Factors propelling mathematics learning: insights from a quantitative empirical study

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ABSTRACT

Mathematics learning (ML) is a fundamental aspect of education that lays the groundwork for various academic disciplines and practical applications. Understanding the factors that propel ML is crucial for optimizing educational outcomes. This quantitative empirical study investigates the impact of logical reasoning (LR), critical thinking (CT), information technology (IT), and distance learning (DL) on ML. The study employs structural equation modeling (SEM) using SmartPLS 4 for data analysis and hypothesis testing. The findings reveal that LR, CT, IT, and DL positively influence ML. The results highlight the importance of fostering LR, CT, and the integration of IT in mathematics education. This study contributes to the existing body of knowledge by providing insights into the factors that promote effective ML. These findings have implications for educators, policymakers, and curriculum developers, aiding in the design of instructional strategies and the integration of technology to enhance ML outcomes.

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1. INTRODUCTION

Education is one of the important components of every individual as it facilitates learning and develops new skills and knowledge that can be helpful in different stages of their life [1]. However, it is a relatively complicated procedure to bring creativity to mathematics education as it is a consistent and dynamic process. The comparative analysis of the education system of Kazakhstan indicated that in the past the teaching method and the performance evaluation approaches of the teachers were not seemed to be good; currently, the trend is changing. It is a fact that the teaching method, content of the different courses, and overall mechanism have improved in Kazakhstan during the last couple of years [2]. The way of teaching and learning varies from region to region as well because most of the regions lack specifically in education. It also creates resistance in their learning process. Most of the students who specifically belong to Kazakhstan face the issue of resolving the critical case studies and mathematical equations, and the COVID-19 pandemic boosted this issue further due to distance learning. It was just because of their lack of understanding of the basic concepts [3].

Intuition is the ability of the individual to understand impulsively that their actions are right or wrong; it is the gut feelings. On the other hand, logic depends on the availability of precise information that is used to create an understanding of the phenomena [4]. Mathematical intuition and logic are the two important components in the overall phase of learning as they lead to creativity in the process of learning that consequently increases the interest of the students. Kazakhstan is a developing country, and most schools in the country still use the obsolete mode of learning. It has been found that the education system of Kazakhstan follows the process of rote learning as it is emphasized just by memorization. According to this approach to learning, the teachers and their instructors provide some of the learning materials in the form of lecture notes and theoretical exercises and expect their students to memorize all this material. In this way, the student's academic performance is measured based on their test or exam score, which excludes any type of evaluation of their learning [5].

Despite the importance of mathematics learning (ML), there is a need to understand the factors that influence its effectiveness. There is limited empirical evidence on the factors influencing ML. Therefore, this study aims to investigate the relationships between logical reasoning (LR), critical thinking (CT), information technology (IT), distance learning (DL), and ML. By examining these relationships, the study seeks to provide insights into the factors that propel ML, contributing to a deeper understanding of how these variables interact and impact students' ability to acquire mathematical knowledge and skills. In other words, this study attempts to answer the following research questions: i) what factors affect ML? and ii) how do these factors affect ML?

The findings of this study have significant implications for educators, policymakers, and curriculum developers as they shed light on the factors that play a pivotal role in enhancing mathematics learning. The insights gained from this research can inform the development of instructional strategies, curriculum design, and the integration of technology to create effective learning environments that foster mathematical proficiency and engagement among students.

The manuscript is structured to provide a comprehensive exploration of the factors influencing ML. The literature review section presents a research background that highlights the significance of ML. The theoretical framework section outlines the research hypotheses and establishes a theoretical foundation for the study. The research method section describes the research design, data collection procedures, and statistical analysis techniques, including structural equation modeling (SEM) with SmartPLS 4. The results, findings, and discussion section present the empirical findings, interprets the results, and discusses their implications. This structured approach ensures a logical flow of information, enabling readers to understand the context, methodology, results, and implications of the study in a coherent and systematic manner.

2. LITERATURE REVIEW

2.1. Research background

The inclusion and integration of mathematical intuition, logic, and critical and computation thinking in the learning environment and educational system are one of the most discussed topics among educational institutes in Kazakhstan. Mindetbay [6] conducted research to determine the importance of computational thinking on the general school achievement of the students in Kazakhstan. The findings of Mindetbay [6] demonstrate that "the sciences subjects like physics and chemistry, and the overall perception of the students regarding the computational thinking is significantly correlated with the computational performance of the students. Thus, computational thinking skills have a moderate association with the achievement of the school specifically in Kazakhstan."

