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Gearing towards Efficient Problem Solving: Exploring the Determinants That Influence Success

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ABSTRACT

Enhancing students' problem solving skills is one of the primary educational challenges. For students to succeed, it is essential to determine the elements that best develop problem-solving abilities. Using SEM, a model that shows how self-efficacy, grit, utility value, help seeking behavior and executive control contribute to problem solving efficiency was developed. The path analysis, combined with students' explanation, provided strong support for the framework, and among the determinants, utility value and executive control, exerted a significant influence on problem solving proficiency. The implication of these findings is that enhancement of students' higher-order cognitive processes involved in planning, monitoring and regulating cognition and their perceptions of task usefulness should be the main goals of interventions designed to increase problem-solving abilities.

Keywords: executive control, grit, problem solving proficiency, self-efficacy, help seeking behavior, utility value

INTRODUCTION

Using student data to inform instructional decisions is becoming a widely accepted technique. Teachers are using data analytics more and more to customize curricula and teaching strategies to each student's individual needs. As a matter of fact, a lot of teachers already modify their lessons in response to the unique qualities of their students - especially their past experiences and expertise. Instructors observe how students' preferences vary in terms of learning, and when it is practical, they find and employ teaching methods and resources that suit these variances (Yotta, 2023). Others carry out structural equation modeling (SEM), which offers a guide to fully account for the performance of students.

Developing students' skills as competent problem solvers is one of the main educational issues. Filipino students have consistently demonstrated limited skills in international assessments, including the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA). Filipino students performed substantially less than the Organization for Economic Co-operation and Development (OECD) average of 472 points in mathematics on the 2022 PISA exam, with an average score of only 355 points. This significant difference suggests that, when it comes to their comprehension of mathematics and their capacity for problem-solving, Filipino students are lagging behind their counterparts in several OECD nations. Even college students have difficulty learning and comprehending mathematics; in fact, many of them failed their mathematics classes and did not complete their degree programs on time (Casinillo, 2019). Despite its significance, a lot of students say they hate math and think it is a useless, dull, and even challenging subject. It is unsurprising that mathematics presents one of the most formidable academic challenges for Filipino students (Abalde & Oco, 2023). It is imperative to concentrate on improving this problem solving skills because Filipino students struggle with this, as seen by their results on international examinations such as PISA. Enhancing their ability to solve problems would not only help them perform better academically but also provide them with the necessary tools to handle challenging situations in the real world. By placing emphasis on this, teachers may encourage critical thinking and analytical abilities, which will ultimately equip students to thrive in a global economy that is changing quickly and to compete successfully on a global scale.

Problem solving necessitates the growth of logical analysis, inventiveness, and resilience in addition to memorization. The process of solving a problem is quite complicated and entails defining the problem precisely, determining its underlying cause, coming up with several possible solutions, ranking and assessing them, and ultimately choosing the best one (Çavaş et al., 2023). If there are any mathematical procedures required to solve the problem, this skill is also necessary. Thus, for students to succeed, it is essential to determine the elements that best encourage and develop problem-solving abilities.

To address one of the primary educational challenges, this study strives to answer the following research questions:

1. What is the correlation between self-efficacy, grit, utility value, help seeking behavior and executive control and the problem solving proficiency of students?
2. How do self-efficacy, grit, utility value, help seeking behavior and executive control, interconnected through different pathways, influence problem solving proficiency as modeled by a Structural Equation Model?
3. How are determinants with significant and meaningful influence reflected in students' ability to solve quantitative problems in chemistry, as demonstrated by their performance on various problem-solving tests and their responses during interviews?

With the help of Structural Equation Modeling's strong statistical framework, teachers can represent, estimate, and test a network of relationships between several factors and their complex interactions at once. This in turn helps to guide instructional tactics and focused interventions. SEM gives educators the ability to make well-informed judgments that improve instructional strategies and maximize learning objectives according to students' capacity for problem-solving. While SEM offers highly comprehensive quantitative approach, this study is subject to certain limitations. Specifically, the determinants of problem solving efficiency examined in this research were confined to self-efficacy, grit, utility value, help seeking behavior, and executive control. While these elements are crucial, other possible influences that might possibly have a major impact on problem-solving ability are not included in the study.

LITERATURE REVIEW

Problem solving cognitive skills entail the ability to identify and define problems, come up with possible solutions, assess their efficiency, and decide on the best line of action (Jonassen, 2000). Problem solving is the capability for critical thought, analytical reasoning, and productive creation—all of which require aptitudes in mathematics, communication, and critical thinking. Students were able to apply their mathematical knowledge through problem-solving, integrate and link unrelated mathematical ideas and achieve a more profound conceptual understanding of mathematics as a field (Lester & Cai, 2016).

In the process of addressing quantitative problems, students frequently make a variety of mistakes and difficulties. According to Newman (1977), student's errors are classified into reading, comprehension, transformation, processes, and encoding errors. Mistakes made during the initial reading of the problem, often due to misinterpretation of words or phrases. Comprehension errors arise from a failure to fully understand the problem or its requirements. Transformation errors are made when converting the problem from its verbal form into a mathematical equation or expression. Students can identify an operation or series of operations, but they are unaware of the steps involved in correctly performing the process. Process errors occur during the execution of mathematical operations essential for solving the problem. Encoding errors are mistakes that happen when recording the final answer, including misrepresentation of the solution or improper notation. Similar findings were made by Inci Kuzu (2021), which indicated that the students' potential problems were a lack of conceptual comprehension and vocal language deficiencies. According to research by Lin and Chiu (2004), students frequently take the problem's figures and statements, execute calculations without considering if they are correct, and then ignore how the problem's associated concepts relate to one another. When faced with a difficulty, students frequently have a tendency to search for figures or statements that seem instantly relevant. This avoids the important step of participating in deeper knowledge retrieval to confirm that the approaches they are using to address the problem are acceptable.

The synergy of cognitive, affective, and social cognitive factors profoundly influences students' problem solving proficiency. Cognitive elements such as executive control and utility value dictate how students approach and manage tasks. Affective traits like grit provide the perseverance and passion essential for overcoming challenges. Social cognitive aspects, including self-efficacy and support seeking behavior, shape learners' beliefs in their abilities and their willingness to seek support when needed.

