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Effectiveness of Problem-Centered Learning in Enhancing Senior High School Students' Achievements in Genetics

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ABSTRACT

Twenty-first-century competencies and mathematical literacy have many overlapping features. Although mathematical literacy is one of the necessary components to create 21st-century skills, each individual needs to understand mathematical literacy to solve the problems encountered in daily life. This study examined the effects of pre-service teachers' mathematical literacy self-efficacy on their perceptions of 21st-century skills efficiency. A total of 230 pre-service primary school teachers, 102 (44.3%) male and 128 (55.7%) female, participated in this study. The Mathematical Literacy Self-Efficacy scale and 21st Century Skills Efficiency Perceptions scale were used as data collection tools. Quantitative data were analyzed with structural equation modeling. The following measures were employed: Mathematical literacy self-efficacy positively affects perceptions of learning and innovation skills, mathematical literacy self-efficacy positively affects perceptions of life and career skills, and mathematical literacy self-efficacy affects perceptions of information-media and technology skills positively. The finding suggested that a significant and strong relationship was found between pre-service primary school teachers' mathematical literacy efficacy and 21st century skills efficiency and its sub-categories.

Keywords: mathematical literacy, 21st-century skills, structural equation modeling, pre-service teachers.

Introduction

Today's education doctrine considers transferable skills very important and is rapidly evolving to meet global education needs (Kotsiou et al., 2022). Furthermore, education seeks to equip students with the skills necessary to face an unpredictable future (Meegan et al., 2022). It is argued that education's main roles are to contribute to both the business sector and society, empowering students to develop their abilities, meet their social obligations, and maintain social cultures and values (Trilling & Fadel, 2009). In addition to these roles, education is a concept that is affected by the development of an individual and also has a direct impact on society.

One of the core objectives of modern education is integrating 21st-century skills—creativity, critical thinking, collaboration, and communication—into curricula (Jumriani & Prasetyo, 2022). These skills are crucial for personal and professional success and sustaining societal advancement in the digital era (Bybee, 2010). The need for these skills is increasingly recognized, especially given the global challenges in economic growth, competitiveness, and social cohesion (Voogt & Pareja Roblin, 2012). Thus, educational systems worldwide emphasize cultivating these abilities to prepare learners for complex, interdisciplinary problem-solving and adapting to the rapid technological changes that define the 21st century.

In this context, self-efficacy emerges as a pivotal construct that connects the teaching and learning of 21st-century skills with educational outcomes, particularly in areas like mathematics, where these skills are essential for deeper cognitive engagement (Pajares, 1996). According to Bandura (1994), self-efficacy is "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" (p.1). Martin and others (2019) also explained self-efficacy as individuals' personal beliefs about planning and performing their own actions. Teachers' self-efficacy refers to teachers' beliefs in their capacity to carry out the educational process effectively and successfully. Self-efficacy beliefs affect individuals' emotions, thoughts, motivations, and actions. In mathematics education, for instance, a strong sense of self-efficacy can enhance motivation, effort, and persistence, which are crucial for mastering complex skills (Zimmerman, 2000).

As education moves towards a competency-based model that emphasizes lifelong learning and adaptability, understanding the link between self-efficacy and 21st-century skills becomes essential. Research indicates that students with higher self-efficacy beliefs in subjects like mathematics tend to engage more actively and demonstrate resilience in the face of challenges (Bandura, 1997; Schunk & Pajares, 2005). Integrating self-efficacy within the framework of 21st-century education goals enriches educational research and supports the broader mission of preparing students for personal success and societal contribution.

21st Century Skills

21st-century skills aim to provide students with the learning and application skills necessary for the development of today's globalized society (Rajoo et al., 2022). The implementation of 21st-century skills and competency-based learning demonstrates positive action in global education systems to develop a wider range of skills beyond traditional literacy and simple numeracy skills. There is broad agreement and important common interests in national and international qualification frameworks on the importance of 21st-century skills (UNESCO, 2021). This consensus is supported by the necessary educational situations to equip learners with usable knowledge and skills, rather than teaching outdated basic-level skills.

