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Interrelation of levels of mathematical literacy in conditions of distance learning

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Abstract

Mathematical literacy and knowledge play a significant role in the formation of competencies. The purpose of the study is to determine the levels of mathematical literacy and their dependence on the type of thinking and the level of creative abilities in a distance learning environment. The research objectives are as follows: assess thinking (by type) and creativity; assess mathematical literacy; and determine the relationship between the level of mathematical literacy and thinking/creativity indicators. In line with this, it was established that the ratio of the spread in the values of the dependence of mathematical literacy on the basic forms of thinking (objective, symbolic, sign) is high. In practice, the study findings can become a starting point for further research in the field of critical thinking or may be applied during the development of mathematics training courses for students.

Keywords: correlation analysis; creativity; mathematical literacy; regression analysis; school; thinking skills.

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1. Introduction

Thinking skills remain the most critical competencies for students of today and the future (Koh et al., 2019). The practice shows that thinking skills mastered in secondary school contribute to the development of higher-order thinking at a later age. Usually, students have a positive attitude towards using thinking skills developing methods within distance learning (Bağ & Gürsoy, 2021). This may well be the result of understanding that thinking promotes the development of logical conclusions and literacy in response to a specific situation or problem. Different types of thinking can help a person develop self-regulation tactics and make multiple decisions (Lin et al., 2020). Each individual must have knowledge in order to show their thinking and creative abilities (Bicer, 2021; Ganeeva et al., 2017). Mathematical literacy promotes mental aptitude and awareness in real life. It is essential for people to solve various problems, analyze, and draw conclusions. Thus, mathematical literacy is beneficial not only to individual citizens but also to the whole society as it strengthens democracy and culture (Genc & Erbas, 2019). Individual mathematical knowledge is the mathematical basis for responding to problem situations. The formation of strategic mathematical literacy requires skills of various thinking types: visual thinking, conceptual knowledge, metacognitive awareness, understanding of problem-solving strategies. The students acquire these skills during their studies in primary and secondary school (Abdullah et al., 2014).

Creativity is also a significant factor becoming increasingly important in future professional activities not only in the field of arts and crafts but also in science, technology, engineering, and mathematics. Therefore, the development of creativity should begin at school age (Müller & Pietzner, 2020).

1.1. Conceptual or Theoretical Framework

Development of mathematical literacy and thinking skills requires knowledge, beliefs, and understanding of teachers (Bicer, 2021). Newly-emerging opportunities in the field of thinking and mathematical literacy advancement have become extremely relevant in networked and distance learning, especially in the context of the pandemic (Qi, 2021). The spread of COVID-19 has challenged educational systems around the world, forcing them to switch from traditional methods to online teaching approaches (Qarkaxhja et al., 2021). As a result, the number of digital tools employed in education is increasing every day. Digital environment has many advantages and disadvantages, but the opinion of teachers, their perception, and qualifications remain of the highest value, especially in the context of distance education (Kaoud et al., 2021).

This research is an original and reflective study of the dependence of the level of mathematical literacy on the type of thinking and creativity level.

The effect of combining synchronous online learning with visual thinking was investigated by Ruan (2019). The results obtained from that investigation demonstrated that (1) networked learning considerably affects creativity, (2) visual thinking influences creativity, and (3) combining networked learning with visual thinking learning affects skill development.

The study of the formation of mathematical literacy and thinking skills in secondary school students in the context of distance learning has scientific aspects, and the present paper seeks to complement and deepen previous research on these aspects.

1.2. Related Research

The formation of mathematical literacy and its dependence on the type of thinking and the level of creativity in a secondary school represent two important aspects of learning and acquiring relevant competencies.

Fang and Chapman (2020) studied mathematical literacy from the standpoint of strategies for reading, summarizing, paraphrasing, storytelling, questioning, grading, and visualization. This enabled them to come up with solutions that can help mathematics teachers develop mathematical literacy in their students (Fang & Chapman, 2020).

A study on the use of modern web technologies for intellectual and mathematical skills development was carried out by Zabiyeva et al. (2021). They described the problems of professional and pedagogical education, in particular those related to the use of modern web technologies in mathematics education (Zabiyeva et al., 2021).

