a cunning shortcut that would allow to have tasks done instead of them and thus limit learning.

However, the versatility and potential of these tools is beyond question and, to date, AI in education is an application about which there is great interest and where the prospects for implementation appear boundless. The possibility of assisting students during the various stages of learning, customizing the tool based on their individual needs in order to optimize effectiveness, for example, by making them interact with a chatbot that simulates the role of a teacher who explains more or less complex concepts, submits and corrects exercises to consolidate skills, or stimulates them to deepen certain topics even in more interactive modes such as gamification, overall constitute a new frontier that can lead to results previously unthinkable. The benefit is also reflected on the side of the teacher who, in addition to enjoying a series of new tools that allow to vary and make the explanation more interesting, receives concrete support for teaching that can thus become more effective and at the same time require less time and effort.

In the world of teaching technical subjects such as engineering, in particular, having tools to assist the student in learning and applying complex methodologies could provide significant support. The authors focused particularly on the area of product and process innovation to which they belong, developing and testing an AI-based software application aimed at teaching TRIZ methodology for Systematic Innovation and Problem-Solving, also integrating modules for advanced patent research to conduct prior art searches and draw insights to accomplish Technology Transfer. Over the past two years, an experimental phase was conducted on samples of several hundred students of different levels of education and training on the TRIZ method, comparing the results with the history of case studies derived from the industrial world faced by students in courses delivered in previous years, in which this type of software was not available to candidates.

The article is structured as follows. Chapter 2 describes the state of the art of AI tools for education and an overview of CAI (Computer Aided Innovation) software for TRIZ. Chapter 3 describes the methodology implemented in the AI-based software developed by the authors. Chapter 4 describes the testing phase within academic activities on varied samples of students. Chapter 5 sets out the results and related considerations. Finally, Chapter 6 describes the conclusions of the research.

## **2. State of the art of AI tools for Education and CAI (Computer Aided Innovation)**

Artificial Intelligence is set to have an increasingly substantial influence on the education field, offering innovative tools to improve the quality of teaching and effectiveness in learning for students. This progressive paradigm shift, characterized by a growing adoption of alternative forms of teaching that converge toward the concept of e-learning, was initially stimulated by a concrete and sudden need that arose during the years marked by the pandemic and, subsequently, the appearance of Generative AI tools stimulated their development and diffusion, making it obvious to all the enormous contribution that this new generation of tools could bring in this and many other contexts. In such a new scenario, traditional Machine Learning techniques and, above all, Generative AI tools now enable many methods and tools to evolve in a simpler and more effective way, even for people without advanced computing skills. Among these, a particular interest is directed toward solutions such as adaptive learning, to provide tailored training paths for students and increase their involvement, interactive exercises and corrections, simulating the role of a personal teacher, self-generated concept maps as a study support, but also fun and challenging practices such as gamification [1,2,3], always keeping in mind the importance of ethical and fair adoption of these tools and the technological limitations that make them still immature for some contexts [4].

In the field of Computer Aided Innovation (CAI) a particular interest involves the TRIZ methodology, a theory for solving technical problems in a systematic and innovative way developed by Genrich Altshuller from a wide analysis of patents. Artificial Intelligence has today revolutionized the way experts interact with these tools, who now dispose of technologies that enable the automation and large-scale extension of processes that were typically carried out manually, but it has also, and more importantly, made it possible to make accessible to a much wider audience a complex methodology that in the past could only be applied effectively by those with solid skills and a strong capacity for lateral thinking. Since the appearance of the first LLM chatbots, therefore, there have been numerous attempts to implement the concepts of the methodology in an AI-based form, progressively refining the quality of the response through increasingly advanced prompt engineering techniques. Typically, these are individual tools, perhaps implemented by models like GPT or Gemini, designed to perform specific tasks such as Problem Reformulation,