At this point, there are three basic skills that have become the focus of 21st-century learning: "information, media, and technology skills", "learning and innovation skills," and "life and career skills" (Alismail & McGuire, 2015). One of the sub-themes of these focal skills is "critical thinking and problem solving" (Saavedra & Opfer, 2015). Mathematics comes to the forefront as a course in which critical thinking and problem-solving skills are taught, and these skills should be taught to children from an early age. In addition, critical thinking includes the activities or skills of filtering, analyzing, criticizing, and summarizing information according to one's expertise (Güner & Gökçe, 2021). Teachers are expected to have these skills, and teachers with 21st-century competence will be able to apply these skills to their lesson practices.

Many organizations have emphasized the skills required for the 21st century. Partnership for 21st Century Learning ([P21], 2002) stated these competencies as critical thinking, applying knowledge to new situations, analyzing knowledge, grasping new ideas, communicating, collaborating, problem

solving, and decision making. OECD (2019) stated these competencies as communication, mathematization, representation, reasoning and discussion, developing strategies to solve problems, using symbolic, formal, and technical language and operations, and using mathematical tools. The International Society for Technology in Education (ISTE) emphasized that students should have skills such as communication and collaboration, creativity and innovation, critical thinking, research and knowledge fluency, digital citizenship, problem-solving, and decision making. In other words, although there are different definitions of the skills that students should have in the 21st century, it generally focuses on how students can realize what they can do with the knowledge they have acquired, and how they will use what they have learned in a real context. In addition, when the competencies stated by organizations such as P21 and OECD for the 21st century are examined, the competencies covered by mathematical literacy are at the core of 21st-century skills.

Globally, there is a growing emphasis on teaching competencies related to 21st-century skills (Reimers, 2021). The abilities and attitudes of teachers are crucial to the successful application of 21st-century education in the classroom (Shafiee & Ghani, 2022); however, the process of 21st-century skills into the classroom practice is unfortunately not at the desired level. One of the biggest reasons for this is that teachers do not feel sufficiently competent in this regard. The slow pace is partly attributed to the complexity of the integration process, which involves content, pedagogy, and assessment alignment (Volman et al., 2020). Teachers with a high level of self-efficacy could handle any difficulties in the classroom and improve the quality of instruction (Bandura, 1977). Considering these, teachers are the prominent leaders for implementing 21st-century pedagogy into practice, there is a need to focus more on teacher self-efficacy (Schleicher, 2012).

Mathematical Literacy Self-Efficacy

One of the fundamental skills that everyone should possess is 21st-century literacy competence, another mathematical literacy self-efficacy (Umbara & Suryadi, 2019). OECD (2019) defines mathematical literacy as the formulation, use, and interpretation of mathematics by individuals. Mathematical literacy is the ability of individuals to understand and apply some mathematical practices such as principles, operations, and problem solving in daily life (Ojose, 2011). In other words, mathematical literacy involves mathematical reasoning and the application of mathematical concepts, procedures, facts, and tools for mathematical prediction. Another definition of mathematical literacy is that it helps to understand the role of mathematics in the world, to draw informed conclusions, and to make the decisions that people need as creative, active, and informed citizens (Hrynevych et al., 2022). Mathematical literacy has several core competencies (Rizki & Priatna, 2019) such as mathematical thinking and reasoning, mathematical argumentation, mathematical communication, modeling, problem posing and solving, representation, and technology use.

