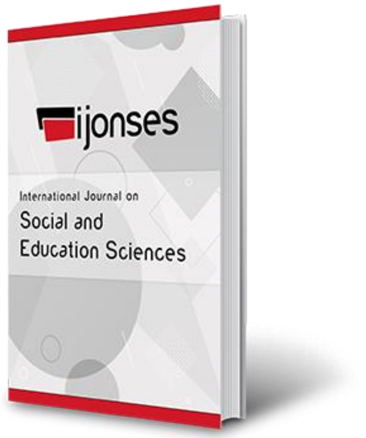

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The Mediating Role of Cognitive Load in the Relationship between Metacognitive Skills Perceptions and Problem-solving Skills in Pre-service Teachers

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Abstract

Pre-service teachers' metacognitive and problem-solving skills are highly important in the process of becoming effective teachers for providing their students with guided learning support. Determination of these two higher-order thinking processes and skills and investigation of the relationship between them is very important for enabling qualified prospective teachers to reach the necessary competencies and qualifications. This study aimed to investigate the relationship between metacognition and problem-solving skills. The study also examined the mediating role of cognitive load. The study was conducted with 342 pre-service teachers enrolled in two universities located in different regions of Turkey. Data were collected through the Cognitive Load Scale, the Metacognition Scale, and the Problem-Solving Scale. The study proposed hypotheses and models based on the theoretical framework and related research. The validity of the proposed model was examined according to the fit index values. Path analysis was performed to determine the significance of the hypotheses of the model. The results of the study showed that metacognitive skills perception directly and positively affected problem-solving skills perception. On the other hand, cognitive load did not mediate between metacognitive skills perception and problem-solving skills perception.

Introduction

Learning has a complex structure affected by many internal and external variables. The information that is gained based on experience and becomes permanent in our minds waits ready to be used whenever needed. However, how the information is perceived, processed, organized, repeated, and remembered until it is sent to long-term memory is also important. Cognitive Load Theory (CLT) offers a perspective in terms of attempting to explain whether learning performance is affected positively or negatively. Cognitive load theory posits that the human cognitive structure consists of two memories, which include long-term memory and working memory (Sweller, 2008). While the former has unlimited capacity, the latter has limited capacity, and the retention time of the information in working memory becomes shorter when the interaction between the elements of the new information to be learned increases. Therefore, the cognitive load on working memory is expected to increase in direct proportion with the increase in the interaction between the pieces of information of a task (Sweller, 2010).

According to cognitive load theory, there are three types of load: intrinsic cognitive load (ICL), extraneous cognitive load (ECL), and germane cognitive load (GCL; Sweller et al., 1998). Intrinsic cognitive load is related to the level of interaction between the elements (any operations or concepts that need to be understood and learned by learners). Therefore, the amount of intrinsic cognitive load increases as the content to be learned becomes more complex. This load changes only when the nature of what is to be learned changes (Sweller, 2010). Intrinsic load can also be defined as the complexity of the content presented according to prior learning levels (Shadiev, Hwang, Huang and Liu, 2015).

Extraneous load is considered as a type of poor instruction (Schmeck, Opfermann, Van Gog, Paas and Leutner, 2015) in which learners are presented in a way that requires them to process unnecessary information. Extraneous cognitive load is related to the way the learning task is presented, so extraneous cognitive load is affected if the quality of the instructional design is not functional. According to Sweller, Van Merrienboer and Paas (1998), intrinsic load is the invariant type of load that is found in the parameters of a task. Extraneous load is defined as the load resulting from irrelevant or unnecessary task characteristics. Reducing the off-topic cognitive load as much as possible is an important element in this theory. In such a process, cognitive load theory is based on the assumption that unnecessary cognitive load will be eliminated or reduced by making necessary adjustments in the teaching materials during instructional design (Sweller et al., 1998). Germane cognitive load is the third type of load in the theory. According to Paas et al. (2003), germane load is the type of load that arises from the relevant and appropriate cognitive activities necessary to achieve instructional goals and increases the learner's ability to retain information in a meaningful way. In other words, this type of load is related to the learner’s schema acquisition and automatization during learning (Sweller, 2010). In other words, it refers to the cognitive resources that the learner allocates when dealing with the actual cognitive load related to the nature of the information. Therefore, this load has a direct contribution to learning.

Germane load is the cognitive effort that needs to be shown by the student to make sense of the content to be learned (Plass, Moreno and Brünken, 2010). This effort is reported to be directly related to the learner’s level of motivation and metacognition (Mayer, 2009; in Park, 2022). While intrinsic and extraneous cognitive load are related to the characteristics of the learning task, germane cognitive load is related to the learner (Sweller, 2010). Germane cognitive load is a functional load in which the learner activates metacognitive and self-regulation processes. Germane cognitive load (Sweller, 2010) involves schema creation, automatization, and procedural thinking action, and it is considered as the learning process itself (Chanquoy et al., 2007 in Armougum, Orriols, Gaston-Bellegarde, La Marle and Piolino, 2019). Therefore, to avoid cognitive overload, we should optimize intrinsic cognitive load, reduce extraneous cognitive load, and maximize germane cognitive load. However, with the developments in the field, Sweller et al. (2019) presented a revised version of the CLT and made a change in the model in 1998. This change included removing the germane load (GCL) from the additive equation of the total load and instead introducing a dimension now called "germane processing". Therefore, an increased germane load is no longer believed to lead to cognitive overload (Sweller et al., 1998). While the CLT model includes three components (intrinsic cognitive load (ICL), extraneous cognitive load (ECL), and germane cognitive load (GCL) that make up the total cognitive load that students need to retain, the two-component (intrinsic and extraneous cognitive load) model (Sweller et al., 2019) excludes the germane load (GCL) from the total cognitive load.

According to cognitive load theory (CLT), learning involves organizing information into cognitive schemas stored in long-term memory. The schema, namely organized information elements in chunks, can hold a vast amount of data, but it is processed as a single unit in our working memory (Mancinettia, Guttormsen and Berendonk, 2019).