In addition to this, most non-math students face difficulties in understanding advanced mathematical concepts due to the obsolete and lack of activity-based learning. Siddiqui [7] conducted research with the intent to minimize the hurdles specifically for students in Kazakhstan whose interest is in non-mathematical subjects. In order to achieve the actual outcomes, the intuitive approach of limits and integration is applied, and an activity-based introduction about the topic is provided. It has been found that the student's understanding of the mathematical concepts improved [7]. However, some engineering students also participated in this research as most of them had a clear understanding of the basic concepts. It shows that the mathematical intuition is one of the important components and its access to achieve the desired outcome. The mathematical intuition not only changes the behavior of the individual toward learning, but the learning of the learned things lasts for a longer period.

Trained teachers generally produce effective results compared with untrained mathematical teachers. Bakhytkul *et al.* [8] believed that in Kazakhstan the culturological approach should be applied in the educational system of the country as it is one of the effective ways of delivering highly valued results. The primary principles of this approach can perform activity-based learning with competence strategies. In addition, Bakhytkul *et al.* [8] also suggested that the awareness of teachers regarding advanced schools of thought is also one of the major determinants behind the development of the activity-based approach. It facilitates to know the required development of the skills in the students. In addition to this, it is also the responsibility of the private and public sectors of Kazakhstan to bring advancement by introducing new technologies and infrastructure. It is also considered one of the major determinants of developing problem-solving skills. Kropachev *et al.* [9] conducted research to evaluate and analyze the digitalization of education by focusing on some of the most relatable problems in the country. Kropachev *et al.* [9] believed that consistent growth in different sectors can only be attained with the provision of valued information and skills development.

Educational technologies assist in developing problem-solving skills, the creation of logic, the development of intelligence, and the creative ability to think outside the box.

The findings of Iskakova *et al.* [10] demonstrated that the deep analysis and evaluation of the problem without the use of any formula that is generally student memorized in math and other scientific subjects assist in developing the thinking skills in the students specifically in Kazakhstan. It was also demonstrated by Iskakova *et al.* [10] that a student generally started to take interest in the problems once the problem is explained in a way that is derived from their interest and their environment. This means that the development of logical reasons in mathematics subjects can improve learning outcomes and prove to be more effective. However, there are some logical issues that can arise and create troubles in the development of mathematical intuition and logic. The way of learning and teaching is changing day by day with the development of new strategies and technologies. Most students prefer to acquire knowledge that contains creativity as it is the most effective approach to learning. Mirzaxolmatovna and Fozilov [11] investigated the importance of the logical issues that can arise in the learning process specifically in teaching mathematics in primary schools. Mirzaxolmatovna and Fozilov [11] suggested that the process of cognition is not limited and only revolves around textbooks and mathematics exercises; however, it encompasses whole lives.

Technological advancement and gradation have made a mathematical intuition easier for students. The findings of Smagulov and Karaseva [12] suggested that information and communication technologies play a significant role in establishing algorithmic skills in students. Most of the students face hurdles and issues in resolving the mathematical questions and exercises; this is just because of their limited and narrow understanding. On the other hand, one of the other reasons behind the coming of these issues is that most of these students rely and depend only on intuition and memorization.

The mathematical equations are also based on different ideas and experiments, which usually help to understand the balance between two or more components. The findings of Temirova [13] indicated that mathematics is the universal language and can be understood in the wider part of the world, so it contains the formation of a variety of areas. Similarly, teachers try to bring creativity by including different activities in order to assist students in the development of logical responses and reasoning by elaborating on the goals and objectives. Ibadildin *et al.* [14] demonstrated that COVID-19 realizes that different schoolteachers are not capable enough to successfully engage their students as both instructors and students were comfortable with their old approach to teaching. The teachers that were trained enough to apply the concepts of mathematical intuition received better outcomes. Hence, the development of mathematical intuition and logic can lead to effective and better results in terms of learning and developing problem-solving skills.

2.2. Theoretical framework

2.2.1. Logical reasoning

Logical reasoning, a fundamental cognitive skill, encompasses the capacity to think critically, engage in deductive and inductive reasoning, and employ analytical thinking in mathematical contexts [15], [16]. It involves the ability to identify patterns, recognize errors, and comprehend the conceptual implications of mathematical concepts and problems. Extensive research has consistently demonstrated that strong LR skills are crucial for successful ML across various educational levels [17], [18].