Modern primary school mathematics courses also provide students with content that improves their problem-solving and critical thinking skills and creative activities (Mirzaxolmatovna et al., 2022). In this context, critical thinking and problem-solving skills have an important place in daily life and in the field of mathematics. In addition, being able to think critically and solve problems can also be stated as understanding mathematics (Polya, 2017). Research shows that teachers who have developed mathematical literacy self-efficacy, who can solve problems and think critically, prevent the anxiety of teaching mathematics and the difficulties in answering students' mathematics questions (Doruk & Kaplan, 2016; Ural, 2015). In addition, students with high mathematical literacy self-efficacy also have high academic motivation and mathematics achievement (Gan & Peng, 2024). Geng and others (2023) suggest that individuals with different mathematical literacy self-efficacy levels may have different learning times and learning styles.

The accuracy of primary school students in acquiring 21st-century mathematical skills between different groups of students (for example, low- and high-performing students) is of interest because

these may require a different focus in interventions (Oudman et al., 2022). Mathematics teaching styles are essential in increasing students' achievement in life and school, and their mathematical self-efficacy. Especially in recent years, while mathematics skills lead the learning stages of the 21st century, classroom teachers also use 21st-century learning skills to develop better mathematical learning environments for their students (Rajoo et al., 2022).

A prospective teacher must possess mathematical literacy skills to effectively formulate, apply, and interpret mathematics in various contexts, including the ability to perform mathematical reasoning and utilize concepts (Sawatzki & Sullivan, 2018). Considering the difficulty of prospective teachers who still need to become competent in giving confidence to their students and carrying out the teaching process in an ideal way, prospective teachers must have high mathematical literacy self-efficacy perceptions. It is also essential to investigate self-efficacy perceptions, which may provide important clues for mathematics (Topbaş Tat, 2018). Analyzing the self-efficacy perceptions of prospective teachers during their education, determining their competencies, and taking measures in line with the results is one of the critical steps in preparing them for their professions. Investigating self-efficacy perceptions is essential, as it may provide important clues for mathematics (Özgen & Bindak, 2008).

Mathematical Literacy Self-Efficacy and 21st Century Skills

Mathematical literacy self-efficacy is one of the necessary components for building 21st-century skills efficacy. In this context, interest in the effect of mathematical literacy self-efficacy on 21st-century skills is increasing. By strengthening their self-efficacy, teachers can more effectively apply teaching strategies such as problem-based learning and inquiry-based learning, which are compatible with the development of 21st-century skills (Öpengin & Elmas, 2023). However, integrating these skills into mathematics and other subjects is progressing slowly (Varas et al., 2023), and there are not many studies determining the effect of pre-service teachers' mathematical literacy self-efficacy on their 21st-century skills (Yenilmez & Ata, 2019). Determining the impact of mathematical literacy self-efficacy on prospective teachers, who will educate their students in the future on their 21st-century skills, is an essential factor in realizing effective teaching strategies and practices. In this context, it is important to determine the effects of pre-service teachers' mathematical literacy self-efficacy on their 21st-century skills.

Twenty-first-century self-efficacy and mathematical literacy have many overlapping features (Niemi et al., 2018). Although mathematical literacy is one of the necessary components to create 21st-century skills (Julie et al., 2017), each individual needs to understand mathematical literacy to solve the problems encountered in daily life (Rizki & Priatna, 2019). Students who develop mathematical literacy and 21st-century skills cope more easily with the competitive global changes they need to prepare themselves after graduating from the relevant schools (Haviz & Maris, 2020). In conclusion, the mathematically literate skills of individuals (e.g., problem-solving, reasoning, argument generation, and communication) overlap with the 21st-century skills stated by P21 (2019). In other words, as stated by Julie et al. (2017), mathematical literacy is the basis of 21st-century skills. However, some studies have shown that self-efficacy can directly affect mathematical learning (e.g., academic engagement and achievement) without relying on mathematical literacy alone (Geng et al., 2023; Li et al., 2020). In this study, the aim was to examine the relationship between pre-service teachers' perceptions of 21st-century skills self-efficacy and their mathematical literacy self-efficacy.