Self-efficacy and Problem Solving Proficiency

Empirical studies reveal that students' self-efficacy significantly enhances their problem-solving skills by molding their problem-solving methodology and cultivating a more resilient and strategic mindset that is essential for overcoming complex obstacles (Zakariya et al., 2019). Moreover, students who demonstrate strong self-efficacy experience reduced anxiety when tackling quantitative problems, thereby decreasing their likelihood of encountering difficulties in mathematics (Rozgonjuk et al., 2020; Zakariya, 2021). Their elevated self-efficacy not only enhances their accuracy in numerical activities but also liberates them from the need to engage in time-consuming stress management strategies. Consequently, these students can devote more cognitive resources to understanding and solving problems effectively. This ability to bypass anxiety-related distractions allows them to better calibrate their efforts and utilize their study time more efficiently, ultimately leading to improved academic performance (Vancouver & Kendall, 2006). Students who do not think they can solve difficulties will spend less time doing so, which will make problems harder for them to solve (Öztürk et al., 2019). Self-efficacy perception is significantly and positively influenced by the ability of the students to solve quantitative problems. A strong sense of self-efficacy encourages curiosity and self-assurance in one's mathematical skills, which results in a deeper engagement with the subject. This self-assurance promotes the application of self-regulation techniques, which are critical for efficient learning and include goal-setting, self-monitoring, and asking for assistance when needed. By using these techniques, students can improve their problem-solving skills by approaching mathematics issues with a systematic and resilient mindset. Consequently, they typically outperform their peers who do not employ these strategies in terms of results. Thus, a positive feedback loop is created when high self-efficacy and strong problem-solving abilities combine, strengthening one another and leading to excellent academic success (Nicolaidou & Philippou, 2003). However, several studies found that there is not enough data to support the claim that mathematics self-efficacy predicts students' ability to solve problems. Even if they have self-confidence, some pupils with high self-efficacy are unable to answer word problems. Unavoidably, they will doubt themselves and give up, particularly if the math word problem proves to be too challenging for them. Excessively high self-efficacy may not always transfer to students having superior problem-solving abilities, and there may be instances in which students with exaggerated self-efficacy in mathematics find it difficult to solve problems (Shimizu, 2022; Kaskens et al., 2022, Hay et al., 2022).

Grit and Problem Solving Proficiency

Grit embodies the determination and enthusiasm for achieving long-term objectives. It recognizes the value of the effort one invests in an endeavor during a particular moment. This investment requires sustained eagerness and energy over a longer time frame rather than just a quick fix. Such persistent work is essential, particularly in the face of setbacks and disappointments.

Students encounter temporary challenges or lose courage when they wish to specialize in a new field of study or learn a new approach to addressing problems, according to Ayres et al. (1990) and Torgesen and Licht (1983). In spite of these obstacles and their broken bravery, less gritty individuals typically fail. In relation to quantitative problem solving, West et al. (2016), who conducted their research on a large group of public school learners, discovered a strong positive correlation between grit and math test scores. These findings suggest the importance of grit for academic success in mathematics. When students approach tough mathematics tasks with an optimistic mindset, they not only identify the challenges they face but also come up with solutions. Grit is important because it deals with the self-regulation and tenacity required to withstand the uncertainty and frustration that come with worthwhile struggle (DiNapoli, 2023). Other than self-regulation, grit is closely associated with self-discipline and goal orientation (Duckworth & Quinn, 2009), which are also important to enhance problem solving performance. Furthermore, according to Duckworth et al. (2007), this indicates that in educational contexts, students demonstrating substantial grit tend to maintain their involvement in difficult tasks, revisiting and improving their approaches until they find a solution. Gritty students can behave more flexible and tolerant and they can also deal with problems with an analytical view. They approach difficulties with a methodical and systematic mindset, carefully analyzing the situation and considering various options before deciding on a course of action. This reflective stance enables individuals to refine their strategies and improve their problem-solving skills over time (Wilis, 2008).

Utility Value and Problem Solving Proficiency

Eccles et al. (1983) define utility value as the importance assigned to a tangible resource in achieving one's future goals. Learners tend to demonstrate higher engagement and perform well in class when they feel that what they are learning will be useful (Hulleman et al., 2008). The likelihood of students engaging with and attempting to solve academic tasks is tied to their perception of the value associated with those tasks. This perceived value, often referred to as utility value, manifests in various forms: object, activity or task-specific that influence student motivation and behavior (Harackiewicz & Priniski, 2018; Krawitz & Schukajlow, 2018). Students are inclined to invest effort in completing a task when they perceive its direct relevance to understanding the material comprehensively or its practical application in real-world scenarios. Students are more encouraged to participate more fully in the problem-solving process, not only to finish tasks right away but also as a necessary skill set for their academic endeavors if they understand how crucial problem-solving abilities are to their success in school or in their future employment. Students are more likely to tackle assignments in a course with more dedication when they place a high value on it because it fits well with their interests, career objectives, or provides excellent training.

Studies have indicated a favorable relationship between achievement and utility value. Utility value interventions aimed to enhance the perceived relevance of course material to students' lives, particularly benefiting the least successful students (Hulleman et al., 2016; Hulleman et al., 2017), notably in mathematics education (Schukajlow, 2017). Herrington et al. (2013) found that college students were more adept at integrating and applying information when taught in realistic learning settings or particular real-life scenarios. Positive attitudes toward the value of learning mathematics are typically linked to increased effort, increased self-efficacy in the subject, and engagement in the learning process—all of which are related to improved accomplishment in the subject. Students' self-confidence in their mathematical abilities is also correlated with how valuable they believe mathematics to be (Pajares & Miller, 1994).

Help Seeking Behavior and Problem Solving Proficiency

Help seeking has been considered a cognitive and social development activity for learners. Help seeking is the ability to use other people or different resources to solve problems when faced with obstacles, complex settings, or learning difficulties, according to Ryan and Pintrich (1997). This strategy entails determining when support is required, locating suitable resources, and efficiently locating and utilizing that support to resolve certain problems. Nelson-Le Gall (1981) suggested stages in the help seeking model, which was enhanced by Karebenick and Dembo (2011). Both begin with the realization that help is needed, which is brought on by running into a problem or obstacle that is beyond one's current skills. The evaluation phase then lays the groundwork for proactive and focused aid-seeking activity.

Students' academic progress has been proven to positively correlate with the organized and interactive social activity of asking for help (Karabenick & Newman, 2009). Compared to other studies, Osborne and Ma (2020) offer more proof that students' problem-solving abilities are positively correlated with their help-seeking activities. The word "stronger" refers to the fact that a sizable, randomly selected sample that was nationally representative was used in this investigation. Students who want to improve their learning and problem-solving skills frequently turn to instrumental help-seeking for assistance. Students demonstrating instrumental inclinations tend to achieve better performance compared to those exhibiting executive tendencies or choosing not to seek assistance at all (Ryan et al., 2005; Schenke et al., 2015). Instrumental help seeking entails utilizing outside assistance to get knowledge, or insights that can help with problem-solving. Students not only overcome immediate barriers but also enhance their comprehension of the subject matter and problem-solving abilities by incorporating this outside support into their own efforts. Contrariwise, without placing too much emphasis on comprehending or internalizing the learning process, executive help seekers seek assistance in order to solve problems or achieve goals. According to Ryan and Shim (2012), students are more inclined to ask their teachers for help than their peers, and they are also more likely to do so if they believe that the teacher encourages them to ask questions. Cooperative learning improves students' readiness to ask for assistance, according to Mehdizadeh et al. (2013).