Having well-developed LR abilities empowers students to effectively analyze complex mathematical problems, break them down into manageable components, and systematically explore potential solutions. By employing logical thinking processes, students can discern underlying patterns, relationships, and structures within mathematical problems, enabling them to establish connections between different mathematical ideas and domains. This interconnectedness fosters a deeper understanding of mathematical concepts, facilitating the transfer and application of knowledge to novel problem-solving situations. Therefore, this study hypothesizes the first hypothesis: LR has a positive impact on ML (H1).

2.2.2. Critical thinking

Critical thinking, an essential cognitive skill, encompasses a multifaceted set of abilities that enable individuals to ask insightful questions, critically evaluate evidence, explore alternative solutions, and engage in analytical reasoning when approaching mathematical problems and concepts. Extensive research conducted by several scholars [19], [20] consistently underscores the vital role that CT plays in the realm of mathematics education.

By fostering CT skills, mathematics education nurtures a deep understanding of mathematical concepts beyond mere procedural fluency. CT empowers students to approach mathematical challenges from diverse perspectives, encouraging them to explore different problem-solving strategies, perspectives, and solution pathways. Through the lens of CT, students are able to make connections between various mathematical concepts, uncover underlying patterns and relationships, and engage in abstraction and generalization, thereby enhancing their conceptual understanding of mathematics. Hence, the second hypothesis of this study is: CT has a positive impact on ML (H2).

2.2.3. Information technology

Information technology refers to the use of technological tools such as computers, software applications, and digital resources to augment the learning and comprehension of mathematics [21], [22]. The integration of IT in mathematics education has demonstrated substantial benefits across multiple domains. Extensive research conducted by previous scholars [23]–[25] underscores the positive effects observed when incorporating IT into ML environments.

One notable advantage of integrating IT in mathematics education is the promotion of increased student engagement. The interactive nature of technology tools coupled with the use of multimedia resources, stimulates students' curiosity, motivates active participation, and enhances their overall enthusiasm for learning mathematical concepts. Through dynamic visualizations, simulations and interactive applications, students are able to explore mathematical phenomena in an immersive and captivating manner, fostering a deeper connection with the subject matter. Thus, the third hypothesis of this study is written: IT has a positive impact on ML (H3).

2.2.4. Distance learning

Distance learning, also known as online learning, has emerged as a prominent approach in mathematics education, leveraging digital platforms and resources to facilitate learning experiences beyond the confines of traditional classroom settings [26]. Particularly in recent times, DL has gained significant prominence, offering flexible and accessible opportunities for students to engage in mathematical content. This educational modality provides a range of benefits, including personalized instruction, anytime-anywhere access to learning materials, collaborative online tools, and a wealth of digital resources and interactive activities.

Previous researchers [27]–[29] emphasizes the positive impact of DL in mathematics education, shedding light on its potential to enhance student outcomes. The flexibility offered by DL allows for personalized instruction, accommodating individual learning styles and paces. Students have the freedom to engage with mathematical content at their convenience, providing opportunities for self-directed learning and the ability to review materials as needed. This personalized approach supports student agency and autonomy, fostering a sense of ownership and responsibility for their own learning. Hence, the fourth hypothesis of this study is considered: DL has a positive impact on ML (H4).

Figure 1 illustrates the proposed relationships between the independent variables and mathematics learning. Logical reasoning, critical thinking, information technology, and distance learning are hypothesized to have positive impacts on ML. These variables are expected to contribute to improved performance, problem-solving abilities, conceptual understanding, and engagement in mathematics.