Function Analysis, Resources Identification, Substance-Field Analysis or a more generic Systematic Idea Generation, including cross-domain Technology Transfer [5]. Often these applications converge into an integrated approach of Multi-directional prompting to bring together the various tools and stimulate the user interacting with the chatbot in several directions simultaneously on different facets of the problem [6], up to the development of complete software that integrate a plurality of TRIZ tools and dedicated modules to perform more specific tasks [7,8]. One of the areas of greatest interest is related to the TRIZ notion of Contradiction, which is one of the most useful and effective cornerstones of the methodology, but at the same time is often quite complex to apply. The goal therefore becomes both to make AI capable of identifying the contradictions that characterize a technical problem and finding ways to solve them, perhaps by applying the 40 Inventive Principles or 76 Standard Solutions, but also to exploit the extremely rich source of technical knowledge embodied in patents to analyze large volumes of documents, identify technical contradictions described within and extract information about the solutions that have been implemented to solve them, gathering ideas that can in turn become insights for innovation and solving other problems [9,10].

### 3. Methodology and AI-based software for Problem-Solving with TRIZ

The aim of the article is to assess how much AI can really be of practical support in the world of education nowadays, both on the side of the student and the teacher. The authors, in collaboration with the company Tinexta Innovation Hub [11], have developed an AI-based software (Fig. 1) aimed at providing help for students in the learning and consolidation phases during “Product and Process Innovation” courses delivered to master's degree classes in engineering and technical institutes of higher education, in which the TRIZ methodology for systemic innovation is taught [12]. The ambition was to overcome the limitations of existing approaches and tools for AI-enhanced problem-solving, described in Chapter 2, which are mainly based on general-purpose LLMs, by instead integrating patent source thoroughly within a complete TRIZ process by implementing a RAG architecture [13].

A large-scale experimental phase was conducted, which will be discussed more in detail in Chapter 3, involving candidates with different levels of education. Since it has not yet been possible to design an ad hoc test to obtain objective and reliable quantitative results, without merely counting the number of solutions found by the candidates without weighing the real inventive contribution made, in this analysis the authors opted for a qualitative type of measurement based on a comparison with past experience and the history of exams and assignments from the same course taken in previous years. Students were asked to solve more or less complex technical problems derived from real business case studies that past years' learners had already tackled without the help of the software. It was also chosen to analyze the advantages and disadvantages perceived by the teacher during the various stages of teaching in comparison with the traditional method.

The tool has a module that leverages Generative AI, by means of an LLM, to reproduce a guided Problem-Solving process according to a selected set of tools from the TRIZ methodology. Through simple prompt engineering techniques, such as few-shot or chain-of-thought prompting [14], the teacher may customize this section extensively at his discretion, including predefined texts that, for example, contain methodological explanations or instructions on how to proceed, but simultaneously also exploit the potential of AI to obtain contextualized answers thanks to its semantic comprehension capabilities, so as to provide the student with a trigger that helps him in solving the technical problem and stimulates his creative thinking into an out of the box mental process.

Indeed, the ambition of the software is not to provide a final solution and completely replace the student's task, but rather to suggest possible solving directions that must then be properly investigated and deepened based on one's own expertise. Sometimes some cues may appear too abstract or exotic, but this is not so much due to a factor of AI's limitations in the technical domain, as the risk of hallucination is limited by the RAG technology integrating external patent databases, but rather to a type of response that is deliberately forced to be more creative when appropriate and make associations with different domains than usual, precisely to stimulate the user to find solutions that are not obvious, bringing him out of his psychological inertia. The basic requirement that is therefore demanded from students and in which it is necessary to invest in training becomes that of the “mental disposition” to accept a given suggestion, that is, the right mindset to grasp that any properly crafted trigger can lead to an interesting and innovative solution when coupled with adequate knowledge of TRIZ methodology, including cues that at first superficial glance might appear misleading and instead have been suggested by the AI precisely because they are connected by some logical or even statistical connection.