Learners who have germane cognitive load are more motivated to learn new information and engage in independent learning processes during the meaningful construction and organization of cognitive structures (Mancinettia, Guttormsen, & Berendonk, 2019). Working memory has a decisive role in cognitive load during thinking processes and can affect it directly (Redifer, Bae, & DeBusk-Lane, 2019). Many educational systems acknowledge that germane cognitive load is valuable for learners to become independent learners and reflect this notion in educational programs. As such, to have higher levels of thinking processes and skills and achieve higher-level goals, learners need to have a germane cognitive load and competencies to organize information. In such a process, it is very important to investigate the factors positively affecting the educational environment as well as improving learners' metacognition and problem solving processes and skills. Thus, teachers to provide learners with cognitive coaching in high-level thinking processes and skills and make them independent learners will assume an important role in raising entrepreneurial individuals who have 21st-century skills.

Determining the current status of these prospective teachers in the context of metacognition, problem solving, and cognitive load are also considered to increase the quality and adequacy of the education to be given to them. For these reasons, this study investigates pre-service teachers' cognitive load about the concepts of metacognitive skills perception and problem solving skills. As emphasized in the last revision by Sweller et al. (2019), structuring the germane cognitive load (GCL) is useful in the use of problem solving and metacognitive skills. In such a process, minimizing the extraneous cognitive load and creating germane cognitive load is necessary to make metacognitive and problem solving skills effective. In addition, in learning situations where metacognitive and problem solving skills are used effectively, learners' cognitive capacities are reflected not only in performing the task assigned to them but also in monitoring, organizing, and evaluating their performance while performing these tasks. As stated in Sweller et al. (2019), since learners have limited cognitive capacity while performing a complex task for the first time, they experience significant intrinsic cognitive load while performing the task. Such a process includes very little working memory, and the capacity may be left to carry out monitoring processes, which may prevent the formation of different skills of accurate self-evaluation and metacognition (Panadero, Brown and Strijbos, 2016). Therefore, the learner's possession of different skills such as problem solving and metacognition could contribute to the decrease in the intrinsic cognitive load.

In this regard, the internalization of the germane load by the learner may contribute to the formation of metacognitive knowledge and strategies by the learner and their reflection in the problem solving process. However, the increase in intrinsic and extraneous cognitive load may have a negative effect on the formation and use of metacognitive and problem solving skills. The learner's having different problem solving skills may play a functional role in this process. Pre-service teachers who are provided with education in teacher training programs that will improve their metacognitive and problem solving skills could regulate their intrinsic and extraneous loads. In this regard, it is important to examine the decrease in the cognitive load that will contribute to the functional use of working memory in increasing metacognitive and problem solving skills in pre-service teachers and the relationship network between these variables. More specifically, revealing the relationship network between these variables is believed to contribute to making necessary arrangements in teacher education programs that train prospective teachers. In this regard, revealing the mediating relationship between cognitive load, metacognitive skills, and problem solving skills is a clear question that needs to be examined.

Model and Hypotheses

Metacognitive Skills and Their Relationship with Germane Cognitive Load Tendencies

The process of metacognition is a macro-level higher-order thinking process that includes knowledge and control of oneself and knowledge and control of the teaching process. In this process, the learner is a self-regulating participant who takes responsibility for his/her own learning. Learners who create and functionally use germane cognitive load will become more effective in learning to learn in this process of self-regulation, planning, organization, and evaluation. As much as possible, these learners are also expected to reduce and control the intrinsic and extraneous cognitive load in their learning process. When the necessary adjustments are made in intrinsic and extraneous cognitive load, an increase could be expected in the retention time of information in working memory. López-Vargas, Ibáñez-Ibáñez and Racines-Prada (2017) also emphasized that students who interacted with the cognitive mindfulness construct were significantly more successful than those who did not and experienced a desired regulation of their intrinsic and extraneous cognitive load. As students participate in inquiry processes that involve questioning, formulating hypotheses, experimenting, making observations, gathering and analyzing data, interpreting and explaining, and drawing conclusions, metacognition becomes especially important (Donnelly, Linn, and Ludvigsen, 2014). The deliberate, tactical, intentional, goal-directed, and future-focused mental behaviors that make up these metacognitive thoughts are mental activities that can be implemented in cognitive tasks (Flavell, 1979).

Declarative metacognitions comprise information about the task (e.g., its nature), the individual (e.g., one's ability), and strategies. Process knowledge for controlling and tracking advancement is a component of executive metacognitions (Breuer, Ettmüller, Schu, & Tauschek, 2011 in Zumbach, Rammerstorfer, and Deibl, 2020; Ebert, 2015). These two constructs of metacognition have an impact on the extent to which germane cognitive load organizes one's own learning process. Learners can decide how to perceive cognitive load, how much mental effort to spend, and how to allocate and organize it (de Bruin et al., 2020). Metacognitive skills play an active role in this decision-making process. Hence, Mark (2017) emphasized that metacognitive knowledge and organization are closely related to cognitive load and affect learners' participatory roles. In addition, Zimmerman's (2000) cyclical stages model and Winne and Hadwin's (1998) COPES (conditions-operations-products-evaluations-standard) model propose integrative frameworks for incorporating cognitive load into the theory of metacognition associated with self-regulation. In this regard, the first (H1) hypothesis of the study was formed as follows: "H1: Metacognitive skills perception positively affects cognitive load perception." An analysis of the relationships between metacognitive skills and cognitive load perceptions in the literature showed that although different studies exist in this field (Scott & Schwartz, 2007; López-Vargas, Ibáñez-Ibáñez, & Racines-Prada, 2017; Zheng, Li, Zhang, & Sun, 2019; Wang & Lajoie, 2023), the predictive relationship between the two variables is addressed for the first time, which is valuable in terms of filling an important gap in the literature. In fact, metacognitive skills and the mental effort dimension of cognitive load perceptions are two important components of higher-order thinking. Addressing these variables in the context of relationships is believed to contribute to the field.