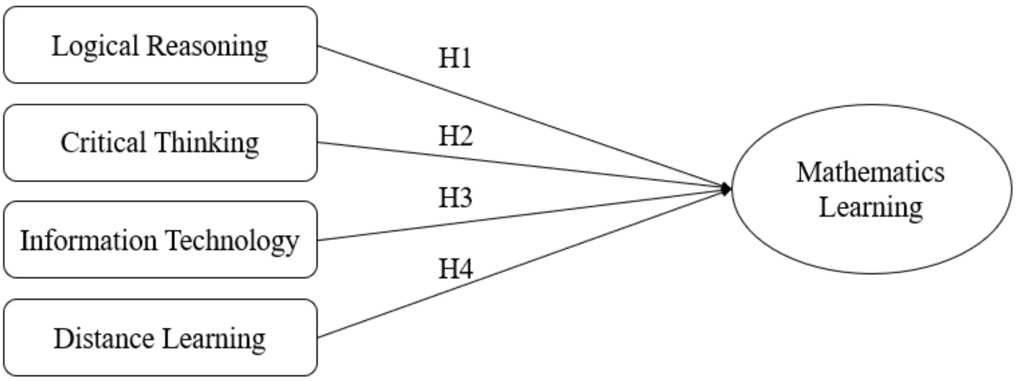

Figure 1. Proposed relationships between independent variables and ML

3. RESEARCH METHOD

3.1. Introduction

The aim of the research is to identify factors affecting the ML of 8th-grade students at Kazakhstan schools. In this chapter, different research methods are used to evaluate and analyze the problem statement and present the justification for using the research method. The chapter covers different sections including research philosophy, approach, design, data sources and data collection, sample strategy, data analysis, and ethical considerations.

3.2. Research philosophy

The research philosophies can be categorized based on methodology, epistemology, and ontology and are of different types including pragmatism, positivism, interpretivism, and realism [30]. In relevance to the aim of the study, a positivist philosophy is applied that focuses on credible facts and relies on causality using the quantitative method, a large sample size, and highly structured methods. This philosophy is suitable to analyze the learning outcomes of Kazakhstan students as it emphasizes on analyzing data based on human interaction. On the other hand, the use of interpretivism philosophy may not be justified as it relies on qualitative methods for analysis and measurement and evaluates multiple realities, whereas positivist philosophy evaluates a single reality [31]. Hence, the use of positivism philosophy is justified to accomplish the research objectives.

3.3. Research approach

The research approach is classified into either qualitative, quantitative, or mixed methods. For this study, assuming the selected philosophy of the research, a quantitative approach is considered that relies on the testing of hypothesis, measurement, and observation of data. This approach is important in analyzing the data using statistical tools and evaluating the relationship between the variables (i.e., mathematical intuition and logic and students learning outcomes). In contrast, the qualitative approach is not suitable for this study. First, it is not compatible with positivist philosophy. Second, it considers a comprehensive analysis of the data without involving statistical tools for analysis [32], which nevertheless are required to achieve the objective of the study. Therefore, the use of quantitative approach is suitable and in line with the research aim.

3.4. Research design

Research design is the process of achieving the research objectives using data sources, data collection instruments, and analysis techniques. It is of different forms depending on the nature of the study. However, for this study, a descriptive design is selected that involves a case study, surveys, and observation. This design is commonly applied in quantitative studies to allow the data collection using surveys. In this study, survey strategies are suitable for collecting as they can produce data suitable for statistical analysis and are less time-consuming. In addition to this, surveys are important in collecting large samples of data and allow quantitative analysis through descriptive statistics [30]. Moreover, survey design is relevant to explain the development of mathematical intuition and logic in students to improve the learning outcomes of 8th-grade students. In addition to this, a correlation design is also considered to assess the association between the variables and help to develop a greater understanding of the key constructs and their related association [33]. The use of correlation design can help determine the link between mathematical institutions and logic and students' learning outcomes; therefore, this design is critical to achieving the objectives of the study.

3.5. Data sources and data collection process

Primary and secondary are the two main data sources used in the study depending on their purpose and nature. Correlating with the objective, research philosophy, approach and design of the study, a primary data source is preferred to collect new, recent and updated data directly from the respondents, unlike secondary sources where the published primary data has to be molded to relate with the research objectives. In addition, primary data provide more control over the data and hence is selected for the study.

In relation to the data collection process, an online open-ended questionnaire survey is used to collect data from mathematics teachers in Kazakhstan secondary schools. The participants are contacted through an online professional social networking site (LinkedIn). A formal email was sent to them for participating in this study and giving responses in relation to the development of mathematical intuition and logic to enhance the learning outcomes of the students. Upon receiving a positive reply to the study, a copy of the questionnaire was emailed to them along with the instructions to be followed in filling out the questionnaire. In relation to the structure of the questionnaires, five indicators including LR, CT, IT, DL, and ML are included, and each of them has five questions as presented in Table 1. Besides, the indicators are distributed on the basis of the demographic characteristics of the participants, including age, gender, and social status as shown in Table 2. The responses received from the participants are then evaluated using the 5 Likert scale. Overall, the duration of collecting the data lasted between 4 and 6 weeks.