**Omnia PS**

Your chats

- squeegee for cleaning
- fireproof iron
- snow chains for cars
- spring coupling between
- silent beard razor

**Problem Solving Toolkit**

MTS Multiscreen Inertia Resources

Tech Transfer Pointer to Effects Contradictions Evolution Trends

**Contradictions**

Take inspiration from TRIZ 40 Inventive Principles to solve Technical Contradictions

Contradictions	TRIZ Inventive Principle	Suggested Solution
Blade Pressure (CP): High cleans better (EP1), but reduces durability (EP2).	1. Segmentation	Segmented blade with adjustable pressure for each segment.
Blade Softness (CP): High conforms better (EP1), but reduces water removal (EP2).	35. Property Transformation	Blade material changes properties based on moisture.
Handle Length (CP): Long reaches further (EP1), but reduces maneuverability (EP2).	15. Dynamism	Telescoping handle with adjustable length.
Blade Angle (CP): Optimal angle removes water well (EP1), but reduces user comfort (EP2).	15. Dynamism	Adjustable blade angle that can be locked into different positions.
Blade Flexibility (CP): More flexible cleans curved surfaces better (EP1), but less flexible cleans flat surfaces better (EP2).	4. Asymmetry	Design a blade that is flexible on one side for curved surfaces and rigid on the other side for flat surfaces.

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Discovery may display inaccurate info, please double-check its responses.

**Patent Squeegee assembly with improved waste pick-up**

The document discusses a squeegee assembly with front and rear blades designed for improved waste pickup, which relates to the design and effectiveness of squeegee blades, a concept shared with the question. The document also mentions issues with blade wear and streaking, touching on the durability aspect mentioned in the question.

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**Patent Hinged squeegee**

The question is about the design of a squeegee with a segmented blade to improve cleaning effectiveness and durability. The document describes a hinged squeegee for cleaning planar surfaces. Both the question and the document share the concept of a 'squeegee'.

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**Patent Squeegee with selectable rotation mode**

The question is about designing a squeegee with a segmented blade to improve cleaning effectiveness and durability. The document describes a squeegee with a selectable rotation mode. Both the question and the document share the concept of a 'squeegee'.

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Fig. 1. AI-based software interface to assist students in learning TRIZ methodology and access the patent source.

Within the software, various TRIZ tools are arranged in a pattern that follows a flow for solving technical problems that has proven most effective for the majority of cases typically addressed. The user is first guided to reason about the Problem to be solved, reframing it appropriately so as to identify the actual causes behind it and consequently have a broader view that will allow a more complete spectrum of solutions to be found. At this point, it is possible to start analyzing the System with the help of a number of useful tools, but always focusing on the concept of the Function it is supposed to perform and not strictly on its Structure. Indeed, it would not be effective to think directly about the final solution by immediately going down into its design details, since this would lead the person to fall into a mechanism of psychological inertia and thus to keep thinking about a limited number of solutions that are similar to each other and to what already exists in the state of the art, thus missing most of the most innovative and interesting ideas. Only after these steps, it now makes sense to start elaborating solutions that will then populate a tree of alternatives, again with the help of the software that tries to suggest stimulating concepts and identify alternative systems that share a similar function to the one sought and from which to try to carry out a Technology Transfer. The user can repeat this first part of the process recursively, rephrasing his question in an alternative way, until he is ready to move on to the second part of the flow, in which he will have to state his idea of solution and try to exploit the suggestions of the new instruments, such as the Technical Contradictions and the 40 TRIZ Inventive Principles, to evolve and further improve the solution.

This framework is combined with a module which automatically performs a corresponding advanced patent search, providing the user with real-time feedback of concrete examples of solutions outlined by global companies within patent documents contained in the RAG database. User input is used both for the generative section related to Problem-Solving and also as a reference for the automatic construction of the query suitable for the patent search, thus allowing the user to also take advantage of a very rich and valuable source of technical knowledge without the need to be an expert in the field. Patents can be useful both for conducting a prior art search, which is always essential for determining whether an idea is already covered by some form of intellectual property protection, but in this context also and especially as an additional resource that provides very interesting concrete insights to inspire a solution. In some steps of the methodology, information derived from patents is also integrated within the response, enriching its content and bypassing the total dependence of LLMs on training data when a more reliable technical knowledge is

required. As needed, in addition or as an alternative to patents, this external database could obviously be equipped with teacher-selected sources such as academic books, scientific articles or other types of documents.

