Insight into STEM Education

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Abstract. This article explains the importance of problem-solving skills in STEM education and why insight is an efficient problem solution searching technology. This paper uses the searching inference model to propose insight as a mechanism in heuristic thinking used to help cognitive agents restructure problem formulation and find problem solutions quickly and efficiently. Lastly, through reviewing previous empirical researches, this paper provides the most reasonable assumption about students can use visual-spatial training and mindfulness meditation to help students develop heuristics to solve STEM problems. The visual-spatial training can include the 3D STEM education game and 3D virtual geometry game. Besides, the mindfulness mediation can be training and used to develop mind-flow states, and it also can increases the insight experiences. This paper suggests that future research should increase the sample size and use tools such as fMRI to demonstrate the mechanisms behind heuristic thinking training. As STEM education is relevant to the country's engineering, science, and economics, integrating training of students in problem-solving skills into the education system and developing students' reasoning, decision-making, and problem-solving skills by enhancing the insight experience is worth investigating for the development of STEM education in different countries.

Keywords: STEM Education · Problem-solving · Insight · Spatial-visual ability · Searching inference framework

1 Introduction

STEM is often referred to as short for Science, Technology, Engineering, and Mathematics. STEM education is dedicated to helping students solve scientific problems across different domains. Problem-solving skills are an important part of STEM education because most problem representations in STEM fields are abstract and difficult to define, called ill-defined problems. Therefore, it is important for STEM problem-solving to clearly define the relevant information of the problem and to use these features to transform undefined problems into well-defined ones, then find efficient solutions.

Cognitive psychologists are also interested in the process of how agents solve problems. Newell and Simon's general problem solving (G.P.S) and search inference framework gives a conjectural model of how people solve problems [1]. The model presents those cognitive agents (as "humans") that could enter the problem space, attempt to detect the consequences of actions, always adapt, and learn to process different cross-domain

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problem-solving [1]. Here, insight, as known as a heuristic, is the type of problem-solving technique to help agents restructure problem formulation [2]. Insight, like perceptual restructuring, can be used to provoke agents to find good problem formulation. Therefore, agents can use relevance realization to prespecifying the parts they should pay attention to in the problem spaces, so they can quickly find a problem solution [2]. If the cognitive process of G.P.S using insight to solve problems could be explored and manipulated, this would have a positive impact on the quality of stem education and the overall academic development of students.

This paper reviews the importance of insight for STEM problem-solving and then suggests how insight can be conceptualized and manipulated to its possible feasibility for use in STEM education. The paper will first review Newell and Simon's searching interference framework for how general problem-solvers uses algorithm and heuristic to solve the problem. The algorithm is the method that asks agents to find the most efficient one among infinite solutions. The algorithm cannot be used in STEM problem-solving because the ill-defined problems can cause a combinational explosion. The heuristic is often used in STEM problems by agents to transform an ill-defined problem into a well-defined problem and help people find problem solutions. Moreover, the heuristic can help agents avoid combinatorial explosions and cause "death of consciousness". Heuristics can also help agents get into a state of mind flow and improve performance in problem-solving. Here, there is experimental evidence that training the brain's ability to conceptualize visuospatial can facilitate memory and recall, and ultimately activate heuristic production. Mind flow can also facilitate heuristics, and most studies show that mindfulness meditation can help people get into a state of flow, and enhance students' visual space, and memory. Overall, the paper will conclude by suggesting that the addition of spatial conceptualization training and mindfulness mediation training to STEM education can improve students' problem-solving skills.

2 STEM Education and Problem-Solving

2.1 What is STEM?

Since the twenty-first century, there has been a growing global focus on how to harness the new industries brought about by technological advances to increase the possibilities for national economic development [3, 4]. The emerging industries require a large number of science, mathematics, engineering, and technology drivers, and as a result, a focus on how to enhance STEM (science, technology, engineering, and mathematics) education is becoming the goal of reform in primary, secondary and tertiary education worldwide [3, 5]. STEM education requires innovative, critical thinking and problem-solving skills, and creative thinking and related practices are huge drivers of new industries [6]. The extent to which STEM education is flourishing can therefore be used as an important predictor of a country's future international competitiveness and productivity [3, 6].

STEM is often used to refer to a range of cross-cutting, but highly science-related educational and vocational fields [4]. The level of STEM education varies depending on the grade level of the student, for example, primary schools level STEM education focuses solely on math and science engagement, while in middle school or high school, students learn more specific and specialized STEM educational knowledge [6]. STEM education for undergraduates is assigned courses based on specific disciplines and the courses are often interdisciplinary in area, for example, engineering technology requires the study of both math and physics as well as the computing [4].