Teachers' self-efficacy beliefs significantly influence their teaching practices and students' learning outcomes. Research suggests that teachers with lower self-efficacy may feel less confident in delivering complex tasks that require 21st-century skills, potentially avoiding or simplifying such tasks to minimize cognitive load for themselves and their students (Bandura, 1997; Klassen & Tze, 2014). This reduction in task complexity not only limits opportunities for students to engage deeply with

content but also hampers the development of essential competencies (Tschannen-Moran & Hoy, 2001). Conversely, teachers with high self-efficacy are more likely to adopt innovative teaching strategies and encourage critical thinking, problem-solving, and creativity among their students, which are fundamental components of 21st-century skills (Kahraman & Demirtaş, 2021).

As pre-service teachers develop their instructional practices, understanding the relationship between their mathematical literacy self-efficacy and 21st-century skill efficacy is essential. Teachers who feel capable of mathematical literacy are more likely to implement tasks that demand higher-order thinking, fostering a classroom environment that supports students' development in line with the broader educational goals of preparing learners for complex societal and professional challenges (Darling-Hammond, 2010). This study, therefore, aims to examine the relationship between pre-service teachers' perceptions of 21st-century skills efficacy and their mathematical literacy self-efficacy, highlighting the crucial role of self-efficacy in preparing learners for the challenges of the future.

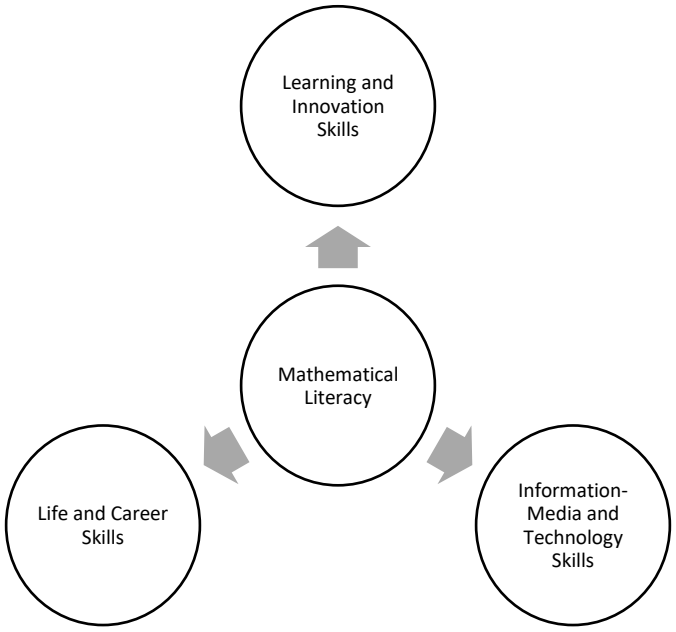
Empirical research highlights a significant relationship between teachers' self-efficacy beliefs and their ability to integrate 21st-century skills into classroom practice effectively. For example, Göçen et al. (2023) emphasized that high teacher self-efficacy positively influences the integration of complex educational competencies, thereby enhancing student engagement and learning outcomes. However, recent studies (Yılmaz & Turan, 2020) have indicated that the specific impact of mathematical literacy self-efficacy on pre-service teachers' proficiency in delivering 21st-century skills remains underexplored. Addressing this gap, this study examines how mathematical literacy self-efficacy correlates with perceived efficacy in 21st-century skills among pre-service teachers, thereby contributing to existing research by clarifying this critical interrelationship (Niemi et al., 2018).

Objectives of the Study

The hypotheses of this study were determined according to the model indicated in Figure 1.

Figure 1.

Structural Equation Modeling



Ha1: Mathematical literacy self-efficacy positively affects perceptions of learning and innovation skills.
Ha2: Mathematical literacy self-efficacy positively affects perceptions of life and career skills.
Ha3: Mathematical literacy self-efficacy positively affects perceptions of information-media and technology skills.