Executive Control and Problem Solving Proficiency

Together with knowledge of cognition, regulation of cognition—also referred to as executive control in psychology—is one of the main elements of metacognition. Executive Control refers to the higher-order cognitive processes involved in planning, monitoring, and regulating cognition. The five stages of regulation of cognition in problem-solving are as follows: planning (identifying the goals and tactics employed to address problems), information management strategies (particular approaches that can be employed to address problems successfully), monitoring (regularly examining the application of strategies when problem-solving), debugging (a tactic to reduce confusion and effort), and evaluation (assessing outcomes) (Taasoobshirazi & Farley, 2013).

Previous studies have demonstrated that efficient problem-solving is strongly correlated with the abilities learners employ to control their mental processes (Wilson & Clarke, 2004; Desoete, 2008; Hollingworth & McLoughlin, 2005). When it comes to problem-solving, students who possess strong executive control usually use proper procedures, mathematical notations, and logical reasoning (Güner & Erbay, 2021). These students are skilled at navigating the complex processes of problem-solving and are capable of critically evaluating whether a problem is sensible and analyzing the consistency between their chosen strategies and the solutions they derive. Their self-awareness enables them to recognize when they are acting strategically or deviating from effective methods. Consciously approaching learning increases its efficacy, and these students exhibit a keen ability to monitor and modify their strategies in real-time (Sevgi & Caglikӧse, 2019). On the other hand, students who struggle with executive control have a difficult time addressing problems in a variety of ways. These students have difficulty not only comprehending the problem at hand but also choosing the best approaches to take on it and, in the end, determining the right solution. The work-checking, error-detecting, and mistake-correcting practices of students with low executive control were lacking (Güner & Erbay, 2021). More proficient problem solvers typically describe the problem taking into account all available information, while less proficient problem solvers primarily obtain mathematical operations by concentrating on the keywords (Kramarski et al., 2002).

RESEARCH METHOD

This study was divided into two phases: (1) the development and validation of instruments, including the Determinants of Problem Solving Proficiency Questionnaire (DPSPQ) and Problem Solving Test (PST), and (2) the development of Structural Equation Model of determinants influencing problem-solving proficiency among college students.

Development and Validation of DPSPQ and PST

Five significant constructs that affect problem solving proficiency have been recognized and categorized in the Determinants of Problem Solving Proficiency Questionnaire namely: self - efficacy, grit, utility value, help seeking behavior, and executive control. These constructs work together to influence how students approach and solve problems. Self-efficacy increases one's confidence to take on quantitative problems, grit drives persistence, utility value improves motivation by connecting tasks to real-world applications, support seeking behavior maximizes the use of available support, and executive control entails analyzing, planning, debugging, monitoring, and evaluating cognitive processes to strengthen problem solving techniques.

For each construct, six or more statements were generated utilizing a range of previously published questionnaires, guaranteeing extensive coverage and reliability. Some of these tools are written by Cooper and Sandi-Urena (2009) which measures students' awareness of and control over their cognitive processes, Schraw and Dennison (1994) which evaluates students' general metacognitive knowledge and abilities, Walker Wheeler (2007) which investigates beliefs regarding the practical application of mathematical knowledge, Fennema and Sherman (1976) which assesses attitudes toward mathematics, Pajares (1996) which evaluates confidence in one's ability to solve problems, and Pintrich et al. (1993) which examines motivational orientations and learning strategies. At Technological University of the Philippines, 449 students were randomly selected to complete the 38-statements DPSPQ, which was delivered with appropriate negotiations and protocols. The questionnaire is appropriate for group administration and may be completed in less time than a typical class session.

Using an exploratory factor analysis (EFA), the questionnaire's construct validity was determined. The most popular orthogonal rotation, varimax raw rotation, was utilized in principal component analysis, which yields straightforward data about which items are most closely linked to a known construct. The item's Kaiser-Meyer-Olkin (KMO) value of 0.818 indicates a good association with the other items in the correlation matrix.

There were nine constructs possible for the DPSPQ; however, two were not considered, which comprise weak items or items that did not load above 0.39 on multiple factors in the rotated solution, and general items loaded at or above 0.40 on many factors. These led to the retention of only seven strong constructs. Only 35 items were ultimately accepted for the questionnaire: six items each for self-efficacy (construct 1), grit (construct 2), utility value (construct 3), five items for help seeking behavior (construct 4), and four items each for executive control: analysis and planning (construct 5), debugging and monitoring (construct 6), and evaluation (construct 7). The factor loadings fell between 0.491 to 0.712 for self-efficacy, 0.400 to 0.742 for grit, 0.400 to 0.610 for utility value, 0.586 to 0.726 for support seeking behavior, 0.583 to 0.719 for analysis and planning, 0.435 to 0.725 for debugging and monitoring strategies, and 0.612 to 0.658 for evaluation. Afterward, the responses to these acceptable items were analyzed using Cronbach's alpha, which yielded a high reliability score of 0.836. This indicates an 83.6% trustworthiness in the scores, demonstrating the instrument's robustness and dependability in measuring the intended factors.

On the other hand, the well-defined mathematical problems in the problem-solving test were chosen from various undergraduate textbooks, specifically targeting chemistry quantitative problems. The PST was utilized to assess a student's problem-solving proficiency; scores ranged from 0 to 125 points. For every item, students received a score of 25 points. Each criterion, which included accurately identifying the provided variables, accurately manipulating the working equation, appropriately converting terms or units, accurately substituting values, and carefully reviewing the final answer, was worth five points in order to assess the students' approach to problem-solving.

Development of Structural Equation Model of Determinants Influencing Problem Solving Proficiency among College Students

In this study, the Structural Equation Model (SEM) was used to create a framework that illustrates the relations among determinants of problem-solving proficiency and how these influence the performance of the students in solving well-defined quantitative problems. The SEM is an analytical tool for examining intricate interactions between constructs and indicators.

The score of 99 students in PST and on each construct of DPSPQ were entered in Statistical Package for Social Sciences, or SPSS 23.0. This software was used to compute the descriptive statistics and correlations between key constructs influencing problem-solving proficiency. Next, utilizing the same dataset, SEM was conducted using SPSS AMOS 23.0 to evaluate the model. SEM is still reliable for small sample sizes such as 50–100 individuals (Iacobucci, 2010).