Table 1. TRIZ tools and methodology implemented in the AI-based software.

TRIZ TOOL	DESCRIPTION
<b>STEP 1</b>	<b>In this step, done recursively, the system to be innovated is analyzed, the desired function and the problem to be solved are reformulated, until alternative solving directions are drafted</b>
Main Useful Function and Verb Reformulation	Identify the desired Function and reformulate the Verb expressing it in alternative ways, to broaden the vision of the Problem
Multiscreen	Reframe the Problem by moving it into the past, imagining how to prevent it, or into the future, to mitigate its undesirable effects
Psychological Inertia	Overcome Psychological Inertia by looking at the Problem from a different perspective, with suggestions that stimulate lateral thinking
Minimal Technical System	Define what the System looks like, focusing on the Object and Product of the transformation
Resources	Thinking about how to exploit the Resources of the environment, using the harmful and unnecessary ones to own advantage or removing them
Alternative Solutions for Technology Transfer	Identify solutions by taking cues from alternative systems that perform a similar Function in a different context to carry out a Technology Transfer cross-domain
Pointer to Physical Effects and MATCHEM	Imagine performing the desired Function by exploiting a different Physical Effect or other sources of energy, to outline alternative solutions
<b>STEP 2</b>	<b>After choosing one of the alternative solving directions, in this step there is an attempt to contextualize and evolve it, identifying the technical contradictions and resolving them</b>
Technical Contradictions	Identify the parameters that determine a Technical Contradiction in the system
40 Inventive Principles	Overcoming the technical contradictions by applying the 40 Inventive Principles
Evolutionary Trends	Imagine how the solution might evolve in the future based on the TRIZ Evolutionary Trends
Patent Analysis	Compare the solution with state of the art, to verify the FTO and take inspiration from existing patents

## 4. Experimental stage and Testing

The AI-based software for Problem-Solving was tested directly in the field, employing it as a tool that supported students during lectures in the “Product and Process Innovation” course in the academic years 2023/24 and 2024/25, then allowing it to be used during the months of exam preparation and production of related end-of-year projects. As AI performance progressed over the months and updated versions of LLMs were published, the software was progressively optimized in order to improve the quality of the response as much as possible, but its structure, the type of prompts implemented, and the methodological flow according to which the tools and TRIZ principles were organized remained consistent over time. The control sample on which to base the comparison is derived from the historical record of assignments, projects and final exams collected in Innovation and TRIZ courses during the years prior to the appearance of this software and, in general, of the various text-to-text Generative AI tools and applications. These documents are also complemented by an evaluation related to the decades of experience of the professors involved in the research on the respective disciplinary areas of expertise and the collaborative activities carried out with companies from different industries.

### 4.1. Experimental sample

The software was tested on the following pool of candidates, by voluntary application, specifically involving students with different levels of preparation on TRIZ methodology and variegated educational and work background (aged between 19 and 28 years), but also professionals in different areas of the engineering field, although in the industrial context the sample is not large enough so far to derive meaningful statistics but only qualitative feedback:

- 80 students (2 classes of 40) from the master's degree program in mechanical engineering who attended a semester course in “Product and Process Innovation” (48 hours) learning the principles of the TRIZ method;
- 150 students (5 classes of 30) from ITS Academy (higher technological institute) who attended a course on “TRIZ and systematic innovation in the AI era” (32 hours);
- 10 students from the master's degree program in biomedical engineering who completed an intensive one-day course on innovation and environmental sustainability, without going into detail on TRIZ methodology;
- 3 bachelor's degree students in mechanical and management engineering who individually conducted a thesis case study using the software, without any prior knowledge of TRIZ;
- 3 PhD students conducting research on topics related to innovation, TRIZ, Problem-Solving and patents;
- 1 full professor with 20 years of TRIZ teaching career and 4 associate professors with 5 to 10 years of experience in industrial design and technical drawing courses, sustainability, and systematic innovation with TRIZ;
- 2 heads of R&D departments of companies in the mechanical and digital services sectors;
- 10 engineers from different branches of the manufacturing sector who attended a 2-day course on TRIZ and innovation (aged between 35 and 60 years).