Method

Participants

The research group was formed through the convenience sampling method. The convenience sampling method is known as a practical sampling method because it provides convenience to researchers in terms of time and cost (Yıldırım & Şimşek, 2018). The participants in the study were selected among the pre-service primary school teachers attending the Institute of Educational Sciences at Eskisehir Osmangazi University in Eskisehir, Türkiye. In addition, the participant pre-service primary school teachers were studying at the same faculty of the state university in the city center. A total of 230 pre-service primary school teachers, 102 (44.3%) male, and 128 (55.7%) female, participated in the study. In addition, 76 (33%) of the pre-service teachers in the study are 1st year students, 55 (23.9%) 2nd year students, 56 (24.3%) 3rd year students, and 43 (18.7%) 4th year students.

Data Collection Tools

In this study, the Mathematical Literacy Self-Efficacy scale and the 21st Century Skills Efficiency Perceptions scale were used as data collection tools. Information on these scales is given.

Mathematical Literacy Self-Efficacy Scale

The related scale was developed by Özgen and Bindak (2008) to determine pre-service teachers' self-efficacy for mathematical literacy. The aim of this scale is to determine pre-service teachers' attitudes towards mathematical literacy self-efficacy beliefs (Özgen & Bindak, 2008). The scale consists of one dimension and 25 items. The items in the scale were structured in a five-point Likert-type scale as "totally agree, agree, undecided, disagree, and strongly disagree". Twenty-one of the items in the scale contain positive judgments, and four of them contain negative judgments. While scoring the statements containing negative judgments, the scores were reversed for calculation. While the Cronbach alpha internal consistency coefficient of the related scale was 0.924, it was calculated as 0.912 in this study. This finding shows that the scale is reliable. Confirmatory factor analysis (CFA) was applied to the data set to gather evidence for the construct validity of the scale. As a result of the analysis, it was calculated as $\chi 2/df=0.94$, *CFI*=0.99, *AGFI*=0.93, *NNFI*=0.99, *RMSEA*=0.010, *SRMR*=0.094. The relevant values confirm that the scale is compatible with the data set (Kline, 2019).

21st Century Skills Efficiency Perceptions Scale

The related scale was developed by Anagün et al. (2016) to determine pre-service teachers' perceptions of 21st-century skills. The aim of this scale is to determine to what extent pre-service teachers have 21st-century skills (Anagün et al., 2016). There are three sub-dimensions and a total of 42 items on the scale. The statements in the scale are in a five-point Likert model as "never, rarely, sometimes, often, and always". There are 18 items in the Learning and Renewal Skills sub-dimension, 16 items in the Life and Career Skills sub-dimension, and eight items in the Information-Media and Technology Skills sub-dimension. The Cronbach alpha internal consistency coefficient of the whole scale was calculated as 0.889, the Learning and Renewal Skills sub-dimension 0.845, the Life and Career Skills sub-dimension 0.826, and the Information-Media and Technology Skills sub-dimension

0.810. In this study, the Cronbach alpha internal consistency coefficient of the whole scale was 0.925, the Learning and Renewal Skills sub-dimension was 0.905, the Life and Career Skills sub-dimension was 0.812, and the Information-Media and Technology Skills sub-dimension was 0.829. Available data indicate that the scale is reliable. CFA was applied to test the construct validity of the scale. As a result of the analysis, it was found as $\chi 2/df=0.53$, *CFI*=0.99, *AGFI*=0.92, *NNFI*=0.99, *RMSEA*=0.010, *SRMR*=0.091. Existing values indicate that the scale is in good agreement with the data (Kline, 2019).

Analysis of Data

Research data were analyzed using SPSS and the R programming language. While SPSS was used for descriptive analysis, the Lavaan package in the R programming language (Yves, 2012) was used for structural equation modeling. Before the data was analyzed, the suitability of the data for the analysis was checked. In this context, assumptions such as missing data, extreme value, sample size, normality, linearity, and multicollinearity were examined.