An examination of the model's fit using indices such as Steiger-Lind RMSEA, p of Close Fit, CFI, GFI, and AGFI was conducted to decide whether or not the model should be approved. This was done acknowledging that each indicator assesses different aspects of the adequacy of the model, including how closely it aligns with the data, how well it reproduces the observed covariance matrix, and how well the model fits in comparison to a reference model. Upon acceptance of the model based on different measures, the data was further analyzed by path analysis with the aim of developing a model that illuminates the connections among a set of determinants. For each variable, kurtosis and skewness were calculated prior to an empirical test of the model. According to the findings, every value fell below the absolute value of two, so satisfying the normalcy assumption. Using the maximum likelihood approach estimate, which works well with normally distributed data, the model was evaluated with this validation of the normality assumption.

Hypotheses

The following hypotheses were proposed in this study:

H_1: Self-efficacy, grit, utility value, help-seeking behavior, and executive control are positively interrelated, with each construct reinforcing the others in a mutually supportive manner.

H_2: Self-efficacy, grit, utility value, help-seeking behavior, and executive control have a significant influence on problem-solving efficiency.

RESULTS AND DISCUSSION

Descriptive Statistics and Correlations Analysis

Table 1 presents the correlation between various determinants and the problem solving proficiency of students.

Table 1: Correlation Matrix and Descriptive Statistics

Determinants of Problem Solving Proficiency	1	2	3	4	5	6
1. Self-efficacy	-					
2. Grit	0.40**	-				
3. Utility Value	0.40**	0.33**				
4. Help Seeking Behavior	.009	0.27**	0.34**	-		
5. Executive Control	0.29**	0.40**	0.49**	0.34**	-	
6. Problem Solving Proficiency	0.24	0.21	0.46**	0.13	0.39**	-
Mean	2.18	2.81	2.82	3.04	3.00	36.28
Standard Deviation	0.47	0.45	0.53	0.39	0.33	26.27
Skewness	0.25	-0.16	-0.20	0.01	-0.21	0.34
Kurtosis	1.21	-0.16	0.46	0.32	0.98	-0.97

Note. ** $p < 0.01$

Table 1 highlights a significant correlation among the different determinants of problem-solving proficiency, except self-efficacy and support-seeking behavior ($r = 0.009$, $p = 0.930$). This suggests that greater self-efficacy scores are typically attained by students who work harder, strongly believe that their learning is important, and use efficient higher-order cognitive processes involved in planning, monitoring, and regulating cognition. Conversely, students who exhibit higher levels of grit, perceive a high utility value in their learning, and employ effective executive control processes are more likely to develop greater self-efficacy. The findings also showed that students with strong executive control foster willingness to seek assistance. There is a reciprocal interaction between these factors that determine one's ability to solve problems and assist one another. But support-seeking behavior is not reflected in this reciprocal link, suggesting that learners demonstrating strong self-efficacy may not necessarily seek assistance more frequently.

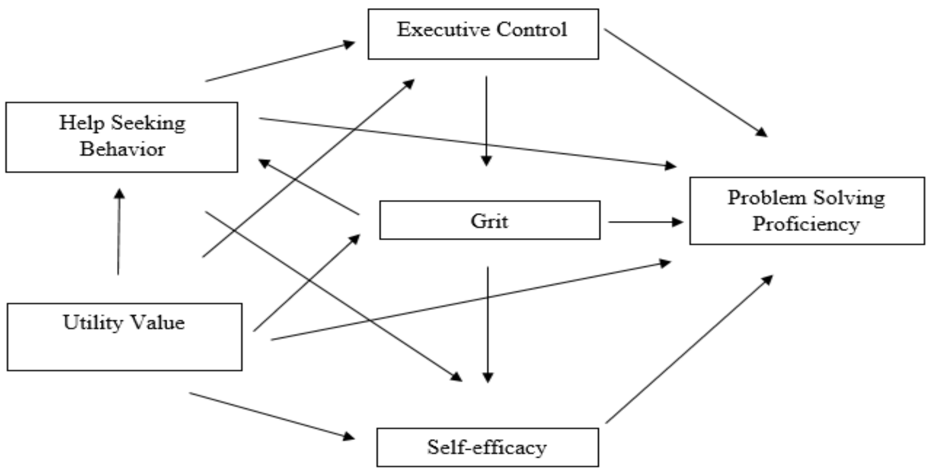
Several previous findings run contradictory to the study's hypothesis. In particular, at the 0.01 level of significance, the findings indicated that self-efficacy, grit, and help-seeking behavior had negligible relation with problem-solving proficiency. These findings imply that, in contrast to the original hypothesis, determinants like grit and self-efficacy could not have a direct influence on problem solving proficiency and that help seeking behavior may not have as much of an impact on self-efficacy as initially anticipated.

Structural Equation Modeling Analysis

Figure 1 depicts the constructed structural equation model using SPSS-AMOS, emphasizing the interconnected pathways through which various determinants influence problem solving proficiency.

Figure 1

Structural Equation Model Emphasizing the Interconnected Pathways through which Various Determinants Influence Problem Solving Proficiency



The fit of the model was determined to be excellent, as evidenced by the various indices shown in Table 2.

The chi-square test for goodness of fit is an essential test for figuring out how the restricted covariance structure matrix and the unrestricted sample covariance matrix fit together (Hu & Bentler, 1999; Byrne, 2013). The suggested model is considered well-fitted to the sample data if the chi-square value is non-significant, indicating that the observed data do not significantly deviate from the model's predicted values (Barrett, 2007). Thus, this model of determinants of problem solving performance with X^2 of 0.48 ($p = 0.503$) signifies a good fit, as the p-value exceeds the threshold of 0.05. The normed chi-square index (X^2/df) further confirmed the fit of the model, which came in at 0.448. Bhale and Bedi

(2023) state that a well-fitting model is indicated by a X^2/df score of less than 3. This number shows that the model captures the data accurately.

Table 2: Profile of the Model Indices

Profile of Indices	Best Fit Value	Statistic
Chi - square Statistics	p > 0.05 (Barrett, 2007)	0.50
Normed Chi-Square Index	< 3 (Bhale & Bedi, 2023)	0.45
Goodness of Fit Index (GFI)	> 0.90 (Jöreskog & Sörbom,1993)	1.00
Adjusted Goodness of Fit Index (AGFI)	> 0.90 (Tanaka & Huba, 1985)	0.97
Steiger- Lind root-mean square error of approximation (RMSEA)	≤ 0.08 (MacCallum et al.,1996; Brown & Cudeck,1992)	0.00
p of Close Fit (PCLOSE)	p > 0.05 (Bhale & Bedi, 2023)	0.55
Comparative Fit Index (CFI)	> 0.95 (Hu & Bentler, 1999)	1.00
Incremental Fit Index (IFI)	> 0.90 (Tabachnick & Fidell, 2006).	1.00
Normal Fit Index (NFI)	> 0.90 (Bentler & Bonnet, 1980)	1.00
Tucker Lewis Index (TLI)	> 0.90 (Bentler & Bonnet, 1980)	1.00

The degree of similarity between the observed data and the proposed model is assessed by the GFI. This index shows the degree to which the model can be replicated using actual data. It quantifies the proportion of variance in the observed data that can be accounted for by the expected population covariance (Tabachnick & Fidell, 2006). Any result above 0.90 indicates a satisfactory fit for this index, which has a range of 0 to 1 (Jöreskog & Sörbom, 1993; Hair et al., 2008). AGFI adjusts for a model's degrees of freedom relative to its total number of variables. Similar to the GFI, the AGFI varies from 0 to 1; models typically indicate good fit when the AGFI reaches 0.90 or higher. In this study, the GFI score of 0.998 suggests an almost perfect fit, indicating that the model illuminates nearly all the variance observed in the data. The AGFI value of 0.968 further supports this, indicating that the model accounts for a substantial portion of the variance while adjusting for the model's complexity.