The matter of visual thinking and visual representation when solving mathematical problems was investigated by Abdullah et al. (2014). The results they achieved generally demonstrate that approaches to strategic and visual thinking (VStops) positively affected achievement, conceptual knowledge, metacognitive awareness, and mathematical strategies (Abdullah et al., 2014).

The effectiveness of the development of thinking in students in the course of thematic classes in the advanced areas of discrete mathematics, computer science, and digital technologies was considered by Anisimova et al. (2021). Researchers showed that the study of discrete mathematics contributes to the development of logical thinking and independent work skills, forms the ability to use information technologies in solving problems, contributes to deeper and more durable assimilation of knowledge, and positively affects the development of communicative competence, digital competence and engineering thinking (Anisimova et al., 2021).

The presence of methodological techniques in the organization of creative interdisciplinary activities with the aim of creating mobile applications that contribute to the formation of mathematical thinking skills was revealed by Soboleva et al. (2020).

Koh et al. (2019) identified conditions for the improvement of different types of thinking in the context of networked learning in secondary school. As such, networked learning teaches students how to think critically through dialogue and negotiation. Optimal conditions for this presuppose connecting students and educators in question-and-answering activities taking place, for example, under posts in the network.

A study devoted to literacy formation and improvement of thinking skills of high school students showed that every individual needs competence and thinking skills (Bağ & Gürsoy, 2021). Science uses strategies that develop higher-order thinking skills, such as case studies and reading scientific articles. Hugerat and Kortam (2014) found that teaching methods have a significant impact on the development of higher-order thinking skills. Also, they can notably affect students' emotional and cognitive attitudes (Hugerat & Kortam, 2014).

The significance of the work by Heong et al. (2020) resides in data obtained from consideration of learning styles integration and higher-order thinking skills (HOTS). The role of HOTS was given top attention in their study as these skills, as researchers stated, represent different individual preferences and strengths in learning as well as can show new learning possibilities. Following the inferences of Heong et al. (2020), the most critical HOTS are comparison and induction.

The paper of Chen and Chen (2021) on the impact of STEM (Science, Technology, Engineering, and Mathematics) on learning and creativity emphasizes the continuous integration of digital technologies in school education. In this respect, researchers note that the development of creative thinking in students is facilitated by combining different situations (e.g., scientific, industrial, and real-life) with a creative approach, developing original research, as well as solving problems with specific engineering

goals (Zhienbayeva & Tapalova, 2014). Consequently, STEM education and creativity are claimed to be able to provide students with deep knowledge and skills to be used in real life. Furthermore, their research shows that higher-order thinking skills and creativity contribute to problem-solving.

1.3. Purpose of the Study

Currently, teaching methods used in secondary schools are faced with the necessity to shape and develop mathematical literacy and thinking skills during distance education. As a result, students acquire the chance to use new skills and competencies in real life and solve problems that differ in complexity, amount of support, and/or content in other, often simplified, ways. The current study considers the formation of mathematical literacy and thinking skills in high school students and the relationship between mathematical literacy and thinking skills in a distance learning environment.

2. Method and Materials

The importance of this work stems from the choice of its topic – formation of mathematical literacy and thinking in secondary school students under distance learning conditions

Its ultimate goal is to determine the levels of mathematical literacy and their dependence on the type of thinking and the level of creative abilities in a distance learning environment.

The study's hypothesis assumes the presence of a relationship between mathematical literacy and thinking and creativity indicators.

The objectives that are to be accomplished for its acceptance or rejection are as follows: (1) assess thinking and creativity according to the method developed by Jerome Bruner; (2) determine the level of mathematical literacy based on the PISA tasks; (3) determine the relationship between the level of mathematical literacy and thinking/creativity indicators.

The scientific novelty of this paper lies in the determination of the correlation and regression between mathematical literacy and thinking skills and the level of creativity, which can further be used in the course of distance education planning. Potential mathematical literacy, thinking skills, and creativity are highly appreciated both in distance education and in practice.

2.1. Research Model

Research design, methodology, survey, and mathematical calculations were jointly developed by the authors. The very study process was carried out at Abai Gymnasium (Kaskelen, Kazakhstan).