#### 4.2. Case studies addressed in the tests

As regard the selection of case studies to be used as test, the choice was made for topics that were accessible to all candidates without the need for in-depth prior knowledge, so as not to affect the quality of the answers obtained, but at the same time to be challenging, regardless of one's level of education, so as to stimulate the desire to find innovative solutions to problems often related to everyday life. However, these problems were strategically formulated by the teachers in order to include implicit complexities with which the candidate had to interface in his search for solutions.

1. Car snow chains that are easy to apply, possibly without having to physically touch them for fastening;
2. Steam iron with safety system that prevents a fire when forgotten on a dress;
3. Shower squeegee to remove water droplets and prevent or eliminate limescale;
4. Car that covers the same route on a busy city street but consumes half as much fuel;
5. Light bulb that illuminates a room all day but costs half as much in energy;
6. Lid of a hot water tank for industrial use that must allow large objects of variable shape to be submerged at irregular intervals automatically and without dissipating too much heat, but on a limited budget.

These exercises, which are derived from reworkings and readaptations of case studies truly faced by the authors during projects and collaborations with companies, are intended to measure the potential of software when called upon to assist the user in two typical scenarios. The first reflects cases in which it is relatively easy to find some solution to the problem, but none of them stands out particularly for inventiveness and generally falls back by inertia into existing solutions that are often neither really interesting nor patentable (for most candidates, exercises 1, 2 and 3). The second refers instead to cases where one encounters more complex problems characterized by multiple externally imposed constraints, which lead the problem solver to run up against a psychological wall that prevents him from even developing a single solution (statistically, exercises 4, 5 and 6).

In order to find valuable solutions, the mental step that each student is asked to perform is to reformulate the problem to identify the real function in which he is interested, abstract the system that is desired to innovate, and thus identify a range of solutions that is as wide and varied as possible, without discarding even the seemingly more exotic cues, which are often the very ones that lead to the most innovative solutions. For example, when dealing with exercise number 3, one should not just imagine alternative squeegees, falling into the cognitive bias of always thinking of objects similar to existing ones, but should reason about the concept of function that that system performs. Only in this way can one come, in a systematic way and not by pure intuition or chance, to realize that among the families of solutions next to the most obvious one of “Clean the glass” we can also find the function “Do not dirty the glass,” thus imagining water-repellent coatings, water purification systems from limescale, diverters that prevent water from reaching the walls, showers without glass or even without water! But equally good solutions could also come from the “Don't clean the glass” function, for example, thinking of satin glass that hides limescale, retractable glass when

not needed, but also automatic cleaning systems by transferring the technology of car windshield wipers or that of robots for cleaning aquarium and swimming pool windows.

The tools in Step 1 of the software, used recursively, therefore emerged as particularly useful for exercises 4, 5 and 6 precisely because they help in the reformulation of the problem and stimulate lateral thinking to find alternative cues and solutions that break down the psychological wall that prevents from finding even a solution to the problem. Step 2, on the other hand, appeared very effective when the user, having identified a possible solution direction, wanted to try to contextualize it better and evolve it, getting help in applying more complex TRIZ tools such as contradictions or accessing the patent source, so especially for exercises 1, 2 and 3 where the candidate generally manages to find several solutions but none of them yet appears to be entirely ideal.