2.2 Problems in STEM Education

STEM education focuses on competency-based, hands-on experiences, and this hands-on learning has been identified as the best way to learn the STEM model [7]. And among other things, some researchers have found through meta-analysis and statistics that the use of problem-posing, problem-solving instructional strategies, and curriculum design within the limited framework of STEM courses is most effective in enhancing desired educational outcomes and the expansion of students' subject knowledge in K-12 education [8]. Universities are placing even more emphasis on integrated STEM education. Many undergraduate and postgraduate students require interdisciplinary training. The ability to encounter obstacles and solve potential challenges in disciplines that are not one's specialty can also be one of the student qualities that universities focus on and improve [9]. Therefore, current STEM education focuses on how to help students develop rapid, flexible problem-solving skills. Analysed from a cognitive psychology perspective, as the related research work derived from STEM education requires a flexible problem-solving heuristics mechanism [10].

This heuristic mechanism is considered to be a process of importing a problem into a conceptualization and creating a set of solutions to the problem through subjective experience and cognitive orientation [10]. There may be a positive linear relationship between this problem-solving ability and the performance of the problem agents end up solving [10]. Past research has discussed different heuristics for problem-solving, and one of them, the "Aha!" heuristic mechanism, strongly predicts people's objective problem-solving abilities [1, 11]. This unique pattern of cognitive processing can be referred to as insight experience from a cognitive psychology perspective.

3 Insight

3.1 Search Inference Framework

Newell and Simon's general problem solving (G.P.S.) and search inference framework emphasized that humans have a unique intelligence as cognitive agents to solve cross-domain problems [12, 13]. In this, they discovered that humans have an insight experience to solve problems. Search inference framework poses a problem that can be decomposed into the initial state, the operator that can transform states, path constraints, and goal states [13]. The significant difference between the initial state and goal states creates a problem. If the agents try to solve the problem, they must find a pathway that will move through the problem spaces between the initial and goal state [13]. The problem solution includes any sequence of operations that must obey the path constraints to transform the initial state to the goal state [13]. Here, Newell and Simon presented two types of problem-solving methods as techniques for searching through the problem spaces to find a problem solution: algorithm and heuristic [12, 13].

The algorithm is a completely reliable strategy that is guaranteed to find an effective solution to the problem infinite number of steps or prove that no solution can be found. However, the algorithm method has to search the majority of the problem spaces, so much so that even the entire problem space has to be searched to find a solution. The number of steps agents can go through in the searching spaces and the number of options available at any sort of stage in searching spaces creates infinite solutions, called a combinational explosion. The most famous example of combinatorial explosion comes from Vervaeke and Ferraro [2], where a person in a chess game can make 30 moves and 60 turns, then the paths agents can choose are 60 times 30, quantitatively achieving combinatorial explosion. The complexity of a problem related to the rapid growth of combinational explosives, any agents and A.I. can be stuck and never finishing to compute a most effective pathway to the goal state. Therefore, the heuristic is essential for the G.P.S.

The heuristic is a problem-solving technique that improves the chance to find a problem solution but cannot be guaranteed a problem solution [2]. The heuristic mechanism includes random research, hill climbing, and means-ends analysis [14]. Here, agents can use a heuristic to avoid combinational explosives, then pre-specifying attention that what relevant information they should pay attention to and zero in on the other relevant information. Therefore, the agents can follow all the heuristics but still not achieve the goal state they ignore in advance the vast majority of possible solutions in the problem space and focus only on the small part of the space they decide to search.

Searching inference framework has been a very successful G.P.S. framework in the past but has been found to have significant errors over time. Firstly, the framework assumes that all the problems are essentially the same [2]. If one can figure out the relevance feature for all problems, problem-solving can generalize across many kinds of problems. There are many domain-specific problems in terms of skill and knowledge that seem not transferable and even incompatible [2]. For example, having a deep understanding of the swimming domain does not help people study better. In addition, the framework assumes that all the problems are essentially well-defined problems, and problem formulation is a small job compared to the solving problem. A well-defined problem states the salient difference between the initial state and the goal state, a unique solution can be shown to exist [2]. However, ill-defined problems are more common in real life. The heuristic in problem-solving presupposes that agents have the ability of problem formulation and relevance realization, but they are not the phenomena that can assume.