To ensure distance learning, the Microsoft Teams platform was used. This choice enabled creating a virtual classroom that meets the requirements of the educational process (speeches, two-way conversations, file exchange, setting individual tasks, receiving and checking the exercises done) and preserving training effectiveness. When conducting classes in the distance format, the experience of the Yelabuga Institute of KFU was used (Ganeev & Ganeeva, 2015; Ganeeva et al., 2017).

2.2. Participants

The sample of participants consisted of 25 ninth-graders studying online as these students could take part in a special mathematical literacy test (OECD, 2018). As for gender distribution, 55% females and 45% males were enrolled. Their average age was 15.34 ± 1.25.

2.3. Data Collection Tools

In order to judge respondents' mathematical literacy, this research turned to PISA (Program for International Student Assessment) scientific literacy test, particularly its written math assignments. In this regard, mathematical literacy level was assessed on an international six-point scale, where:

(6) – Students can generalize and use information based on complex task research and modeling; they use knowledge in a non-standard context, as well as advanced mathematical thinking.

(5) – Students can apply mathematical concepts and perform operations to solve unfamiliar problems; they explain the course of the solution, choose, compare, evaluate, and argue the solution strategy.

(4) – Students can select and combine information, analyze practical problems, use a limited range of skills, reason things out in a direct context, argue actions.

(3) – Students can follow a detailed algorithm of decisions while briefly arguing their actions, giving simple interpretations of the results, and providing basic reasoning.

(2) – Students can solve problems that require direct inference based on the use of the simplest algorithms, formulas, actions, rules.

(1) – Students can cope with the simplest actions if the problem has an explicit situation and a step-by-step solution algorithm is given.

2.4. Data Collection Process

This research took advantage of the methodology proposed by Jerome Bruner, which made it possible to determine the basic (dominant) type of thinking and creativity level. The corresponding questionnaire distinguished four main types of thinking (objective, visual, sign, symbolic) and creativity. Overall, it contained 75 statements that were equally divided into five sections and with which respondents were asked to agree ("+") or disagree ("–"). The level of creativity and basic thinking of the respondents was assessed in each section.

2.5. Data Analysis

Multiple correlation and regression analysis was carried out according to the research data using the Microsoft Office Excel 2007 software package. The level of mathematical literacy of the participants was taken as a dependent variable (*Y*). The values of objective thinking (*X1*), symbolic thinking (*X2*), sign thinking (*X3*), visual thinking (*X4*), and creativity (*X5*) were used as factors that potentially affect the value of mathematical literacy. The quantitative values were presented as (*M*±*SD*), where **M** is the mean and **SD** is the standard deviation of the mean. The result was considered statistically significant if $p \leq .05$.

2.6. Research limitations

The limitation of this study was associated with seventh- and eighth-grade students as they could not participate in the mathematical literacy testing (PISA).

3. Results

When assessing thinking and creativity skills following Bruner's method, it was found that the average value for objective thinking was 8.60 ± 3.57, for visual – 8.20 ± 2.43, for sign – 8 ± 1.76, for symbolic – 8.16 ± 1.55, for creativity – 8.04 ± 1.97.

When determining the level of mathematical literacy, it was found that its average value was 4.08 ± 1.35.

Outcomes of the multiple correlation and regression analysis carried out according to the research data is given in Table 1.

Table 1. Multiple correlation and regression analysis

No.	Y Mathematical literacy	X1 Objective thinking	X2 Visual thinking	X3 Sign thinking	X4 Symbolic thinking	X5 Creativity
1	5	10	9	8	7	8
2	4	6	7	8	6	6
3	6	13	11	10	9	9
4	2	5	6	7	8	5
5	3	8	8	9	11	7
6	3	3	4	4	6	5
7	4	9	9	8	10	11
8	4	10	11	8	9	10
9	2	4	4	6	8	9
10	6	15	10	11	9	10
11	5	10	9	8	7	8
12	4	6	7	8	6	6
13	6	13	11	10	9	9
14	4	6	7	8	6	6
15	5	10	9	8	7	8
16	6	13	11	10	9	9
17	2	5	6	7	8	5
18	3	8	8	9	11	7
19	3	3	4	4	6	5
20	4	9	9	8	10	11
21	4	10	11	8	9	10
22	2	4	4	6	8	9
23	6	15	10	11	9	10
24	5	10	9	8	7	8
25	4	10	11	8	9	10
Average mean	4.08	8.6	8.2	8	8.16	8.04
Standard error of the mean	1.35	3.57	2.43	1.76	1.55	1.97

When assessing the strength of the relationship, the correlations on the Chaddock's scale (*X1*, *X2*, *X3*) were selected for further study of the regression relationship. These correlations were positive and significant.