Metacognitive Skills and Their Relationship with Problem Solving Perceptions

In the process of learning to learn, metacognition is a multidimensional concept that includes knowledge and control about oneself and knowledge and control about the learning process. The learner takes part as an active participant in this process. Metacognition, as one of the 21st-century skills, is crucial to teach in order to develop independent learners, which is the ultimate goal of learning and the key to acknowledging the development of 21st-century science education. According to Flavell (1979), metacognition is the capacity of an individual to arrange and track information as well as store, search, and retrieve it from memory. Four elements of action and interaction; namely, goals or tasks, metacognition experiences, metacognition knowledge, and actions or strategies, activate it (Flavell, 1979). Furthermore, metacognition is based on differences between knowledge and regulation of cognition (Schraw et al., 2015), and it is considered to be an activity that is based on one's own and others' thoughts and monitoring and as well as regulating one's own way of thinking (Hartman, 2001). Teacher metacognition is believed to have a substantial impact on both student learning and the teaching process (Prytula, 2012). According to Hartman (2001), teaching with metacognition is the best way to maximize the effectiveness of instruction. Furthermore, a shift in teachers' professional development should begin with learning what they already know about their own teaching (Manning & Payne, 1996; in; Jiang, Ma & Gao, 2016). In the process of learning to learn, the ability of the learner to master his/her own cognitive processes, to plan, organize and evaluate the learning and teaching process, and to be an effective problem solver are the basic processes and skills of today's independent learners. In this process, the active participant roles of pre-service teachers and their possession of higher-order thinking processes and skills (e.g. metacognition and problem solving) are believed to increase the quality and effectiveness of the guided learning support they will provide to their students.

Training learners who use metacognitive and problem solving skills has become a necessity today. As such, learners who have metacognitive and problem solving skills are more independent learners who eliminate as much of the actual and irrelevant cognitive load as possible from their learning process. Students who have metacognitive skills are able to evaluate events from different dimensions without prejudice and are aware that every mistake provides positive feedback on the way to correct learning. Wilson (2022) highlights that the majority of the foundation for educational research in metacognition is a positivist paradigm and empirical epistemological presumptions regarding human cognition as well as its investigation. According to the positivist paradigm, metacognition is a type of high-order thinking with executive control over different cognitive processes (Fernandez-Duque, Baird & Posner, 2000; in Wilson, 2022). Because it is something that needs to be performed before, during, and after learning, metacognition is crucial to the learning process. In a broader sense, metacognition refers to an individual's ability to identify fundamental concepts related to a variety of cognitive tasks as well as their understanding of strategies for completing these tasks through effective planning, finding alternative solutions, analysis, synthesis, and evaluation of processes whenever new issues arise. The two main components of metacognition, according to Flavell et al. (2002), include metacognitive knowledge and metacognitive skills. The question of whether metacognition is a generic skill or a domain-specific skill has been brought up by scholars recently. Even though metacognition was applied in several domains, some researchers asserted that it was transferable and independent of task specificity (Veenman and Verheij 2003). Planning, monitoring, and evaluation—the three fundamental categories of metacognitive skills—were effective for all tasks (Schraw and Gutierrez, 2015). It is often acknowledged that learners who have greater metacognitive awareness would probably perform better than those with lower metacognitive awareness (Pintrich, 2003). Students who use particularly planning, organization and evaluation skills are expected to be more successful in the problem solving process.

Metacognitive awareness may be necessary for overseeing, managing, directing, and regulating the problem solving process (Zhao, Teng, Li, Li, Wang, Wen, and Yi, 2019). Moreover, goal-directed cognition was actively expressed in problem solving (Chrysikou 2006 in Zhao, Teng, Li, Li, Wang, Wen, and Yi, 2019). Metacognition was also utilized in the orientation, organization, execution, and verification phases of problem solving (Pugalee 2001). Furthermore, it is well-known that metacognition is a learner characteristic important for achievement, problem solving, and scaffolding (Cuevas, Fiore, & Oser, 2002; Liu and Liu, 2020). Because it necessitates the ability to recognize and choose the most appropriate problem solving procedures as well as to consider and assess the consequences of learning (Costa, 1984), metacognition plays a crucial role in the strategic aspects of problem solving (Mayer, 1998; Marra, Hacker, and Plumb, 2022). In this regard, the second (H2) hypothesis of the study was formed as follows: "H2: Metacognitive skills perception positively affects problem solving perception."An analysis of the relationships between metacognitive skills and problem solving perceptions according to the literature showed that metacognitive skills and problem solving perceptions are two important components of higher-order thinking and are related to each other. The hypotheses formed according to the relationship between these skills are explained respectively.

Cognitive Load Tendencies and Their Relationship with Problem Solving Skills

Problems are constantly encountered as a part of human life in the balance of life. In this process, it is important how we approach problems, what kind of attitudes we develop, and how we can solve these problems. When learners face problems, they sometimes deny the existence of the problem and ignore it; sometimes despair and do nothing; sometimes insist on the same solutions, and sometimes solve the problem effectively. In such a process, it is very important to have problem solving skills to achieve balance in life and to be an independent learner. According to American and Danish models (Niss & Højgaard Jensen, 2002; in Éva Fülöp, 2021), a problem is an activity that is opposite to a routine task. While a problem necessitates active and creative thinking, a routine activity demands the learner to know a precise routine procedure to arrive at the solution (Éva Fülöp, 2021). At the heart of informal learning is problem solving, a cyclical process that significantly shapes what and how teachers learn in the workplace (Marsick and Watkins 2018). In this cyclical process, defining the problem situation, generating hypotheses to solve the problem, selecting the most appropriate hypothesis and using it to solve the problem, collecting, analyzing, interpreting, evaluating, finalizing, and reporting the data, and providing continuous feedback to each other in each step requires the learner’s functional use of micro and macro higher order processes and skills in tandem. The problem solving process is also a higher-order thinking process in which learners' learning to learn skills (planning, organization, and evaluation) and cognitive flexibility contribute positively to their becoming effective problem solvers. In this process, individuals who have organization and regulation of their cognitive load could handle the problem with all its dimensions rather than a single dimension and produce different solutions.