Steiger and Lind in 1980 created RMSEA, which is a metric employed to assess the inadequacy of the estimated fit with the population data (Steiger, 2016). An index of badness of fit is used to scale the RMSEA, with zero denoting the best fit. The RMSEA value of 0.00 of this model thus suggests an excellent fit, indicating that the model perfectly aligns with the observed data and effectively captures the relationships between the variables. The chance that the RMSEA value indicates a close fit is evaluated by the PCLOSE (p of Close Fit). The model fit may be almost ideal if the PCLOSE value is higher than 0.05. The PCLOSE score for the present model is 0.553, significantly above the 0.05 cutoff.

The CFI, similar to the IFI, NFI, and TLI, assesses how well the given model fits against a baseline model. It is often a null model, meaning it makes no assumptions about the relationships between the model's variables. According to Tabachnick and Fidell (2006), a model that fits perfectly would have an index of 1. However, any value above 0.90 is often indicative of a well-fitting model. In this study, the computed values for IFI, NFI, and TLI were greater than 0.90. The Comparative Fit Index score of 1.00 demonstrated a great fit, indicating that the proposed model adequately captures the data and supports the predicted relationships between the variables.

Path Analysis

Geneticist Sewall Wright first devised path analysis in the 1920s to quantify the direct effect along an interconnected pathway and, thus, to assess the degree to which a given criterion is shaped by distinct predictors. It implies analyzing the amounts and significances of direct, indirect, and total effects among variables using a graphic representation of a SEM (Lleras, 2005).

Table 3: Standardized Direct Path Values in the Structural Equation Model of Determinants Influencing Problem Solving Proficiency among College Students

Predictor	Criterion	Standardized Path Coefficient	p-value
Self-efficacy	Problem Solving Proficiency	0.019	0.850
Grit	Self-efficacy	0.331	0.000
	Help Seeking Behavior	0.134	0.194
	Problem Solving Proficiency	0.016	0.873
Utility Value	Self-efficacy	0.364	0.000
	Grit	0.189	0.073
	Help Seeking Behavior	0.299	0.003
	Executive Control	0.436	0.000
	Problem Solving Proficiency	0.363	0.000
Help Seeking Behavior	Self-efficacy	- 0.206	0.027
	Executive Control	0.160	0.092
	Problem Solving Proficiency	- 0.076	0.437
Executive Control	Grit	0.286	0.008
	Problem Solving Proficiency	0.226	0.003

Table 3 presents the standardized direct path values along with the corresponding p-values, offering a quantitative evaluation of the variable correlations. Furthermore, the model is graphically represented in Figure 2, which helps to clarify the structural linkages and the statistical importance of each path in the model. A threshold of $p > 0.05$ guided the assessment of statistical significance for the direct path values. Standardized path values falling within the range of 0.05 to 0.10 indicate low yet significant determinants; those between 0.11 and 0.25 represent intermediate-sized determinants; and values above 0.25 denote large-sized and influential paths. These guidelines help in classifying the strength and significance of the relationships among interconnected pathways in a model.

Six standardized direct paths were identified as large in size and statistically significant, suggesting substantial and impactful influences within the model ($p < 0.05$). Grit exhibited a significant and substantial influence ($\beta = 0.331$) on self-efficacy, suggesting that determination and enthusiasm for achieving long-term objectives contribute to enhanced beliefs in one's capabilities. Utility value demonstrated significant and substantial influences on self-efficacy ($\beta = 0.364$), help-seeking behavior ($\beta = 0.299$), executive control ($\beta = 0.436$), and problem-solving proficiency ($\beta = 0.363$). This suggests that learners who perceive quantitative problems as pertinent to their daily experiences tend to have faith in their ability to organize and execute problem-solving tasks effectively, engage in collaborative learning, apply metacognitive strategies, and achieve better problem-solving proficiency. Moreover, executive control was identified as a substantial determinant of grit ($\beta = 0.286$); those who had higher levels of grit were those who showed good cognitive process management. Effective regulation implies that they were better able to control their determination and enthusiasm for accomplishing long-term objectives in spite of difficulties.

The significant and large influence of utility value on problem-solving proficiency aligns consistently with findings across various studies (Schukajlow, 2017; Pajares & Miller, 1994). These studies revealed that when students perceive problem-solving tasks as relevant and connected to real-world situations, their learning becomes more effective. This practical relevance assists students in recognizing the real-world applications of their learning, which enhances their engagement, self-efficacy, and motivation. As a result, they are inclined to commit the necessary effort and employ effective strategies to arrive at the best solutions. This alignment between perception and performance emphasizes the importance of designing educational experiences that integrate real-world contexts to enhance problem-solving skills.

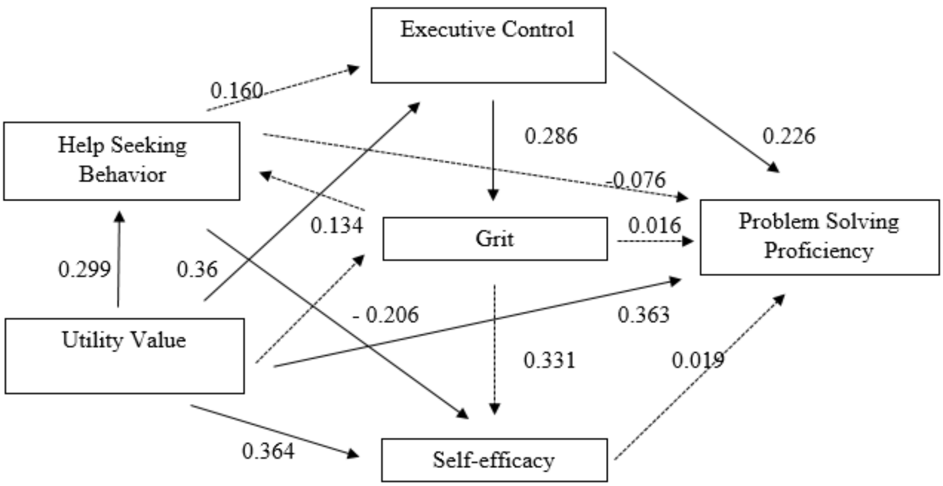
Utility value is a moderate and significant determinant of grit ($\beta = 0.189$), and those who perceive the relevance of their tasks tend to demonstrate elevated levels of grit. Help seeking behavior had a positive moderate influence on executive control ($\beta = 0.160$) and had a detrimental effect on self-efficacy ($\beta = -0.206$), suggesting that while collaborative strategies enhance the higher-order cognitive processes involved in planning, monitoring, and regulating cognition, they might lower self-efficacy due to dependence on others. Grit was found an intermediate determinant of help behavior ($\beta = 0.134$), showing that more gritty students are inclined to engage with peers and seek assistance. Lastly, executive control was identified as an intermediate determinant of problem-solving proficiency ($\beta = 0.226$), indicating that students who actively regulate their cognitive processes perform better in problem-solving tasks.