According to Tabachnick and Fidell (2013), missing data should be checked before starting the analysis. In this context, first of all, it was checked whether there was missing data in the data set, and it was determined that there was no missing data in the data set. Then, univariate and multivariate outlier control were performed on the data set. To determine univariate outliers, the raw scores in the data set were converted into Z scores, and the scores outside the -3 to +3 score range were accepted as univariate outliers. As a result of the relevant analysis, the information of a total of nine participants who were outside the range of scores determined were excluded from the data set. Then, the Mahalanobis values of the data were examined to determine the multivariate outliers in the data set. Tabachnick and Fidell (2013) state that 0.001 is the critical value for the Mahalanobis value, and values below this value are considered as multivariate extreme values. After the tests were carried out in this context, the data of three participants with a Mahalanobis value below 0.001 were deleted.

After univariate and multivariate outliers were removed from the data set, the sample size of the study was 218. According to Heck and Thomas (2015), a sample size of at least 200 people is sufficient for structural equation modeling. The sample size is expected to be sufficient for structural equation modeling.

For structural equation modeling, the univariate and multivariate normality conditions of the data set should be determined. For the univariate normality assumption, the kurtosis and skewness values were examined, and the relevant values were found to be between -2 and +2. According to George and Mallery (2010), the values of kurtosis and skewness in the range of -2 to +2 indicate that the data provide univariate normality. According to Field (2009), univariate normality is a prerequisite for multivariate normality, but ensuring univariate normality does not guarantee multivariate normality. Therefore, the Henze-Zirkler multivariate normality test was applied to the data set to determine whether the data set provides multivariate normality. The relevant value was calculated as 2.03, and it was determined that the data set did not meet the multivariate normality assumption ($p>0.01$). The Unweighted Least Squares (ULS) method was preferred as the estimation method in the multivariate analysis process. Because Koğar and Yılmaz Koğar (2015) revealed that ULS produces more effective results than other methods in cases where the assumption of multivariate normality cannot be met.

The multicollinearity problem is expressed as the high similarity between independent variables. According to Tabachnick and Fidell (2013), correlation, VIF, and tolerance values between independent variables should be examined. A correlation between independent variables greater than 0.85, a VIF value greater than 10, and a tolerance value less than 0.01 are indicators of multicollinearity (Kline, 2005). First of all, the correlation between independent variables was examined. Relevant values were found to be between 0.468 and 0.595. Afterward, it was determined that the VIF values were between 1.404 and 1.695, and the tolerance values were between 0.590 and .0712. As a result,

there is no multicollinearity problem among the independent variables. After it was determined that the data set met the assumptions required for feed analysis, descriptive analyses were applied to the data set. The values obtained after the related analyses are presented in Table 1.

Table 1

Descriptive Statistics of Mathematical Literacy Self-Efficacy and 21st Century Skills Efficacy Perceptions Scales and Sub-Dimensions

Scales and Sub-Dimensions	N	Min	Max	$\bar{x}$	SD
Mathematical Literacy Self-Efficacy Scale	218	2.20	4.76	3.56	0.43
21st Century Skills Competence Perceptions Scale	218	3.00	5.00	4.00	0.35
Learning and Renewal Skills Sub-Dimension	218	2.33	5.00	3.74	0.46
Life and Career Skills Sub-Dimension	218	3.00	5.00	4.19	0.35
Information-Media and Technology Skills Sub-Dimension	218	3.00	5.00	4.21	0.47