Germane cognitive load refers to the cognitive resources used by the learner to cope with intrinsic cognitive load, one of which is the learner's problem solving skills. Having and using problem solving skills in the cognitive effort of the learner to make sense of the content to be learned in germane cognitive load will make learners more independent learners. Hence, the cognitive efforts shown in germane cognitive load appear directly as the problem solving process itself. However, an increase in intrinsic cognitive load will have a negative effect on the problem solving process of the learner. In this regard, decreasing the intrinsic cognitive load in learner performance will have a positive effect on the higher-order problem solving process. In this regard, the third (H3) hypothesis of the study was formed as follows: "H3: Cognitive load perception positively affects problem solving perception." When the relationships between cognitive load perception and problem solving perceptions were examined according to the literature, it was found that cognitive load perception and problem solving perceptions were the two important components of higher-order thinking and were related to each other. The hypotheses formed according to the relationship between these skills are explained respectively.

Cognitive Load As a Mediating Variable

Mental load, mental effort, and performance, which represent the evaluation factors of cognitive load (Paas & Van Merriënboer, 1994; as cited in Wang & Lajoie, 2023), are important variables in metacognitive and problem solving skills. Thus, the literature indicates that self-regulation, metacognition, and problem solving affect cognitive load, and that cognitive load affects self-regulation and metacognition (De Bruin et al., 2020, Wirth, Stebner, Trypke, Schuster & Leutner, 2020). Cognitive load perceptions may have a mediating role between metacognitive skills perceptions and problem solving skills perceptions. In this regard, the 3 (a) hypothesis of the study was as follows: "H3a: Cognitive load perception is a significant mediating variable between metacognitive skills perceptions and problem solving skills perceptions."

Current Study

In this study, metacognitive skills perceptions are considered to affect cognitive load perceptions, and cognitive load perceptions are considered to affect problem solving skills. In this framework, the model proposed in the study tests cognitive load as a mediating variable. Although the relationships between metacognition, problem solving and cognitive load were examined as bivariate in the literature, no studies were found to have investigated a model proposed in the study. In this study, the relationship between metacognitive skills perception, cognitive load perception, and problem solving skills perception is explained in light of the related literature. A theoretical model is proposed in the light of theories and studies explaining the relationships between variables. The theoretical representation of the proposed model is shown in Figure 1. The predicted variables are shown with the symbol (X) for the metacognitive skills perception dimension to explain the proposed theoretical model. Problem solving skills perceptions are shown with the symbol (Y). The cognitive load perception dimension is the mediating variable indicated by the symbol M.

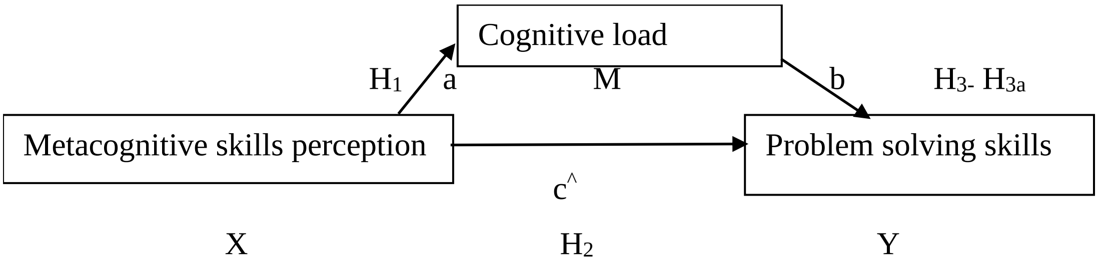

Figure 1. Theoretical Presentation of the Proposed Model

This study aims to investigate the hypotheses formulated to test the relationships between pre-service teachers' metacognitive skills perception, cognitive loads perception, and problem solving skills perception. Accordingly, the main research question guiding the study is: Do pre-service teachers' cognitive load perceptions play a mediating role in the relationship between their metacognitive skills perception and problem solving skills perception?

Method

Participants

The population of the study consisted of pre-service teachers enrolled in the Classroom Teaching, Elementary Science Teaching, Psychological Counseling and Guidance, Preschool Teaching, Turkish Teaching, Pre-school Teaching, Mathematics Teaching, Social Studies Teaching, English Teaching and Special Education Teaching departments at the Education Faculties of two universities located in two different regions of Turkey in the fall semester of the 2022-2023 academic year. The participants of the study consisted of 342 pre-service teachers who were selected from this population using a non-probability cluster sampling method. The demographic distribution of pre-service teachers according to departments is 25(%7.3) in Turkish teaching, 90(%26.3) in Pre-school teaching, 21(%6.1) in Classroom teaching, 40(%11.7) in Social Studies teaching, 38(%11.1) in Mathematics teaching, 19(%5.6) in Science teaching, 14(%4.1) in English teaching, 58(%17) in Guidance and Psychological Counseling and 37(%10.8) in Special Education Teaching.

Procedure

After the official ethical permissions were obtained, the participants were informed about the purpose of the study, and data were collected after obtaining their permission. Because of the distance education process carried out due to COVID and the earthquake, the study data were collected online via Google Forms.

Data Collection Tools

Data were collected through the "Personal Information Form", the "Cognitive Load Scale" (CLS), the "Metacognition Scale" (MS) and the "Adult Problem Solving Skills Scale" (APSS).

Personal Information Form

The Personal Information Form developed by the researchers was used to collect data on the independent variables of the scale and to describe the sample in terms of personal characteristics.

Cognitive Load Scale

The "Cognitive Load Scale (CLS)" developed by Hwang, Yang, and Wang (2013) aims to determine the cognitive load spent by learners in any learning and teaching activity. It consists of eight items responded on a six-point Likert scale, including 5 items for "mental load" and 3 items for "mental effort". Cronbach's alpha values of the two dimensions were found to be 0.86 and 0.85, respectively. The adaptation study of the scale to Turkish culture was conducted on a sample of 376 pre-service teachers from two different education faculties. The four-item Turkish scale, whose reliability and validity study was conducted on 230 pre-service teachers, was found to have a two-factor structure; the factor structures were valid; the internal consistency coefficients were 0.84 for the total, .90 in the first sub-factor, and .85 in the second sub-factor. In addition, confirmatory factor analysis performed on a normally distributed (n=230 data) set within the scope of this study indicated the fit index values as $\chi 2$=3,4, sd=1, p>. 01, RMSEA=.071 and $\chi 2$/df=3.411, RMR=0.14, GFI=.993, AGFI=.927, PGFI= .099, CMIN= 3.411, CFI= .995, NFI= .993, RFI=.960, IFI= .995, meeting the recommended criteria.