## 5. Results and Analysis

### 5.1. Strategic query formulation

The first consideration that needs to be pointed out is that relating to the influence that more or less appropriate wording of the input sentence can have on the user's interaction with the software. The system is capable of understanding the request even if it is expressed in different forms, but it has generally proved to be more effective when asked to analyze a system (that is, a product, a process or a method), a system with the related problem to be solved or goal to be achieved, the function to be performed, but also directly an initial hypothesis of a solution that the software will have to try to evolve. One of the advantages that has been observed in educational terms is the fact that, to obtain an answer that is more useful for the purposes of the problem-solving activity, the student is asked to think carefully about the problem to be solved, reformulating it iteratively to find different ways to express it, focusing especially on the concept of the desired function. In order to find a solution that is not obvious, in fact, it is not enough to look for the system as a “structure,” that is, as the physical element that we are used to seeing when we think of that system, since the software would also return suggestions that refer to that same structure, thus going to limit the user even more, who will only be able to think of systems and solutions that are similar to those he already knows.

For example, in Exercise 1, the real target function to focus on is to ensure adequate vehicle grip on snowy or icy roads, actually even without the requirement to use chains with the design we are used to. Artificial Intelligence, in fact, being trained on natural language documents that replicate human reasoning, also unintentionally reproduces the cognitive bias mechanisms that characterize humans. Instead, by forcing AI to reason in terms of function, it is like pushing it to perform analysis in broader terms, breaking out of the constraint of the system we know, enhancing its abilities to abstract and identify similarities with other systems. The best strategy therefore becomes to not limit ourselves to a single search, but to repeat the process recursively, formulating the query in all the previously mentioned variants, each expressed alternatively with synonyms and periphrases, so as to advantageously exploit the non-repeatability that characterizes AI responses to obtain different and useful results each time.

To give another example, when the student faces the second exercise concerning a clothes iron with a fire extinguishing system, first of all he runs into a homonymy problem that is not at all obvious to the AI. In fact, by simply searching for “iron,” the software may respond by referring to the clothes iron, which tends to be steam-powered, but also to a hair straightener or the generic metal material. Only those who are able to grasp the really desired function, going beyond the concept of steam iron, understand the advantage of asking the software for solutions to “remove creases from a fabric” or “flatten a tissue,” getting suggestions and alternative solutions from which they can make TT. For instance, following this approach, some students caught the software's cue to take inspiration from the techniques to remove creases on car seats, or from hot press machines, or even just from the concept of hair straighteners, breaking out of their mental preconceptions and finding potentially innovative solutions.

### 5.2. Advantages for students and teacher

Overall, the main advantages highlighted by the students within the survey submitted at the end of the activities are related to the benefit of having a logical order according to which to use the various tools and suggestions on how to better apply them, allowing them to overcome the mental block condition of not having new ideas, as well as the effect of being stimulated to break out of their mental patterns to strive for original solutions. In order to have a direct

comparison with other tools a student might today choose to interact with, in some of the tests candidates were asked to first make use of GPT, Gemini, Claude or other LLMs to interrogate the chatbot and autonomously drive the problem-solving process. The limitations highlighted using these models, besides the difficulty in formulating a chain of prompts adequate to obtain answers that follow a truly effective mental path leading to the identification of a satisfactory number of possible solution directions, are mainly related to the fact that, since they are general purpose models, they return less focused information on the problem to be analyzed and on the specific solutions that can be implemented. Thus, on the whole, they turn out to be less exhaustive and, to date, do not guarantee completely reliable access to external sources of technical knowledge, especially regarding patents. As a result, 90% of the candidates gave a favorable opinion of the software developed by the authors and prefer to have the tool at their disposal during self-study activities and as a support during the performance of assignments and final projects. The student is guided through a process that follows a series of established mental pathways that have proven to be reliable and effective for doing TRIZ, since they trace the methodology used by experts in the field, which, on the other hand, a non-expert user would be unlikely to implement on his own.

The tool may not even be able to suggest 100% of the answers or directly return definitive solutions, but in any case any insights provided will be useful and result in substantial time savings, because anyway the learner would have needed to go through that mental process of identifying all possible solution directions, and then decide later whether to accept or discard them. At the same time, for teaching purposes, the inherent limitations that characterize AI, paradoxically, can also become a positive aspect for learning, because the fact that it is sometimes unable to generate fully comprehensive answers means that the software never completely replaces the student's role, providing only hints that would not be sufficient to answer the requests correctly, but leaving it up to the user to figure out what suggestions are worth exploring and how to expand on them to construct his own answer, also based on his expertise on the methodology. This new mode of interaction also makes it easier and much quicker to apply an iterative process, which is essential to carry out the TRIZ methodology correctly. In fact, by simply querying the chatbot in succession or opening a new dialog box, it is possible to repeat a single step or the entire analysis, choosing the desired level of detail and refining the accuracy of the query, all with real-time feedback of the variation in the response, contextualized suggestions from the LLM, and the corresponding patent search.