Path coefficients between help seeking behavior and self-efficacy reached statistical significance at the 95% confidence level. The direct path from help-seeking behavior to self-efficacy was intermediate-negative in size ($\beta = -0.206$), signifying that learners who frequently ask for support and learn collaboratively tend to have lower self-efficacy. This finding contrasts with much of the existing literature, which suggests that learners with low self-efficacy for learning are inclined to refrain from seeking assistance due to fears of appearing less capable than their peers (Kiefer & Shim, 2016; Ryan et al., 1997). However, the deviation in this study's results suggests that the sampled students view help-seeking behavior as a strategic advantage for learning. Students with lower self-efficacy in this study recognize their need for assistance and actively seek help, understanding that collaborative learning can be beneficial. They are not deterred by negative criticism, which demonstrates a practical adaptation where students leverage available help to enhance their learning outcomes despite their initial low self-efficacy.

Furthermore, the path coefficient between executive control and problem solving proficiency demonstrated statistical significance at the 0.05 threshold, indicating a meaningful relationship between these variables in the model. The moderate-sized and significant influence of executive control on problem solving proficiency is supported by various studies (Wilson & Clarke, 2004; Desoete, 2008; Hollingworth & McLoughlin, 2005; Güner & Erbay, 2021; Sevgi & Cagliköse, 2019), highlighting executive control abilities, such as strategizing, monitoring progress, and self-assessment, lead to greater success in problem-solving. Their research revealed that failures in executive control often stem from an inability to organize mathematical operations, select the most effective methods, analyze problems accurately, understand the problem's core issues, and monitor or control the operations performed.

Figure 2

Path model for effects of the Different Determinants Influencing Problem Solving Proficiency among College Students



Note. Solid paths represent significant Direct Path coefficients.

Consistent with the findings of the correlational analysis, self-efficacy (β = 0.019, p = 0.850), grit (β = 0.016, p = 0.873), and help-seeking behavior (β = -0.076, p = 0.437), were found to have no notable impact on problem solving proficiency. These results align with a minority of studies that posit the contrary. For instance, Shimizu (2022), Kaskens et al. (2022), and Hay et al. (2022) demonstrated that self-efficacy is a weak predictor of problem solving proficiency, noting that learners sometimes develop overconfidence regarding their capabilities, which can hinder their actual performance. Some students with strong self-efficacy might encounter challenges to solve quantitative problems even when they are confident in themselves. As a result, student could unavoidably feel self-doubt and give up when presented with really difficult math word problems.

The lack of significant influence of help seeking behavior on problem solving proficiency may stem from the observation that many learners scoring high in help seeking behavior also have low self-efficacy, meaning they lack confidence in their own abilities. Their excessive need for outside help is a result of their lack of confidence, yet this dependence does not necessarily result into better problem-solving abilities. Instead of developing their own skills, these students become reliant on others, which perpetuates their low self-efficacy and hinders their ability to solve problems independently. When students use expedient help-seeking, they usually look for quick cuts, expect others to finish work for them, or ask for answers up front without really trying to understand the problem. Such actions can have the opposite effect, sometimes leading to worse academic results and higher anxiety levels in students.

Furthermore, the absence of a correlation between help seeking behavior and problem solving proficiency can be attributed to many students' strong desire for autonomy and independence (Deci & Ryan, 1987; Butler, 1998). Students prefer to rely on their own abilities rather than seeking external assistance, and because of patience and hard work, these occasionally improve their problem-solving abilities. According to Ryan et al. (1997), some students choose not to ask for assistance in order to preserve their good perception of themselves in society and their value. As per Kiefer and Shim (2016), students' negative behavior when seeking academic support is mostly caused by their belief that asking for help in public suggests they are incapable of learning and that it lowers their self-esteem. Understanding the lesson or getting the right answer are outweighed by the psychological costs such as feelings of indebtedness or humiliation of seeking aid. These findings emphasize the counterintuitive relationships between self-efficacy, grit, help seeking behavior, and academic achievement, suggesting that boosting these factors alone may not necessarily enhance problem-solving skills without addressing underlying issues such as overconfidence or lack of self-efficacy.

Decomposition of Effects from Path Analysis

To fully examine the effects of self-efficacy, grit, utility value, help seeking behavior and executive control on problem solving efficiency, the indirect effect of each determinant was determined, followed by the calculation of total effect. These standardized path coefficients are presented in Table 4.

Including the indirect influences uncovered that grit, by exerting its impact on self-efficacy and help seeking behavior, produced no change on problem solving proficiency ($\beta = 0.001$). Similarly, help seeking behavior, using its sway on self-efficacy and executive control, revealed negligible effect on problem solving proficiency ($\beta = 0.033$). Utility value, through its effect on the four other determinants (self-efficacy, help seeking behavior, executive control, and grit), did not significantly influence problem-solving proficiency either ($\beta = 0.098$). Executive control, through shaping grit, demonstrated no effect on problem solving proficiency ($\beta = 0.005$).

Only utility value and executive control, out of the determinants examined in the study, were found to make a considerable difference in college students' problem solving proficiency when the total of the direct and indirect effects was taken into account. The total coefficient for executive control was ($\beta = 0.231$) and utility value was ($\beta = 0.461$).

Table 4: Direct, Indirect, and Total Influence of Determinants on Problem Solving Proficiency

Predictor	Criterion	Standardized Path Coefficients		
		Direct	Indirect	Total
Self – efficacy	Problem	0.019	0.000	0.019
Grit	Solving	0.016	0.001	0.017
Utility Value	Proficiency	0.363*	0.098	0.461*
Help Seeking Behavior		-0.076	0.033	-0.043
Executive Control		0.226*	0.005	0.231*

Note. * $p < 0.05$

These results emphasize the crucial roles that executive control and utility value play in improving problem solving proficiency. Students who find the tasks valuable have a higher propensity to adopt effective approaches and engage in profound learning, which improves problem-solving proficiency. Executive control is also of enormous benefit to successful problem solving, which entails organizing, observing, and assessing one's cognitive processes. While grit and help-seeking behavior are important components of learning in general, their indirect effects were not significant enough to significantly increase problem-solving skills in this study. This implies that the enhancement of students' higher-order cognitive processes involved in planning, monitoring, and regulating cognition and their perceptions of task usefulness should be the main goals of interventions designed to increase problem-solving abilities.