3.6. Sample size and strategy

In terms of the sample size, earlier a sample of 250 plus participants was considered. Nevertheless, considering the limitations of the researcher, i.e. (resources and time), a sample of 100 participants was finalized; hence, a total of 100 sample sizes of teachers both male and female were collected for data collection. In terms of sampling strategy, a convenience sampling strategy was applied in which the participants were selected based on their availability and accessibility for the study.

Table 1. Online open-ended questionnaire

Section	Statement
Logical reasoning	I have logical understanding of the mathematical concept and a problem.
	I have an ability to identify a pattern and an error.
	Mathematical concept thought in 8th grade helps me under the conceptual consequences of the term.
	Online learning helps me to improve logical thinking.
	Information technology helps logical thinking ability.
Critical thinking	I always ask question about the existence and formation of the things.
	During the online learning my way of the thinking changes in different aspect.
	Using information technologies help me in understanding the mathematical intuition.
	I understand the importance of critical thinking in mathematical problem-solving process.
	I consider the alternative ways to solve the problem.
Information technology	Information technology provide more effective to understand the mathematical problem.
	The utilization of the information technology improves engagement in class.
	Information technology tools provide vast learning environment.
	Information technology tools help me to boost my critical thinking and logical learning.
	Information technologies increase my ability to analyze and solve problems.
Distance learning	Online learning helps me to improve the understanding the mathematical concepts.
	E-learning helps my ability to understand the logic and pattern in problem solving.
	Online learning helps me to improve my ability to do research and analyze the topic apart from syllabus.
	E-learning improves my mathematical intuition ability.
	I find online learning a better tool for improving the problem-solving ability than physical learning.
Learning outcome	I feel that I can solve mathematical problem effectively.
	I have a better understanding of mathematical concept than previous class.
	My knowledge and skills are improved.
	Now I understand the advanced mathematical concept clearly in comparison with the previous class.
	My ability to solve a logical mathematical problem are improved.

Respond to the questionnaire: Strongly agree; Agree; Neutral; Disagree; Strongly disagree.

Table 2. Demographic questionnaire

Question	Respond
What is your age?	12 years; 13 years; 14 years; 15 years.
What is your gender?	Male; Female; Other.
What is your marital status?	Single; Married.

3.7. Data analysis

Data analysis for this study was conducted using SEM with the aid of SmartPLS 4 software. SEM is a statistical technique that allows for the examination of complex relationships between variables and the testing of hypotheses within a comprehensive model. SmartPLS 4 is a powerful tool that facilitates the implementation of SEM, providing researchers with the ability to assess the measurement models and structural relationships among variables. In this study, SEM was employed to evaluate the proposed hypotheses and test the model fit. The analysis involved estimating the path coefficients, assessing the significance of relationships and evaluating the overall fit of the model. SmartPLS 4 enabled the assessment of both the measurement model and the structural model, providing valuable insights into the relationships between the independent variables and the dependent variable. The use of SEM with SmartPLS 4 contributed to the rigorous and comprehensive analysis of the data, allowing for a thorough examination of the proposed theoretical framework.

3.8. Ethical consideration

The researcher has undertaken and followed the necessary ethical rules and conduct while conducting this study. For instance, the objective of the study and its purpose were communicated to the participants both verbally and in written form to increase their knowledge about what is to be investigated. The details of the data collection process and instruments were also shared. To maintain the confidentiality and privacy of the participants, their names, personal details, and contact numbers were hidden. To secure the research data, a password-protected system was used to store the collected data, which was accessible only by the researcher. Besides, formal consent was obtained before starting the study, and the participants were given the choice to withdraw from the study at any moment. The data was collected with the availability of the participant and in their free time; above all not coercion was applied to collect the data.

4. RESULTS

4.1. Demographic characteristics

Before the statistical analysis of the responses, it is important to understand the sociodemographic characteristics of the participants. Table 3 indicates the sociodemographic characteristics of the participants.

These indicators will be taken into account during further analysis to provide more meaningful insights and conclusions from the study.