In here, the definition of insight was then proposed. Insight, implicit cognitive processing of relevance realization, helps us to define the well-defined problem and avoid combinatory explosion. Insight experiences are highly related to our memory capacity and the flexibility of cognitive processing, and it is responsible for helping us solve problems most of the time. From the perspective of cognitive psychology, the prospect of improving the problem-solving skills of agents is evident if scientists can turn the phenomenon of insight into a workable conceptualization.

3.2 Insight

Scientists' exploration and debate about insight have continued for half a century because some cognitive scientists believe there is no processing difference between insight and non-insight problems. All problem solving should be understood as this search inferential process. On the other hand, as this paper and gestalt psychologists have emphasized, insight is a unique cognitive processing process that can be demonstrated experimentally.

The most critical first step in conceptualizing insight is to distinguish between the processes agents use to solve insight problems and non-insight problems. Most insight problems require abstract thinking and accumulated skills, whereas non-insight problems are mostly solvable based on propositional learning, i.e., they only require practice with a rule [1, 15]. Wertheimer's experiments in 1959 revealed that what agents need to solve a completely new mathematical geometry problem is the skill or procedure of how to transform one shape into the other [16]. Non-insight problems can be solved by reasoning through formulas without thinking, as long as they are learned repeatedly. The most famous insight problem is the nine-dot problem. Nine dot problem consists of joining all nine dots with four straight lines and the participant has to draw the start of the before attempting to solve the problem, the participant is either given some simple or fewer dots question to training or is given some similar problem-solving procedure but a different problem formulation. Training [17]. The results showed that the insight problems focused more on procedures and the ability to think abstractly, rather than relying on repetitive learning [17]. More recently, experiments have also shown that agents experiencing insightful experiences can be associated with high activation of the right brain [18]. These findings all point to insight experiences as a unique mechanism used to aid agent resolution. So, is there anything can do to facilitate the generation of insight within the brain?

4 How Can Students Develop Insight?

4.1 Visual-Spatial Skills

Early experiments have found a relationship between eye movement and the ability of people to solve the insight problem, which could assume that people need to process visual information correctly in order to solve problems [19]. Recently, the scientists also proposed that there is a high correlation between spatial-visual reasoning skills associated with visual information processing and agents to provide further insight into the problem [20]. Spatial visual ability is the ability to perceive objects in the environment, and mentally imagine and manipulate objects and figures, which requires a high level of imagination and creativity [20–22]. In STEM education, the ability to have a high degree of spatial vision is associated with success in calculus, physics, and chemistry courses. Spatial visual abilities can be very helpful in providing people with intracerebral navigation, planning, and even reasoning and judgment [10]. In addition, it has been noted in the literature that sophomores lack certain spatial-visual reasoning, decision-making, and thinking skills compared to seniors, and as a result, they are less able to solve insightful problems [23, 24]. Improved spatial visualization skills may enhance the student's attention to problem-related information and thus increase the likelihood of problem solving [25, 26].

Therefore, there is a positive correlation between an individual's spatial and visual abilities and performance in specific areas related to geometric processes and the science and technology [22]. Some researchers have concluded that training students to play engineering 3D model games in groups of 11–14-year-olds can be effective in improving children's spatial-visual ability skills and training in spatial-visual skills can also influence agents' intelligence and problem-solving abilities [21]. Therefore, this paper recommends the inclusion of spatial skills development in post-primary education to enhance students' performance in STEM education, including mathematics and engineering, later on. Primary school is the most effective time to improve students' spatial-visual skills and video games related to exploring objects and geometry can be incorporated into the primary education system [27]. A review of the literature has suggested that even very brief training with 3D video games can improve mental rotation and card rotation skills in university students [28]. 3D video games can also eliminate gender-induced performance differences. In conclusion, the effect of video game training on improving spatial-visual abilities in males or females is predictable [28].

4.2 Mindfulness Training

Mindfulness training becoming very popular in university practice. On the one hand, recent literature suggests that long-term adherence to mindfulness training can improve students' spatial visualization and memory and ultimately their problem-solving skills; on the other hand, mindfulness training appears to help students enter a state of mind flow, thereby increasing their concentration and efficiency in their course work.