Metacognition Scale

The Metacognition Scale was developed by Demir (2013) to measure pre-service teachers' metacognitive skills levels. This scale was administered to 250 students enrolled in different departments at the Faculty of Education of a university. A 14-item scale consisting of "Evaluation", "Organization" and "Planning" sub-scales was formed based on the analyses. Cronbach's alpha internal consistency coefficients for the dimensions explaining 53.074% of the total variance were .89 for the total, .87 in the first factor, .65 in the second factor, and .70 in the third factor. Within the scope of this study, total Cronbach's alpha internal consistency coefficients were .91 in total, .79 in the first factor, .69 in the second factor, and .83 in the third factor. Confirmatory factor analysis conducted within the scope of the study (n=235) indicated the fit index values as ($\chi 2$=215,8 sd=74, p=. 000), CMIN=215.814 CMIN/df=2.916 RMSEA=.090, $\chi 2$/df=2.916, RMR=0.226, GFI=.882, AGFI=.833, PGFI= ,622 and RFI= 0.831, CFI=0.904, IFI= 0.905, meeting the recommended criteria.

Adult Problem Solving Skills Scale

The scale was developed by Yaman and Dede (2008) and consisted of 18 items and 5 factors. Cronbach's alpha values were .95 for thinking about the effects of problem solving, .98 for problem solving by modeling, .82 for determination in implementing the determined solution, .87 for analyzing the problem encountered, and .88 in total. Cronbach's alpha internal consistency coefficients within the scope of this study were .93 in total, .85 in the first factor, .70 in the second factor, .90 in the third factor, .71 in the fourth factor, and .79 in the fifth factor. In addition, the confirmatory factor analysis performed on 235 normally distributed data within the scope of this study showed that the fit index values were CMIN=240,258, (χ2=240,3, sd=125, p=. 000), RMSEA=.063 and χ2/df=1.922, and RMR=.024, GFI=.897, AGFI=.859, PGFI=.655, RFI=.882, NFI=.904, CFI=.951, IFI=.951, meeting the recommended criteria.

Investigating Hypotheses

Missing data, univariate and multivariate normality, outliers, and multicollinearity values were analyzed before the data set analysis was started (Tabachnick and Fidell, 2013). No missing data were found when the data set was analyzed in terms of missing data. Kurtosis and skewness coefficients were examined for univariate normality values. Hence, the distribution of the data collected from 342 pre-service teachers was found to show a nonnormal distribution. For this reason, the extreme values in the data set were removed, and as a result of the Mahalanobis values and the removal of the extreme values from the data set, a structure consisting of data from 230 prospective teachers was reached. In 230 samples, kurtosis and skewness values were found to be within normal values. Linearity was determined with the scatter diagrams of the variables. Multicollinearity and singularity checks of the correlation matrix were also found to be significant. Variance Inflation Factor (VIF) and Tolerance (T) and Conditional Index (CI) values were examined to analyze the multicollinearity problem (Tabachnick & Fidell, 2013). VIF value was found to be less than 10 (Myers, 1990, cited in Myers & Montgomery, 1997), T value was different from 0 (Menard, 1995), and CI value was less than 30 (Paulson, 2007). In addition, the pairwise correlations between the total dimensions of the analyzed variables showed a significant relationship. These results indicated no multicollinearity problem.

Model Fit Assumptions

The fit indices determined to evaluate the results of the CFA were (χ2=3,4, sd=1, p>.01, RMSEA=.071, χ2/df=3.411, RMR=0.14, GFI=.993, AGFI=.927, PGFI= ,099, CMIN= 3.411, CFI= .995, NFI= . 993., RFI=.960, IFI= .995) and fit index values for the validity of the proposed model were (χ2=1266,431, sd=591, p>.01, RMSEA=.071, χ2/df=2.143, RMR=.041, GFI=.753, AGFI= ,721, PGFI= ,099, CMIN= 1266,431, CFI=. 853, NFI= ,757, RFI=,041, IFI= ,854), meeting the recommended criteria. The good fit value ranges of the determined fit indices according to the literature are also presented (Schreiber, Nora, Stage, Barlow and King, 2006; Hooper, Coughlan and Mullen 2008; Tabachnick and Fidell, 2013).

Data Analysis

Mediated structural equation modeling with observed variables was established to test whether cognitive load (M) mediated between metacognitive skills perception (X) and problem solving skills perception (Y) and whether the hypotheses were significant.

Structural Equation Modeling (SEM)

SEM analysis is a multivariate regression model that reveals causal relationships between observed variables

(Kline, 2015). SEM is the examination of covariance between observed variables to make inferences about latent variables (Schreibe et al., 2006). SEM analysis enables the examination of different variables related to models with complex relationships. The proposed model was examined by applying path analysis to the data obtained from the study. SEM analysis made it possible to determine whether there is a significant cause-and-effect relationship between the variables of the model proposed from the mixed hypotheses for the study in Figure 1. In the proposed theoretical model, the bootstrap method was used to determine whether there is a significant difference between the mediator variable cognitive load (M), predictor variable (X), and outcome variable (Y). The literature (Baron & Kenny, 1986; Hayes, 2018) reports that the bootstrap method gives more reliable results than Baron and Kenny's traditional mediation or Sobel mediation tests. In the mediation analysis test done with the bootstrap method with 5000 resampling and a 95% confidence interval, the values that do not include a confidence interval of 0 in the Mediation Test analysis performed with the method are reported to be mediating variables (Hayes, 2018). The results were analyzed according to the model fit assumptions and various good fit indices. AMOS 24 was used for CFA and path analysis, and SPSS 25 was used for data set entry, item statistics, and test statistics.