Student's Utility Value and Executive Control in Solving Quantitative Problems

A grasp of respondents' perspectives on the value of problem solving, especially in chemistry and their executive control can be understood from the examination of actual student responses.

"In response to the open-ended question, "Describe your insights into quantitative problem solving in chemistry,' several students articulated the following perspectives:

"*Solving problems, like those in chemistry, is helpful for my line of work.*"
"*In this subject, solving problems has practical applications.*"
"*It is useful, and it also serves as training for us for cultivating patience in problem-solving and enhancing concentration in classes.*"
"*Yes, it is applicable in our day-to-day activities and even in other subjects"*

“Problem solving is essential. It is about acquiring the skills necessary to create and manufacture products that will enhance and safeguard our lives.”

“I find that problem solving greatly facilitates my understanding of common phenomena, which helps me in my day-to-day activities."

The students' high utility value of chemistry problem-solving suggests that they view the practical relevance and significance of solving problems. This perception is crucial in enhancing problem solving proficiency for several reasons, including motivation and engagement, as emphasized in responses such as *"Solving problems, like those in chemistry, is helpful for my line of work"*; application and transfer of knowledge, as indicated in answers like *"In this subject, solving problems has practical applications"*; development of patience and focus, or cognitive skills, as shown by responses such as *" It is useful, and it also serves as training for us for cultivating patience in problem-solving and enhancing concentration in classes."*; interdisciplinary thinking, as indicated by " *Yes, it is applicable in our day-to-day activities and even in other subjects"*; and understanding of real-world phenomena, as demonstrated in *"I find that problem-solving greatly facilitates my understanding of common phenomena, which helps me in my day-to-day activities."*

On the other hand, in response to the open-ended question, 'When tackling chemistry problems, what are your thoughts and actions?' students provided the following insights:"

“I first tried to consider the formula and whether there might be a more straightforward approach to calculate it.”

"I analyze the question several times over."

"I attempted to remember the topics discussed."

“I tried to grasp and analyze the problem, and when that failed, I turned to my peers for assistance."

I made an effort to connect the issue to the subject. It is similar to trial and error.

"I made an effort to figure out what was required to address the problem at hand. When I get into difficulty, I attempt reading and reanalyzing the question.

“I ponder the formula to use.”

"I write down the formulas before solving a problem so that I can quickly remember them if I forget them."

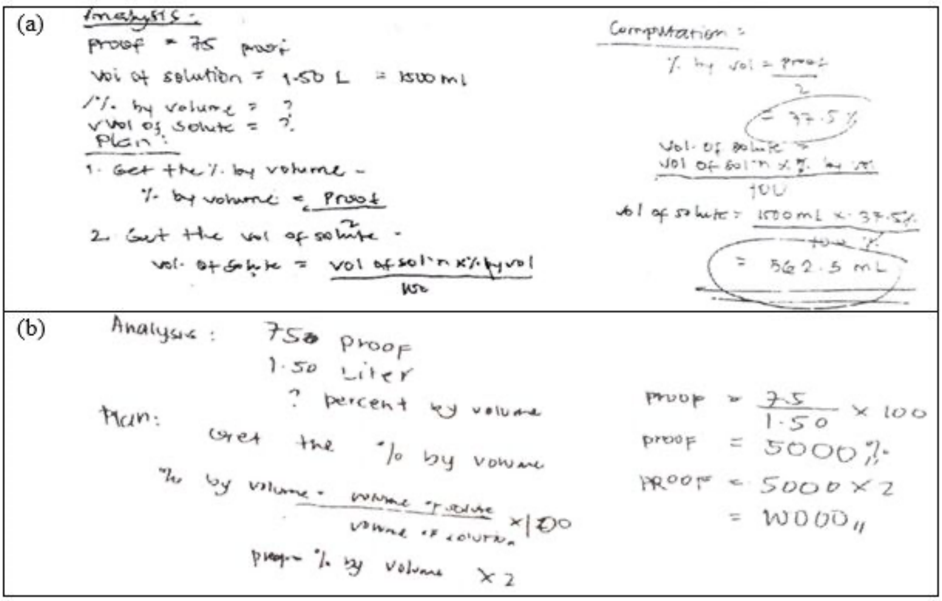
"I take into consideration another computable given."

Students' specific strategies such as remembering formulas, going over the problem several times, connecting it to the lesson, asking for help from peers, and taking into account pertinent examples all improve efficiency, comprehension, resourcefulness, and reflectiveness in their problem solving proficiency. Reflecting on their problem-solving process, considering alternative approaches, and evaluating their strategies promote executive control, leading to continuous improvement in problem-solving skills.

Figures 3 and 4 display the problem solution of students with high and low utility value and executive control.

Figure 3

Comparative Analysis of Problem Solving Approaches in Expressing Concentration: (a) High vs. (b) Low Utility Value and Executive Control

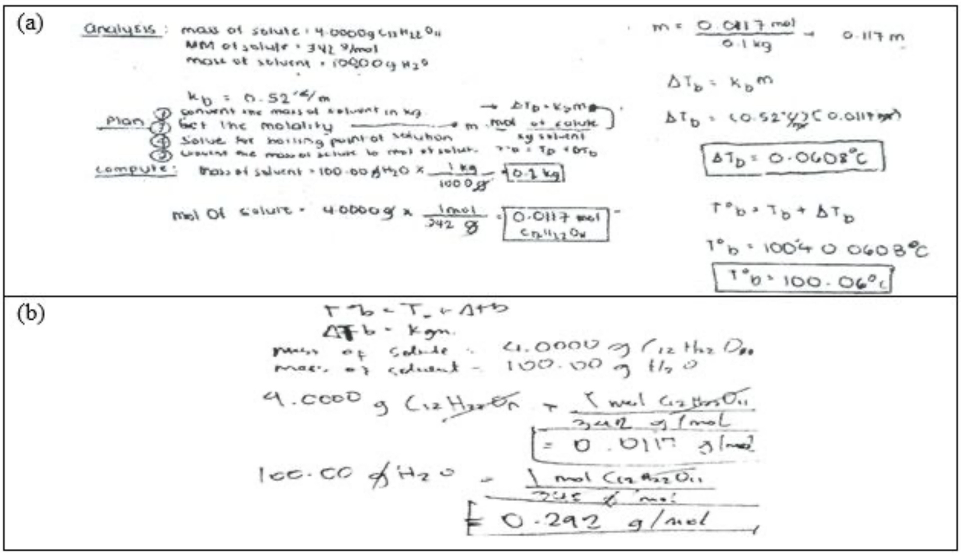


Note. This problem involves solving the following scenario: "The alcohol content of hard liquor is commonly represented by its 'proof,' a measurement defined as twice the ethanol percentage in the beverage. Given this definition, how many milliliters of ethanol are contained in 1.50 liters of wine with a 75.0 proof rating?"