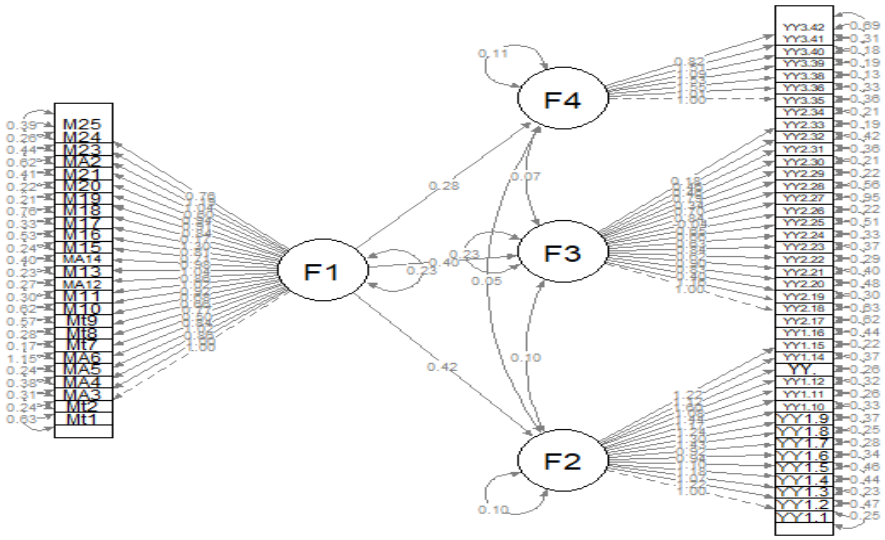
Table 1 shows that the mean score of mathematical literacy self-efficacy is $\bar{x}$=3.56. On the other hand, the mean score of the mathematical literacy self-efficacy of the participants in the research is above average. In addition, the mean score of 21st-century skills efficacy is high ($\bar{x}$=4.00). The perceptions of 21st-century skills efficiency of the participants are at a high level. Moreover, when the mean scores of the sub-dimensions of the 21st Century Skills Efficacy were examined, it was determined that only the perceptions of learning and renewal skills were relatively lower ($\bar{x}$=3.74), and the other sub-dimensions were at a higher level ($\bar{x}$=4.19, $\bar{x}$=4.21). The participants have lower perceptions of learning and renewal skills compared to their perceptions of life and career, information-media, and technology skills. As a result, the mean scores of both the mathematical literacy self-efficacy and 21st-century skills perception scales are high.

Results

Path analysis was applied to reveal the effect of mathematical literacy on learning and renewal, life and career, and information-media technologies skills. The results are presented in Figure 2. In Figure 2, F1 represents mathematical literacy self-efficacy, F2 refers to learning and renewal skills, F3 refers to life and career skills, and F4 refers to information-media and technology skills. Figure 2 shows that learning and renewal skills of mathematical literacy (.42, t=9.92, p<.05), life and career skills (.40, t=9.81, p<0.5), and information-media and technology skills (.28, t=7.33, p<.05) were found to be significant and positive predictors. In other words, the Ha1, Ha2, and Ha3 hypotheses examined within the scope of the research were supported. Furthermore, when the levels of significant effects are examined, it can be stated that a one-unit increase in mathematical literacy self-efficacy causes a 0.42 increase in learning and renewal skills, a 0.40 increase in life and career skills, and a 0.28 increase in information-media and technology skills. In other words, it can be stated that mathematical literacy self-efficacy has a similar level of effect on learning and renewal skills and life and career skills, while it has less effect on information-media and technology skills.

Figure 2.

Path Analysis Diagram for the Tested Model



Confirmatory factor analysis revealed the model's compatibility with the data. Table 2 presents indicators related to the aforementioned analysis.

Table 2

Fit Indices of the Tested Model

Fit Index	Good Fit	Acceptable	Value Achieved	Conclusion
RMSEA	0 ≤ RMSEA ≤ 0.05	.05 <RMSEA ≤ .08	.01	Good Fit
SRMR	0 ≤ SRMR ≤ .05	.05 <SRMR ≤ .10	.09	Acceptable
TLI	.95 ≤ NNFI ≤ 1.00	.90 ≤ TLI <.95	.99	Good Fit
CFI	.95 ≤ CFI ≤ 1.00	.90 ≤ CFI <.95	.99	Good Fit

Source: Schermelleh-Engel et al., 2003

Table 2 shows that the RMSEA, TLI, and CFI values, which are among the fit indices of the established model, are at a good level, and the SRMR value is between acceptable values. Briefly, there is a good level of compatibility between the model established and the data.