Table 3. Demographic characteristics of the participants

	Frequency	Percent (%)
Age		
18-25 years	26	26
26-36 years	25	25
36-45 years	25	25
46-55 years	18	18
Older than 55 years	6	6
Gender		
Female	58	58
Male	33	33
Prefer not to tell	9	9
Social Status		
Divorced	5	5
Married	69	69
Single	26	26

4.2. Measurement model analysis

Validity and reliability testing was conducted to assess the measurement properties of the variables included in the study. Table 4 presents the results of the analysis, including Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) for each variable. The measure of internal consistency reliability, Cronbach's alpha, provides an indication of how well the items within each variable assess the same underlying construct. Table 4 shows that both Cronbach's alpha, CR correspond to all the variables are higher than the threshold (i.e., 0.7) that represents the high reliability of the questionnaire. The AVE results indicate the convergent validity of the variables in the study. The AVE values ranging from 0.563 to 0.843 suggest that a significant proportion of the variance in the items can be attributed to the underlying constructs. This demonstrates that the items collectively measure the intended constructs effectively. These findings support the convergent validity of the measurement model, indicating that the variables reliably capture the targeted constructs and can be used for further analysis in investigating their impact on ML.

Table 4. Validity and reliability test

Variables	Cronbach's alpha	CR	AVE
LR	0.871	0.892	0.634
CT	0.762	0.797	0.563
IT	0.831	0.903	0.794
DL	0.781	0.801	0.843
ML	0.936	0.939	0.663

In assessing the SEM, one criterion for evaluation involves examining the loading factors associated with the observable variables (i.e., questionnaire items). It is expected that these loading factors should exceed 0.7 and display statistical significance within the 95% confidence interval (i.e., $P<0.05$). Table 5 displays the results of loading factor analysis, revealing that all loading factors of the observable variables surpass the threshold of 0.7 and exhibit statistical significance. These findings indicate a strong association between the observed variables and their corresponding latent constructs, reinforcing the reliability and validity of the measurement model employed in the study.

4.3. Hypothesis testing

The results of hypothesis testing using SEM are summarized in Table 6. This table provides insights into the relationships between the independent variables (LR, CT, IT, and DL) and the dependent variable (ML), as well as their associated statistical significance. Hypothesis 1, which posits a relationship between linear reasoning and ML, yielded a standardized regression coefficient (β) of 0.243. This coefficient indicates a positive and significant association between LR and ML ($p<0.05$), confirming Hypothesis 1. The findings suggest that higher levels of LR are positively associated with improved ML outcomes.

Table 5. Results of loading factors test

Variables		Loading factors	Mean	Std. Deviation	P-value
LR	LR1	0.792	4	1	0.001
	LR2	0.792	4.19	1.01	0.000
	LR3	0.882	4.05	1.05	0.012
	LR4	0.876	4.16	0.83	0.043
	LR5	0.79	4.22	1	0.012
CT	CT1	0.79	4.07	1.06	0.000
	CT2	0.779	4.05	0.97	0.004
	CT3	0.787	3.91	0.95	0.028
	CT4	0.846	4.09	0.89	0.000
	CT5	0.741	4.2	0.87	0.033
IT	IT1	0.86	4.1	1.04	0.002
	IT2	0.73	4.03	1.07	0.022
	IT3	0.836	4.12	0.82	0.041
	IT4	0.763	3.86	1.16	0.000
	IT5	0.862	4.12	0.82	0.012
DL	DL1	0.829	4.22	0.76	0.000
	DL2	0.82	4.33	0.79	0.008
	DL3	0.81	4.26	0.96	0.002
	DL4	0.711	4.28	0.85	0.001
	DL5	0.721	4.38	0.75	0.001
ML	ML1	0.728	3.91	0.95	0.000
	ML2	0.715	4.34	0.79	0.032
	ML3	0.791	4.28	0.85	0.033
	ML4	0.831	4.05	1.05	0.002
	ML5	0.718	4.12	0.82	0.008

Table 6. The results of hypothesis testing

Hypotheses	β	Standard deviation	p values	Result
LR->ML	0.243	0.063	0.000	Confirmed
CT->ML	0.149	0.058	0.010	Confirmed
IT->ML	0.264	0.061	0.033	Confirmed
DL->ML	0.453	0.048	0.006	Confirmed

Similarly, Hypothesis 2, which explores the relationship between CT and ML, revealed a standardized regression coefficient (β) of 0.149. This coefficient indicates a positive relationship, and the association was statistically significant ($p>0.05$). Hypothesis 2 is confirmed, suggesting that CT may still play a role in influencing ML, albeit with weaker evidence compared to other hypotheses. Moving on to Hypothesis 3 investigating the relationship between IT and ML, the standardized regression coefficient (β) was found to be 0.264. This coefficient was statistically significant ($p>0.05$). Thus, Hypothesis 3 is confirmed, indicating that the impact of IT on ML was supported by the data in this study. Finally, Hypothesis 4 examined the relationship between DL and ML. The standardized regression coefficient (β) obtained was 0.453 and the associated p-value was lower than 0.05. Consequently, Hypothesis 4 is also confirmed.