The coefficient of determination (R^2) characterizing the proportion of the spread in the values of the dependence of *Y* was .928, that is, 92.8% of the spread of *Y* is explained by the constructed

regression equation. Correspondingly, this means that the calculated parameters of the model explain the relationship between the studied parameters by 92.8%.

The *Y*-intersection coefficient was 3.634100, which indicates that *Y* will be 3.634100 when all variables in the considered model are equal to 0. In other words, other factors that are not described in the model also affect the value of the analyzed parameter.

The analysis of variance was also carried out to assess the quality of the model obtained. Its reliability in accordance with the *p*-value, which is equal to .010637692, means that the relevant independent variables affect the dependent variable, and the coefficient cannot be removed from the equation. The fact that the significance of Fisher's criterion (*F*) does not exceed .05 implies that the model is significant.

To demonstrate the results obtained clearly, a correlation diagram was built (Figure 1).

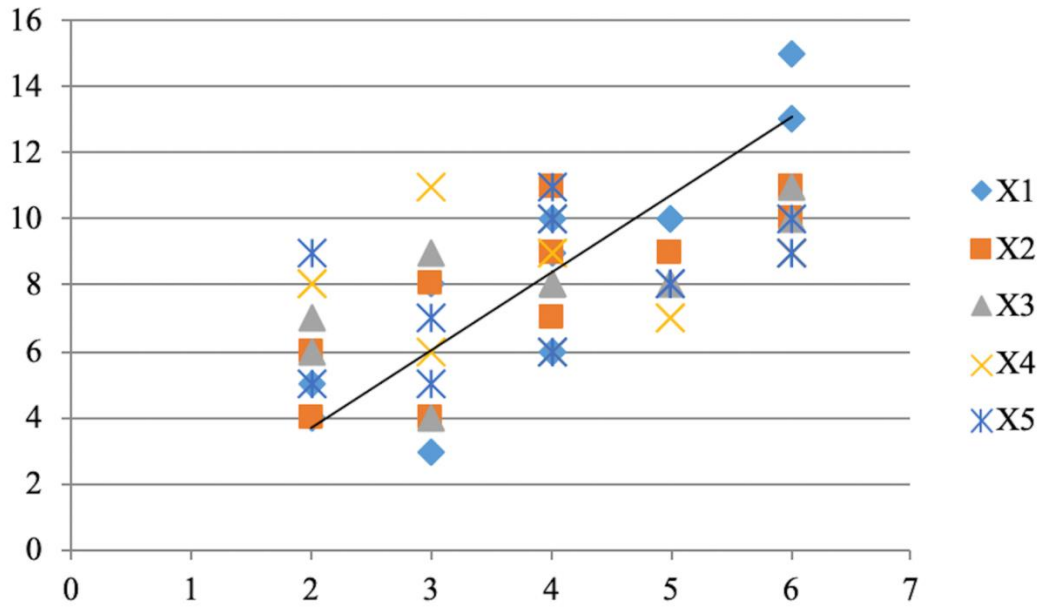

Figure 1. Linear correlation between mathematical literacy and thinking

The linear trendline shows the tendency of changes: the higher the objective (*X1*), symbolic (*X2*), and sign thinking skills (*X3*), the higher the mathematical literacy (*Y*).

Hence, when studying the relationship between mathematical literacy and the level of thinking and creativity, it was found that the higher the critical thinking skills, the higher the mathematical literacy.

As concerns mathematical literacy and critical thinking skills formation in secondary education in the context of distance learning, it can be stated that there is a direct relationship between mathematical literacy and objective, symbolic, and sign thinking.

4. Discussion

Ilhan and Aslaner (2020) analyzed correlations between mathematical literacy, reasoning skills on geometrical shapes, and geometry performance. They reviewed the link between mathematical literacy and reasoning skills, built models of the studied variables, and confirmed the presence of a positive and strong relationship between them. Apart from the fact that this approach is important and interesting, it correlates with the results obtained within the current study.