Discussion and Conclusion

This study examined the effect of mathematical literacy self-efficacy on learning and renewal, life and career, and information-media technology skills. Pre-service primary school teachers' mathematical literacy self-efficacy was found to positively affect the perceptions of learning and renewal, life and career, and information-media technology skills, and all hypotheses were supported. For the first hypothesis, the effect of mathematical literacy self-efficacy on learning and renewal skills was examined, and the hypothesis was supported. As stated by Julie and others (2017), mathematical literacy is required to form the basis of 21st-century skills. In this study, it was concluded that pre-service teachers' mathematical literacy self-efficacy affects their 21st-century skills efficiency. Within the scope of learning and innovation skills specified by P21, creativity and innovation, critical thinking and problem solving, communication and cooperation skills come to the fore. Individuals of the 21st century are expected to develop original ideas to find solutions to problems they face in daily life, find different solutions from different perspectives, look critically at problems, adapt quickly to new situations, and take responsibility by collaborating (Karatas & Zeybek, 2020). In this context, it has been concluded that prospective primary school teachers who are mathematically literate will also have these skills.

For the second hypothesis, the effect of mathematical literacy self-efficacy on life and career skills was examined, and the hypothesis was supported. Within the scope of P21's Life and Career Skills, flexibility and adaptability, initiative and self-direction, social and intercultural skills, productivity and accountability, and leadership and responsibility skills were prerequisites. It is also concluded that mathematical literacy positively affects the skills within the scope of life and career, as stated by P21. For the third hypothesis, the effect of mathematical literacy self-efficacy on information-media technologies skills was examined, and the hypothesis was supported. Information literacy, media literacy, and ICT (information, communication, and technology) literacy are included within information-media technologies skills. In this context, mathematical literacy self-efficacy was found to positively affect information literacy, media literacy, and ICT literacy. Also, digital literacy, which is an important basic skill that individuals should have, especially in the 21st century, is higher among mathematically literate individuals. In other words, individuals with strong mathematical literacy self-efficacy are generally more comfortable with technology and more likely to adapt to new digital tools. As Novita and Herman (2021) stated, it is challenging to develop individuals' digital literacy, and information literacy, media literacy, and ICT literacy can be improved by improving the individual's mathematical literacy.

Mathematical literacy self-efficacy is an important determinant of an individual's ability to develop 21st-century skills. However, pre-service teachers possessed a limited and incomplete understanding of the concept of mathematical literacy (Yenilmez & Ata, 2013). By developing mathematical literacy self-efficacy, individuals can also develop skills such as critical thinking, leadership, problem solving, digital literacy, collaboration, and communication skills necessary for success in the 21st century. The mathematical literacy self-efficacy of prospective teachers is important for preparing the future generations. Students are first introduced to mathematics in formal education through primary-school teachers, and therefore, the importance of mathematics literacy of prospective primary school teachers should not be ignored (Tarım et al, 2017). In the tested model, a significant and strong relationship was found between mathematical literacy self-efficacy and 21st-century skills. Developing 21st-century skills also requires the development of mathematical literacy self-efficacy.

By demonstrating the positive impact of mathematical literacy self-efficacy on perceptions of 21st-century skills efficiency, this study makes an important contribution to the research examining the relationship between these two concepts. While previous studies have primarily addressed mathematical literacy in the context of academic achievement or problem-solving skills (e.g., Pelitli & Yetim, 2020; Zehir & Zehir, 2016), this study adds a new perspective to the literature by showing how it shapes pre-service teachers' perceptions of 21st-century skills. The findings emphasize that strategies

to strengthen mathematical literacy self-efficacy in teacher education programs are critical for developing 21st-century skills efficiency. In this context, it is suggested that teacher education curricula should include modules that provide mathematical literacy practice through real-life problems and support self-efficacy.

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