In any case, this instrument can then always be used with the function of knowledge dispenser in those areas where the user lacks sufficient expertise. The knowledge retrieval capabilities of AI, in terms of the amount of information found and speed of search, are a useful contribution to a user at any level of experience. It provides an immediate benefit by making known an existing answer of which the user was unaware and which may even directly prevent him from carrying out that problem-solving task he was convinced that he needed to undertake. LLMs' abilities of understanding semantics and identifying logical connections between concepts also facilitate the development of links with extra-domain systems from which to take cues for innovative technology transfer. In fact, one of the tools that is most effective is precisely the module related to the generation of alternative solution directions, which allows the user to range over a considerably wider field and in an extremely short time than a human could do even with the help of the Web as a source of knowledge.

On the other hand, one of the main drawbacks that some students have reported is related to the fact that sometimes the software's suggestions appear too obvious or conversely too exotic, and that this has led them to get confused, distracted from the objective or lose confidence in the tool. In this case we get back to the concept of mental disposition previously addressed, that is, the need to further work on making sure that all students are able to grasp the potential of each suggestion and evolve it into interesting solutions, without discarding it out of hand. Properly those students who grasped the most original stimuli were the same ones who reported solutions that were quantitatively and qualitatively better than average. As an example, in the first exercise, only 30% of candidates developed the seemingly trivial suggestion that “in case there was no snow, snow chains would not be necessary,” to try to evolve this concept by thinking about it in relation to the desired function of ensuring adequate vehicle grip on snow, without necessarily using actual chains. In this way, placing themselves in a correct non-inertial mental disposition, some candidates hypothesized original solutions that involved “making snow not exist” only in the operational zone that we really care about, that is, the point of instantaneous contact between the wheel and the ground, imagining methods to move the snow in front of the tire by means of a small snowplow, but also to melt it thermally or chemically.

In the third exercise related to the shower squeegee, students who had shown difficulties doing the exercises on their own, with the help of Step 1 picked up the suggestion of “using water to remove water itself,” moving out of the

constraining idea of a squeegee and broadening the vision of the problem to the concept of a desired function, finding solutions that are not obvious, such as creating grooves in the glass that are designed to concentrate water droplets so that, as they become larger and heavier, they can “remove themselves” by falling downward by gravity.

Table 2. Summary of key qualitative considerations.

<b>CONSIDERATIONS ON THE RESULTS OF SOFTWARE EXPERIMENTATION</b>	
<b>STEP 1</b>	
I.	It resolves the necessity by students to have a guided and consolidated pathway to reformulate the Starting Problem, decompose it into sub-problems and break down psychological inertia to define the real Objective Function. With the help of classic general purpose LLMs, it is more difficult to reproduce this process independently and access useful technical sources for problem analysis.
II.	Enhances human-AI interaction by incentivizing an iterative process to investigate complex technical problems based on the level of detail the user is interested in, generating alternative solutions, selecting the most interesting direction, and progressively moving closer to its ideal evolution.
III.	It performs the function of a Knowledge Dispenser, returning an immediate solution to the user when it already exists, also exploiting patents as a source of technical information accessed in a simplified way. In 40% of the case studies addressed, the solution that was thought needed to be generated through a problem-solving process actually turned out to be already ideated and implemented.
IV.	It identifies contextualized Alternative Solutions, expanding the concept of function even in cross-domain contexts from which to take inspiration to accomplish a Technology Transfer, leveraging AI's capabilities of semantic understanding and identification of logical connections, extremely faster than would be possible even for a user leveraging the Web source.
V.	It reduces the amount of time required by the instructor for teaching without compromising its effectiveness by incentivizing software-assisted independent work. Through RAG, it has the ability to provide verified information tailored to the purpose.
<b>STEP 2</b>	
VI.	It supports the user in identifying Technical Contradictions, one of the most complex steps in TRIZ, saving much learning time. The student is relieved of this effort, but is much more likely to be able to develop and evolve the final solution correctly from this hint.
VII.	It ensures greater simplicity in the application of the 40 Inventive Principles. They were used poorly in the past, due precisely to the difficulty in formulating contradictions correctly.
VIII.	It gives the possibility to leverage the patent source to do FTO or take inspiration for finding new solutions, without the need to be an expert in the field since the search is done in a fully automated way through professional database APIs.