A student possessing high utility value and executive control had a systematic and structured approach to problem-solving. The student showed an orderly approach by clearly distinguishing the problem's provided variables and unknown variables at the beginning of the task. The student identified the % by volume for the solution as an important component. The student understood precisely why consistent units are necessary for accuracy because, in the presented variables, the volume units were transformed from liters to milliliters before any calculations were made. The student then provided an explicit plan of action by illustrating the formulas required to solve the problem. The analysis of the given information was accurate, as evidenced by the correct selection of the formula, highlighting the strong analytical skills. The student then substituted the given data into the formula, including the units in the substitution to ensure dimensional consistency. This careful attention to detail in unit management confirmed that the resulting calculation would have the correct units. The student's algorithmic strategy was evident, as she correctly applied the formula to establish the relationship between the known and unknown variables. The methodical approach, from unit conversion and formula application to data substitution and calculation, exemplified strong executive control.

Figure 4

Comparative Analysis of Problem-Solving Approaches in Colligative Properties: (a) High vs. (b) Low Utility Value and Executive Control



Note. This problem involves solving the following scenario: "Sugar, such as sucrose, can be dissolved in water to create syrup, a viscous, sweet liquid. It is frequently used as a flavoring or sweetener in a variety of culinary applications, such as drinks, desserts, and waffle and pancake toppings. Syrup has a boiling point typically greater than pure water. Prove this by calculating the boiling point of a syrup made by dissolving 4.000 grams of sucrose in 100.00 grams water?"

A closer look at the response from a student who scored poorly on executive control and utility value indicates that the student only partially understood the problem. The student showed some understanding of the requirements of the problem by identifying the appropriate formula required to solve for the unknown variable. However, because the student misinterpreted the provided data, the student incorrectly applied the formula. The logical flow of the solution was interrupted by this misanalysis, which resulted in mistakes in the subsequent stages. As a result, the student resorted to a trial-and-error approach, indicating a lack of confidence and clarity in the problem-solving process. This method not only looped the process but also prevented the student from arriving at the correct answer. The student's inability to consistently apply the correct steps suggested weaknesses in executive control, such as planning, monitoring, and evaluating.

Throughout the interview process of the student possessing high utility value and executive control scores, the following key points were documented:

R: *“Why is it necessary to obtain the solute's molar mass in this particular scenario?”*
S: *“To obtain the mole of sugar, which is the solute.”*
R: *“Why is there a conversion from grams to kilograms in the solution?”*
S: *“It says kilogram, not gram, in the formula.”*
R: *“What does $K_b = 0.52°C/m$ mean?”*
S: *“This implies that for every 1 molal increase in concentration, the boiling point of water will rise by 0.52 degrees Celsius.”*

The student exhibited a grasp of the equation required to calculate the problem, as shown during the interview and corroborated by the procedures taken in the problem-solving process. It was evident that the student had an extensive understanding of the formula's concepts in addition to having memorized them and of how the given data relate to the formula needed to find the unknown variable. The solution was arranged and presented in a logical order. By ensuring that every step in the solution followed logically from the one before it, it improved the solution's coherence and clarity. This method not only helped her come up with the right answer, but it also demonstrated how well she could evaluate and combine data.

Conversely, the following observations were documented during the interview with a student who scored low in utility value and executive control:

R: *"You have solutions where 4 grams and 100 grams are each divided by 342. What does this represent?"*
S: *“My solution to the question ma’am.”*
R: *“Your response is noted. However, could you clarify what the problem is asking?"*
S: *Number of moles ma’am.*
R: *"Why is it necessary to determine the mole of solute?"*

S: *"That calculation is essential."*
R: *"You correctly identified the formula to solve for the unknown at the beginning, but what caused you to stop computing?"*
S: *"I intended to continue it, ma'am, but I became confused. I simply guessed instead."*

Based on the problem solution and the interview results, it was clear that the student's understanding of the problem was limited. This was notably demonstrated by the student's misunderstanding of the unknown variable within the problem statement. Instead of accurately interpreting what needed to be determined, the student misinterpreted or overlooked crucial aspects of the problem. Additionally, during the interview, the student struggled to explain the application and relevance of the two formulas provided for solving the problem. This inability to articulate a clear strategy for using the formulas indicated a lack of comprehension or familiarity with their purpose. In practice, the student resorted to guessing as a method of problem-solving. This approach suggests uncertainty and a lack of confidence in applying systematic methods or established formulas to arrive at the correct solution.

CONCLUSIONS

The findings support the correlation between students' utility value and executive control and their problem solving proficiency. Students who exhibit high levels of utility value and executive control demonstrate a systematic and structured approach to problem solving. Their ability to recognize the value of the tasks and effectively manage their cognitive processes contributes to more organized and effective problem solving strategies. The result of the study emphasizes the need for educational approaches that foster a sense of value and strengthen executive control to optimize students' problem solving abilities.

IMPLICATIONS

The findings suggest that students can improve their problem solving abilities through instructional methods and materials specifically designed to target the development of these beliefs and skills. Creating learning materials designed to enhance problem solving skills can greatly benefit students, especially when these material incorporate problem solving tasks that mirror challenges students might encounter in their future careers or daily lives, present problem solving scenarios that students can relate to, making learning more engaging and applicable to their experiences, integrate tasks that tap into students' varied backgrounds, both inside and outside of school, fostering inclusivity and relevance, provide opportunities for students to solve problems that cut across different subject areas, promoting holistic understanding and transferable skills, and design tasks that have clear connections to real-world problems, encouraging students to see the practical implications of their learning. By incorporating these principles into instructional strategies and materials, educators can significantly enhance students' problem-solving abilities.

This study has revealed several avenues for future research. First, this study has laid the groundwork by testing a model that examines specific cognitive, affective, and social cognitive variables and their impact on problem-solving proficiency. Building upon this foundation, future research could expand the scope to include a broader range of these variables. For instance, exploring how factors such as different aspects of executive control, various dimensions of grit, and nuanced aspects of social interactions like peer collaboration and mentorship influence problem-solving outcomes would enrich our understanding. Furthermore, this can be expanded by exploring how variables such as problem conceptualization, problem solving strategy, working memory capacity, M-demand, functional M-capacity, dissembedding ability, motivation, interest, achievement emotions, etc. influence problem solving proficiency. A longitudinally structured forthcoming research could offer a clearer understanding of how these variables drive achievement overtime.

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