The coefficient of determination, R^2, is a measure of the proportion of the variance in the dependent variable explained by the independent variables in the regression model. In this study, the obtained R^2 value was found to be 0.73, indicating that approximately 73% of the variability in the dependent variable can be accounted for by the independent variables included in the model. This suggests that a substantial amount of variance in the dependent variable is explained by the predictors considered in the analysis. The R^2 value of 0.73 reflects a moderately strong relationship between the independent and dependent variables, demonstrating the utility of the regression model in explaining the observed variations in the dependent variable.

5. DISCUSSION

The importance of mathematical education for schools has always been a part of the discussion. Its importance in building CT and logical philosophy in students cannot be neglected. It is a dynamic and active process that enables the student to think outside the box. The objective of this research was to investigate the importance of the development of mathematical intuition and logic in students to attain the maximum outcome. The results of the study using the methodology of regression and correlation suggest the positive influence of mathematical education on the learning outcome of the student in terms of online learning as well as in terms of IT. The following sections represent a detailed discussion of the results. Comparing the results of this paper with other studies, it is observed that most of the findings relate to the evidence provided by previous researchers [34]–[39].

5.1. Learning outcome and logical reasoning

The findings from the study suggest a positive association of LR from mathematical education and concepts with the overall learning outcome of the student. LR is defined as the student's ability to solve a problem from the experience of developing mathematical reasoning. Moreover, finding the solution to the problem in real life is also a part of the development of LR in students. The positive association of logical thinking with effective learning ability and learning outcomes is evident by many researchers. For instance, Anggraeni and Suratno [34] documented the positive impact of science, technology, education, and mathematics (STEM) subjects including mathematics on the thinking ability of the student as well as their learning ability. The effectiveness of mathematics in terms of finding an innovative and creative solution to the problem by recognizing the pattern and logic behind the problem helps the student to increase their abilities as the student. Moreover, the student's capability of providing a logical argument under various concepts is also a part of the mathematical intuition.

Similarly, the findings from the study suggest a positive impact of logical building from mathematical intuition on the learning outcome of the student. This indicates that the student's ability to analyze the situation and provide an effective and sensible solution to the problem affects the learning outcome of the student. Mathematics is considered one of the subjects that contributes to the scientific development and CT ability of the students that help them to grow their abilities for future development. Understanding mathematical education helps the student specify the solution to the problem. Moreover, the well-developed and organized process in mathematical problem solving provides the ability to logically challenge the ongoing process and solve them critically. LR in a student develops when they utilize their previous knowledge and experience and employ them in solving some problems with the help of the basic mathematical assumption [40]. Moreover, the use of mathematical knowledge in building the relationship between the number and situation to develop the theatrical evidence is an important part of the mathematical intuition that helps in improving the learning outcome of the student. Furthermore, the study also documented the importance of mathematical intuition and logical learning in secondary education. Student ability to implement mathematical skill and theory to solve the problem not only helps them in mathematical concepts but also provides significant improvement in terms of other subjects [35]. Similarly, the ability of the student to create an efficient and effective method for solving mathematical problems increases the learning ability of the student. Moreover, the context of the text and the teaching model and method are also important factors in improving the learning outcome of the student. Challenges associated with arithmetic skills and calculation, integration problems, and measuring facts and figures using mathematical theories are the key factors that improve the learning outcome in students in elementary schools.

5.2. Learning outcome and critical thinking

Moving on, one of the important aspects of mathematical education is the capability of the student in CT. The findings from the study suggest a positive association between CT and learning ability of the student. Similar to LR, CT is another positive consequence of mathematical education that contributes to the mental development of students. Mathematics, which is considered the universal language, provides an understanding of the universal concept. Furthermore, the linkage of mathematical teaching and foundation with other disciplines provides more flexibility to problem-solving ability and skills. Moreover, mathematical education builds the ability to utilize the learned skills and concepts from mathematical theories in other fields including medicine, technological development, physical science, and engineering. The process of modeling and the theoretical building of mathematical theories and concepts are an important part of education that includes creativity and the development of ideas. The abilities of the students to observe, imagine, remember, perceive and solve the problem are the combing factor of developed mental capabilities. The leading focus of the school authorities is mainly associated with the growth of intelligence and the formation of creative qualities in the personality of students Moreover, mathematical education not only develops CT and reasoning ability but also improves the communication ability of the students. This finding shows the positive influence of CT on the learning outcome of the student. In similar research, Hacioğlu and Gülhan [41] studied the CT skills and perception regarding STEM among the 7th-grade students and found positive development among the students.