Results

The findings of the study are presented as follows: First, the descriptive statistical values between the variables that formed the hypothesized relationship research were explained (see Table 1). This is followed by the findings showing whether the hypotheses in the research model were accepted or rejected (see Tables 2 and 3). When the paired relationships between the total dimensions of the analyzed variables were examined, it was found that all the variables were significantly and positively related to each other (p<.01, Table 1). Kurtosis and skewness values showed that the variables took values between -1 and +1. In this regard, the variables of the study showed a normal distribution. Figure 3 displays the AMOS output showing the parameters in the model.

Table 1 presents information regarding the pairwise correlations between the total dimensions of the variables investigated.

Table 1. Pairwise Correlations between the Total Dimensions of the Variables Analyzed

	2	3
1. Cognitive load total	.243**	.177**
	.000	.007
2. Metacognition total	1	.722**
		.000
3. Problem solving total	.722**	1
	.000	

(*p <.05, **p <.01)

Latent variables path analysis was performed to test the hypotheses about the proposed relationships between pre-service teachers' metacognitive skills perceptions, cognitive load perceptions and problem solving skills perceptions. H1, H2, H3, H3a analysis results are given in Table 2.

Table 2. Path Analysis Results

Predictor variables	Extraneous variables										
	Problem-solving skills perceptions (Y)					Cognitive Load Perception (M)					Hypotheses
	B	β	SE	C.R	P	B	β	SE	C.R	P	
Metacognitive Skills Perception (X)	.725*	.783*	.084	8.633	.000	.624*	.313*	.144	4.319	.000	H2 X→ Y (c path) H1 X→ M (a path)
Cognitive Load Perception (M)	-.003	-.007	.024	-.139	.890						H3 M→ Y (b path)

Table 2 shows that metacognitive skills perception directly and positively affects problem solving skills perception (β=,783*; C.R=0,633; p<.01), indicating that the H2 hypothesis is supported. Metacognitive skills perception directly and positively affects cognitive load perception (β=,313*; C.R=4,319; p<.01), indicating that the H1 hypothesis is supported. Cognitive load perception does not directly and positively affect problem solving skills perception (β=-,007; C.R=-,139; p>.01), indicating that H3 and H3a hypotheses are not supported.

The variables in the model (see Figure 2) explain .098% of the variance in cognitive load (R2 = .098) and .609% of the variance in problem solving (R2 = .609). The bootstrap technique was used to determine whether cognitive load is a significant mediating variable in the relationship between metacognitive skills perception and problem solving skills perception. After the relevant mediation effect analysis, the results of the H3 and H3a hypotheses are given in Table 3.

Table 3. Mediation Effect Path Analysis

Dependent Variable	Predictor variable					
Problem solving skills perception (Y)	Metacognitive Skills Perception (X)					
	B	β	95% CI		P	Hypotheses
			Lower	Upper		
Standardized Total Effect	.723	.781	. 701	.849	.000	H3 -H3a
Standard Indirect Effect	-.002	-.002	-. 035	0.23	.858	

B= Nonstandardized Estimations β = Standardized Estimations CI=Confidence Interval

According to the bootstrap standardized total effect results, when cognitive load perception was not included as a mediator variable (simple effect model, [X➔Y]), it was found that the metacognitive skills perception variable directly and positively affected the problem solving skills perception variable (β = .781; p < .01; 95% CI [0.701, 0.849]). When the cognitive load was included as a mediator variable (mediating effect model; [X➔Y; X➔M; M➔Y]), the metacognitive skills perception variable did not directly and positively affect the problem solving skills perception variable (β =-.002; p > .01; 95% CI [-.035, 0.23]) (see Table 3). An analysis of Table 3 shows that the indirect effect between metacognitive skills perception and problem solving skills perception is -,002 and the 95% confidence interval is -,035 - 0,23, and since this interval contains the value 0, the indirect effect is not statistically significant. Since the upper and lower limits of the confidence interval (CI) in the mediating effect model contain a value of 0, cognitive load is not a significant mediating variable between metacognitive skills perception and problem solving skills perception variable. Therefore, hypotheses H3 and H3a are not supported. In this regard, when the results of the standardized indirect effect test representing the standardized total effect and the mediating effect model representing the simple effect model are compared, the significant difference disappears. Therefore, cognitive load does not have a mediating effect between metacognitive skills perception and problem solving skills perception. Figure 2 shows the path analysis values of the standardized prediction values of the model.

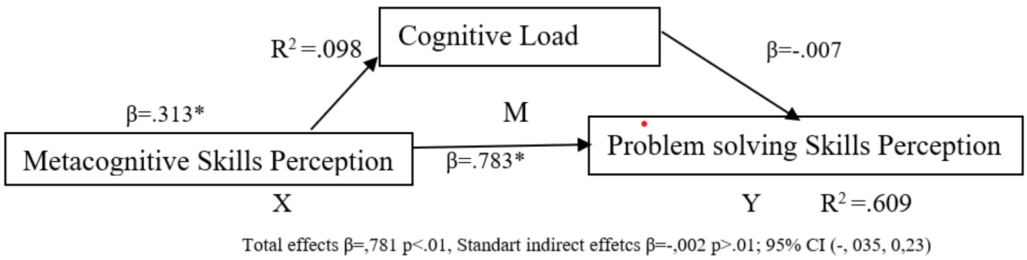

Figure 2. Standardized Predictor Values Path Analysis of the Model (*p < .05, **p <.01., ***p < .001. N = 230)

Figure 3 shows the standardized model.