Mindfulness training can allow for better filtering of those irrelevant thoughts, thereby reducing interference and improving our thinking and problem solving, and it may help us easier to get into the mind flow [29, 30]. According to an experimental study by Basso's study [30], mindfulness mediation improves our Stroop performance, which is a kind of top-bottom cognitive processing, and our recognition skills. Recognition skills can help us to define problem representations more clearly, and related cognitive processing skills can help us to improve our problem-solving heuristics [30]. Results from another study also showed that university participants who received mindfulness mediation were faster at solving mathematical and physical problems that arose in STEM education. At the same time, participants also reported that they entered a 'warm, brief' mind-flow experience. The mind flow state is a state of heightened concentration and has a positive relationship with the efficiency of conscious processing, leading to an increased ability to understand and reason about external stimuli [14]. From this point of view, the mind-flow state enhances perception and observation of problems, which in turn increases insightful problem-solving.

Secondly, as discussed above, the conceptualization of insight is the ability of agents to find problem-solving skills in cognitive space that are relevant to their personal experiences. Thus, enhanced spatial vision and memory appear to be essential to the development of insight experiences. Some experiments have suggested that mindfulness meditation can improve participants' visual and spatial short-term memory fields [31]. The enhancement of short-term memory capacity has beneficial effects on both working memory and long-term memory retention. Assuming that mindfulness mediation leads to improvements in students' short-term visuospatial ability, subsequent improvements in STEM problem-solving performance, which is highly correlated with spatial problem-solving ability, should also be seen. Here, no research has yet emerged on how mindfulness meditation can improve spatial-visual ability and then enhance problem-solving skills, and this paper suggests that future research could be directed in this area.

To conclude this section, this paper argues that promoting positive thinking training in schools and student social media platforms and facilitating students' practice of positive thinking training can potentially contribute to the development of STEM education.

5 Limitations and Future Research

For the limitation, there is literature that highlights the complexity of STEM education and the many variables that affect teaching and learning in this [5]. Most of the current research can only demonstrate that spatial-visual ability and STEM education outcomes are correlated through correlation research, leaving a small proportion of experimental research focused on primary and junior high school populations, which is a small sample size and insufficient to extend to populations such as undergraduate and postgraduate students. In addition, human intelligence, quality, and environmental influences have a huge impact on educational variance, and it is difficult to determine whether spatial vision training can be replicated in universities with a certain amount of success [20]. Overall, this paper is expected that spatial-visual training and related experiment design can be replicated in k-12 and undergraduate programs. In the experimental design, the researchers should ensure that the sample is manageable, and the numbers are valid.

Moreover, all the results that show mindfulness mediation was positively related to problem-solving and mind-flow engagement are based on the combination of self-report and subjective measures. There are not sure whether the mindfulness mediation in the trial actually helped participants to enter a state of mindfulness and improve cognitive processing, perhaps as a result of repeated learning. In addition, due to the difficulty of promoting mindfulness mediation training because of the high drop-out rate of participants and the great individual variation in outcomes, it is difficult to guarantee that mindfulness mediation will have a positive impact on every student's STEM education [32]. Also, although the research literature is small, there are possible negative effects of mindfulness mediation, such as depression and nausea [32]. Future research should, as far as possible, rule out the possibility that repeated learning leads to positive outcomes and also consider the negative effects of mindfulness mediation. Measures of mindfulness mediation should be as objective as possible, such as using EEG and MRI to compare participants' intracerebral activity before and after, to draw objective conclusions.

6 Conclusion

The review focuses on how to develop student's problem-solving skills in STEM education. This article proposes that problem-solving performance can be influenced by enhancing their insight experiences. Insight is used to increase students' cognitive processing and reasoning decisions. This paper has found that insight is an important problem-solving method for dealing with STEM problems and insight as a reasoning process can be systematically trained and enhanced and has the potential to enhance the performance of STEM education through an exploration of different research papers.

The paper indicated that the integration of 3D computer games and mindfulness meditation training into the STEM education system can enhance students' spatial vision and access to mind-flow, thereby improving their ability to observe and transform problem formulations, and increase their insight experiences and ultimately improve their problem-solving skills. The limitations of this paper are that the number of empirical studies on the use of 3D virtual games to explore students' spatial visualization skills and mindfulness meditation to enhance students' problem-solving skills is small and the sample is inadequate; on the other hand, mindfulness meditation may have a negative impact on students. Future research could use a before-and-after experiment to compare the mindfulness mediation, 3D spatial-visual training, and control group participants' ability to solve the insight problem, using an adequate sample and a rigorous experimental design to see whether the two insight training protocols significantly improved participants' insight problem-solving. Furthermore, future studies can use neuroscience-related measures, such as EEG, as an alternative to self-report measures to increase the credibility of the findings.

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