Based on the statistics gathered, about 70% of candidates perceived Exercises 4, 5 and 6 as more complex to solve, that is, those in which there tends to be a mental block and it is difficult to even find a single solution. Thus, in these cases, the software proved particularly effective, especially through the tools contained in Step 1, because it allowed them to broaden their view of the problem, reformulate it to identify the real desired function, and highlight additional resources and physical effects that could be exploited. For instance, in exercise 4 concerning the consumption of a car in city traffic, the software first made it known even to those who were unaware that there is already a solution that performs the desired function, that is the start-and-stop system, and then proposed a problem-solving path by encouraging the user to consider parameters related not only to the car but also to the road or traffic itself on which they could reason to find a solution. Also in exercise 5 about the light bulb, the software made a key contribution as a knowledge dispenser, suggesting the idea of considering the critical flicker fusion frequency as a parameter to play on to hypothesize a rapidly flickering light bulb, or again in exercise 6 for hot water tank insulation, it enabled the identification of existing solutions such as floating spheres for pool and reservoir covers, which can be evolved into the idea of a layer of dense gas floating on water and acting as an insulator.

This second group of exercises, submitted to students in past courses without the availability of the software, generated great difficulties, so much that about 75% of the candidates could not identify at least one novel solution. To date, the same exercises, are in more than 80% of cases solved with at least one solution that is not obvious, even by students who do not show strong creativity. The software gives the advantage of providing suggestions that any average user is able to recognize as interesting and then evolve them according to his own skills.

Looking instead at the teacher's point of view, the implementation of this tool has forced the authors to define a reasoned and predefined structure to order within the software the various tools of the methodology, which by its nature has instead always been rather variable and flexible, instead now giving students a safe reference point on

which they can always rely during their learning. As also explained above, another huge advantage is the ability on the part of the instructor to customize the tool with great freedom according to his own teaching purposes, including, for example, fixed textual parts of explanation alongside the AI-generated content, as well as the possibility of keeping track of the veracity of the information by taking advantage of RAG technology, thus uploading selected documents from which the model extracts the information on which to base its answers, such as patents.

One of the most surprising results is related to the fact that now the same course can be conducted in a shorter time, achieving satisfactory responses due to the fact that the student is assisted during various stages of learning by a tool with which he can interact independently and which clarifies many of the difficulties that typically arise. For example, to explain the most complex module of the methodology concerning technical contradictions, the teacher typically took 12 hours of class time, and only 30% of the students were then able to apply this concept correctly on the final exam. Thanks to the use of the software, the same topic was instead explained in just 2 hours and the percentage of students who did the project correctly rose to 60%. The teacher thus takes significantly less time to teach a complex topic achieving a much greater yield. The most onerous complexity is delegated to the software, leaving the student only the parts he is really called to reason about, finding more solutions and perceiving less frustration.

## 6. Conclusions

The software and methodology presented, overall, yielded satisfactory results both from the teacher's point of view and in terms of the feedback obtained from the students, confirming the initial expectations related to the great potential that this new generation of AI-based tools could have in the field of education, an area within which the perspectives are still very broad and numerous contexts in which interesting possibilities for development and application are evident. The next goal of this work will be to extend experimentation to the business context and to continue to enrich the software with TRIZ methods and tools not yet implemented.

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