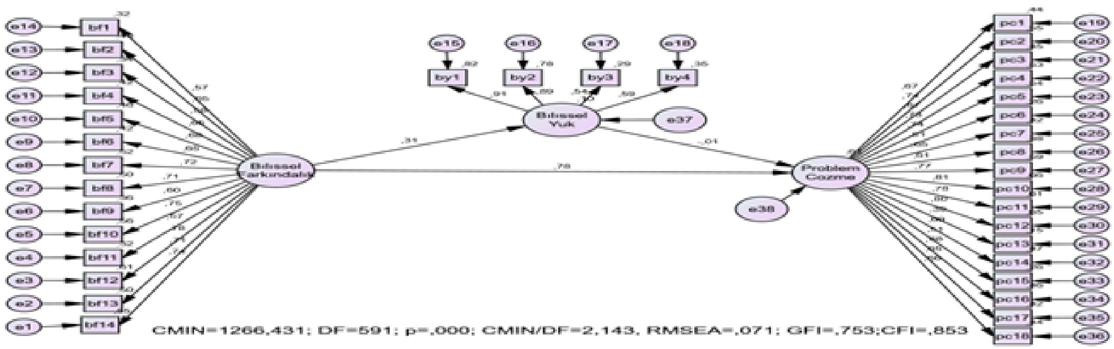

Figure 3. Standardized Model

Discussion

Improving the quality of teacher training programs and developing the professional competencies of pre-service teachers are considered to have a positive impact on the development of future generations. In such a process, the positive development in pre-service teachers' metacognitive skills, problem solving skills and tendencies, and cognitive load are believed to contribute to their becoming learners and mentors who improve themselves. It is very important for pre-service teachers to recognize themselves, their competencies, problem solving skills, and cognitive load and to see the relationships between these variables in the process of becoming a teacher who learns to learn. From this point of view, the hypotheses addressed in the study were discussed in light of the literature. The results of this study showed that while H1 and H2 were confirmed, H3 and H3a were not confirmed. According to the model proposed in the study, cognitive load explains .098% of the variance (R2 = .098) and problem solving explains .609% of the variance (R2 = .609). The research results were analyzed according to the values recommended by Cohen and Cohen (1983) (R2 = .01, small effect size; R2 = .09, medium effect size; R2 = .25, large effect size).

According to H1, metacognitive skills perception positively affected cognitive load perception. An analysis of this hypothesis based on the explanations of various theories in the literature shows that metacognition is an important structure of higher-order thinking processes and skills (Flavell, 1979, 1999; Costa & Garmston, 1984; Marzano, 1998; Veenman et al, 2003). For instance, being aware of cognitive limitations might encourage the adoption of strategies to support prospective remembering (see Smith, 2016 in Cottini, Basso, Pieri & Palladino, 2021). Learners who have learning to learn and learning to think skills can be active participants in organizing their own cognitive load, minimizing their extraneous cognitive load and structuring their germane cognitive load (mental effort). Hence, cognitive load, which refers to the amount of working memory capacity used while solving a task, also affects self-regulation and metacognitive processes (Paas, Renkl & Sweller, 2003). Learners who use the planning, organization, and evaluation skills of metacognition in their own learning processes can eliminate unnecessary cognitive load in their working memory. In such a process, according to the cognitive load theory, it can be said that the cognitive load arising from self-regulation and metacognition processes and skills (i.e. planning, organization, monitoring, or regulation) can be reduced by increased various functional experiences related to these processes.

Some studies (Händel et al. 2020; Roelle et al. 2012) emphasize the positive effects of monitoring, regulation, organization, evaluation, and task selection skills (a type of organizing activity) and activities in this area (Raaijmakers et al, 2018) on functional learning. In this regard, the relationship between metacognition and cognitive load is highly dependent on learners' resources. Resources related to metacognition are influenced not only by the cognitive dimension, how learners experience, plan, organize, and evaluate the load or how they apply metacognitive skills, but also by emotional and social variables. In this context, Pressley, Borkowski and Schneider's (1989) model of Good Information Processing provides a general perspective. Putting effective learning in the central wheel, the model distinguishes three cognitive rack wheels on the left side and two motivational and emotional rack wheels on the right side. They include selective attention and working memory, learning strategies and metacognitive regulation, and domain-specific prior knowledge and cognitive factors. Motivation and self-concept and the emotions accompanying learning are affective factors. The rack-wheel metaphor shows that all these factors are highly interlinked. In such a process, the effective use of metacognitive skills (planning, organization and evaluation) by the learner will positively reflect on the reduction of extraneous cognitive load and the organization of germane load (mental effort).

Hence, Pressley, Borkowski and Schneider (1989) also emphasize this process in their model. It can thus be said that cognitive load is not only a direct consequence of instructional design but rather depends on how learners cope with the design. This brings along the contribution of the effective use of metacognitive skills in the learner in reducing cognitive load. As stated by Mirza et al. (2020), research on self-management of cognitive load focuses on improving cognitive load by reducing extraneous cognitive load (Mirza et al., 2020). However, the use of metacognitive skills may affect increasing "productive mental effort", also referred to as germane cognitive load. In fact, Cierniak et al. (2009) emphasize that the decrease in divided attention (manipulated across subjects) leads to a better understanding of complex information through an increase in germane cognitive load (mental effort) as well as a reduction in extraneous cognitive load. Therefore, learners' mental effort using metacognitive skills may lead to a decrease in extraneous cognitive load. In this process, metacognitive skills take an active role in the learner's self-regulation, leading to a decrease in the extraneous cognitive load and an increase in the germane cognitive load. In their recent cognitive load theory, Sweller et al (2019) also mentioned this issue. Teachers have great responsibilities in such a process. Indeed, it is important to guide the learner on how to integrate text and diagrams on his/her own to decrease divided attention. This guidance can directly contribute to the learner in constructing integrated mental models using metacognitive skills (Mayer & Moreno, 2003). In this process, teachers play a valuable role in increasing learners' "productive" mental efforts, also known as germane cognitive load. In this regard, examining the current situation of pre-service teachers in a relational context and finding a positive predictive relationship between metacognition and cognitive load is a noteworthy finding of this study.

Several studies have also shown that learners can manage their cognitive load on their own when specific instructions are given on how to do so ("guided self-management"; Roodenrys et al. 2012). Sithole et al. (2017) emphasized that providing guided learning support in reorganizing text and diagrams to minimize information seeking in the learning task would lead to a decrease in cognitive load as well as an increase in learners' recall and transfer test performance. In such a process, learners can decrease their divided attention by using self-regulation and metacognitive skills. They may also not process the instructional design in a sub-optimal way once they have improved, which leads to a decrease in their extraneous cognitive load. Such a process may result in (partial) self-management of the learner's cognitive load. Schwonke et al. (2009) concluded that the link between instructional design, cognitive load or performance is governed by learners' processing strategies. Here, the direct effect of metacognitive skills is noticed.