The matter of mathematical literacy and creative thinking was also investigated by Fitrianawati et al. (2020). They examined critical, creative, collaborative, communication, and mathematical literacy skills of modern students and uncovered that the relationship between mathematical literacy and student creative thinking is significant. The outcomes of the current work are fully in line with these inferences.

Along the same lines, Thuneberg et al. (2018) reviewed the link between creativity, autonomy, and visual thinking in distance learning, while Katrancı and Şengül (2019) considered the levels of mathematical literacy and visual thinking in high school students. Data collected by both researchers showed a strong positive correlation between mathematical literacy and visual thinking, which corroborates greatly with the findings of the present paper.

The use of PISA tasks for studying the effect of learning strategies on mathematical literacy was also adopted by Magen-Nagar (2016). Generally, her findings show that learning strategies and thinking skills have a notable impact on mathematical literacy. We used a similar methodology and obtained the same conclusions.

Connection between logical thinking and mathematical literacy was also discussed by Chytry and Kubiatko (2021). To study this matter in full, they used mathematical reasoning, logical thinking tests, and mathematical skills as research tools. As a consequence, logical thinking was confirmed to affect mathematical knowledge, which has much in common with the data obtained in the course of the present research.

The research conducted in Institute Pendidikan examined higher-order thinking skills and mathematical literacy in 21st-century education. It revealed that improving mathematical literacy requires different types of thinking to be developed as they are tightly interconnected. These conclusions were proved by the correlation analysis (Noordyan et al., 2020) and are identical to those obtained in this paper.

The study of mathematical literacy conducted by Maslihah et al. (2020) showed that mathematical competencies (solving mathematical problems, communication, literacy, presentation) are particularly dependent on the thinking level (decisive, critical, creative, metacognitive thinking). High-order thinking indeed can stimulate students to be mathematically literate, which was evidenced within the limits of the experiment described in this article as well.

Makonye (2019) studied the role of thinking in the development of mathematical literacy. Her work demonstrated that thinking skills are associated with mathematical literacy. Hence, she supports the view that thinking skills must be taught to increase mathematical literacy.

A study of mathematical literacy based on abilities was conducted by Asmara et al. (2017). This research was carried out to determine a correlation between thinking and mathematical skills. The collected results showed that individuals with lower thinking skills have lower levels of mathematical literacy, and individuals with more profound thinking skills have a higher level of mathematical literacy. These conclusions are consistent with those provided in the current paper.

A study of thinking, communication, and curiosity skills was conducted by Zetriuslita et al. (2020). They confirmed the relationship between thinking skills and mathematical literacy, which is in complete agreement with the data of this research. On top of this, their research is pretty similar to the current one in terms of the methodology applied.

The relationship between creativity and mathematical ability was investigated by Qadri et al. (2019). They showed the effect of creativity increase on mathematical literacy improvement.

In sum, many scholars share the view that mathematical literacy and thinking skills play a critical role in modern learning and education. What is more, the world academic community is likely to believe that the higher the level of thinking skills, the better the mathematical literacy is. Hence, the central hypothesis of this research was confirmed in full.

5. Conclusions

The key intention of this work was to study the level of mathematical literacy and thinking skills in secondary education students in the context of distance learning and determine the relationship/correlation between these two indicators.

According to thinking and creativity skills assessment under Bruner's method, the average value for objective thinking was 8.60 ± 3.57, for visual – 8.20 ± 2.43, for sign – 8 ± 1.76, for symbolic – 8.16 ± 1.55, and for creativity – 8.04 ± 1.97. When determining the level of mathematical literacy, it was determined that the average value of mathematical literacy was 4.08 ± 1.35.

In order to analyze the link between the level of mathematical literacy and basic forms of thinking (objective, symbolic, sign, visual) and creativity, multiple correlation and regression analysis was carried out. After assessing the correlation strength on Chaddock's scale, objective, symbolic, and sign thinking were taken for further study. As a result, it was found that the ratio of the spread in the values of the dependence of mathematical literacy on the basic forms of thinking (objective, symbolic, sign) is 92.8%. According to the value of Fisher's criterion, the resulting model is reliable. That is, the basic forms of thinking affect the level of mathematical literacy. When constructing a trend line, a linear correlation trend was obtained, indicating that the better the objective, symbolic, and sign thinking, the better the mathematical literacy.

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