Therefore, the concept of self-management of cognitive load is compatible with the concept of self-regulated learners who decide on when and what information to process on their own. These learners will be trained by effective teachers who manage their own cognitive load using metacognitive and self-regulation skills. In addition, an overall analysis of the related study results shows that the emergence of a positive predictive relationship between metacognition and cognitive load in the views of future teachers who bring the learner to the position of an independent learner and provide guided learning support in the use of metacognitive skills may contribute positively to their professional performance.

According to H2, metacognitive skills perception directly and positively affects problem solving skills perception. Metacognition is a high-level thinking structure that contributes to the learner in the problem solving process with its strategies and skills (planning, organization and evaluation). Metacognitive skills are important for the successful structuring of the problem solving process. Socially shared metacognition is also an integral part of collaborative problem solving (De Backer, Van Keer & Valcke, 2015), especially in organizing collective cognition and coordinating external task representations. Such a process requires identifying and selecting appropriate problem solving strategies and reflecting on and evaluating the results of learning (Costa, 1984), which is directly related to metacognitive skills. Several studies put forward that metacognition has a relationship network in which it supports problem solving skills mutually (Tang, Arslan, Xing, & Kamali-Arslantas, 2023; Liu & Liu, 2020; Nicolay, Krieger, Stadler, Vainikainen, Lindner, Hansen & Greif, 2022; Rudolph, Niepel, Greiff, Goldhammer & Kröner, 2017; Zumbach, Ortler, Deibl & Moser, 2020; Urban & Urban, 2023). Thus, by helping students to understand when, why, where, and how they can use their own knowledge for successful problem solving (Carr & Jessup, 1995), metacognitive skills play a key role in the monitoring and regulation of cognitive processes. In this study, the direct and positive effect of metacognitive skills perception on problem solving skills perception is in line with the literature. The need to understand the role of metacognitive skills in complex skills including problem solving and self-regulated learning is becoming increasingly important in the rapidly changing world of the 21st century (Greif, Wüstenberg, Csapó, Demetriou, Hautamäki, Graesser & Martin, 2014).

Revealing this relationship network (between metacognition and problem solving skills) and making necessary arrangements in teacher education programs has become a necessity in this context in order to train teachers who develop themselves and keep pace with changes in the 21st century. Molnár & Csapó (2018) also emphasize that metacognitive skills and strategies, including metastrategic knowledge, could be very important in solving complex problems successfully. Indeed, learners who successfully solve problems actively participate in setting their own goals, developing appropriate strategies, planning the steps, generating a variety of possible solutions, monitoring and organizing the problem solving process, and evaluating the results in terms of innovation and usefulness. This process is directly related to the planning, organization and evaluation skills used in the knowledge and control of metacognition about oneself and knowledge and control of the learning process. In this regard, metacognition including metastrategic knowledge, complex problem solving skills and the establishment of functional relationships between these two variables should be emphasized in the training of effective learning teachers. In addition to this, the emergence of a positive predictive relationship between metacognitive and problem solving skills perceptions in pre-service teachers' views may contribute to their professional performance and provide effective guided learning support to their students on the use of metacognitive and problem solving skills. This study found that cognitive load perception did not positively affect problem solving skills perception and cognitive load perception did not take place as a significant mediating variable between metacognitive and problem solving perceptions.

Hence, hypotheses H3 and H3a are not supported. An analysis of the hypotheses according to the literature shows that the explanations of various theories (Sweller, 1988; Larmuseau, Cornelis, Lancieri, Desmet & Depaepe, 2020; Costley, Gorbunova, Courtney, Chen & Lange, 2023) emphasize that increasing extraneous and intrinsic cognitive load will show negative or no relationship with problem solving and metacognitive skills. However, the literature (Sweller et al., 2019; Hidayanto & Sari, 2020; Larmuseau, Cornelis, Lancieri, Desmet & Depaepe, 2020; Costley, Gorbunova, Courtney, Chen & Lange, 2023) also indicates that if the germane cognitive load attributed to the mental effort is structured and organized, it will show positive relationships with problem solving and metacognitive skills. Most instructional approaches therefore aim to reduce extraneous load to prevent overprocessing in working memory, especially when intrinsic load is high (Sweller et al., 2019). In general, germane load reflects the mental effort that learners exert to transfer information from working memory to long-term memory (Greenberg & Zheng, 2023). In this regard, germane load may be considered as a non-contributory component of cognitive load and shows a positive relationship with metacognitive and problem solving skills because it does not contribute to the overall load in working memory. However, intrinsic and extraneous load (Sweller et al., 2019) may not show a relationship with metacognitive and problem solving skills, as the cognitive process is negatively affected by the unstructured delivery of instruction or information that is irrelevant to learning.

Therefore, the effect of intrinsic and extraneous load reflected in the overall load may be the reason why cognitive load does not cause a mediating effect between metacognitive and problem solving skills. In addition, the study also concluded that the metacognitive skills of pre-service teachers were effective in functionalizing germane cognitive load and reducing intrinsic and extraneous cognitive load, and that there was a positive relationship between the two variables. Similarly, a positive relationship was concluded between metacognitive and problem solving skills perceptions. It was also concluded that the development of metacognitive and problem solving skills of pre-service teachers is critical for the functionalization of germane cognitive loads and the reduction of intrinsic and extraneous cognitive loads. In this regard, it can be said that paying attention to the relationship between metacognitive and problem solving and germane cognitive load and making arrangements to improve the quality of related variables could increase the quality of teacher education programs.

Recommendations

It is recommended to make curriculum arrangements for the functional regulation of metacognitive skills, problem solving skills and cognitive load in teacher education to improve the qualifications of pre-service teachers. It is also recommended to make arrangements that will help pre-service teachers to organize their cognitive loads functionally and to develop metacognitive and problem solving skills that will be reflected in teacher training programs. Future studies could be redesigned and tested according to different theories or research hypotheses and models than the research model proposed in this study.

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