Researchers also documented the effect of the classroom on the student's mathematical development as instructional material and application process in the class process have a positive influence on the behavioral, reasoning, and critical engagement of the student [36]. Moreover, learning possibilities also grow under the effective environment provided to the students. Besides the crucial effect of CT on student learning, students mainly focus on other learning strategies. A study from Nepal suggests that CT is the least common learning strategy among students [42]. However, other learning strategies in mathematical education were disclosed as peer learning, organization, and management skills. The importance of CT is also important for students in developing career ambitions. Blustein *et al.* [37] also suggests the positive association of CT with awareness regarding career. Also, the contribution of STEM education in career is examined as an important factor. The ability to develop CT among the students also helps them in effective decision-making. CT has various advantageous influences on personal development and the country's positive growth. Suggest that CT helps the student develop the ability to overcome problems. Moreover, students with effective critical and LR are the future of the country. Their innovative and advanced ideas contribute positively to the country's economy [43].

5.3. Learning outcome and information technology

The growing use of advanced technology in the education system has provided new opportunities for students to learn more effectively. Moreover, the use of IT in teaching and learning mathematical education has enabled students to understand the basic concepts and theories of mathematics. This research finds a positive association of IT with the learning outcome of the student. Thus, the importance of IT cannot be neglected in mathematical education and skill development. The positive factor that attracts students' attention toward the use of IT in the mathematical classroom is the satisfaction of the student with the IT tool, its usefulness, and the attitude of the student [44]. Moreover, technological support is also a major contributing factor to the advanced technology use in mathematics [45]. Therefore, introducing a new tool in an effective way to the school student can be beneficial in increasing the development of mathematical skills. Similar hedonic motivation and social influence are also potential factors in attracting high school students to IT use among high school students [46]. Besides educational technology tools, the exploration of other technologies provides opportunities for students to discover advanced mathematical concepts. Moreover, the role of special technology use in developing CT is also important for students [38].

Use of advanced technology in the learning process helps students track the dynamics of the universal education system that help them explore new mathematical and scientific developments. Technology plays an important role in the process of learning and developing new mathematical skills. Under the new era of advanced technology and scientific development, students have access to various technological applications that enable them to improve their learning outcomes and explore the background of theoretical approaches. Cai *et al.* [47] explored the utilization of augmented reality (AR) technology in ML to support students to understand advanced concepts in mathematics. The efficiency of these technology tools in mathematics increases the learning ability of the student and they can perform more efficiently. The use of technology in resolving mathematical problems enables the student to save time. The use of advanced technology also enables the student to accelerate the calculating speed of complex mathematical problems. Kaput *et al.* [48] suggest that infrastructural dependence on technology in mathematics education is a basic necessity for students who need more progressive steps. Moreover, video technology enables students to increase their understanding of the content [49]. Videography provides a conceptual understanding of the mathematical concept in detail. Similarly, it motivates students for more exposure and new opportunities for them to engage in class. However, in Kazakhstan, there are many challenges faced by the government and educational authorities in implementing DL due to the insufficient availability of the internet infrastructure and the absence of operative communication and coloration [3]. Thus, a potential regulation from the government can provide an effective learning platform in schools. The proper implementation of digital technologies in mathematics education can only be possible when effective strategies are employed in schools.

The findings from this study suggest the high value of the correlation between IT use and student logical and CT ability. This indicates that increasing the use of developed technology in schools helps students improve their ability to understand mathematic concepts and theories logically and critically. Thus, it can be concluded that technologies also help the student build CT ability. Improvement of technology literacy developed CT ability in students. Similarly, the availability of huge resources of information on the internet enables the student to explore multiple ways to solve the problem, explicit conceptual backgrounds, and use of online technology to evidence the learning from the textbook. Consequently, it relates to the increases in the CT ability of students.

The traditional methodology of teaching involves the algorithmic teaching method and giving the student the opportunity to reinforce it. However, the reinforcing process is associated with the knowledge and lessons from the already existing study in the limited excess. However, the IT used enables the student to increase interactivity [50]. Many advantageous factors of the information in education and more specifically in mathematical education are that it provides the practical implementation of the mathematical theories and concepts, which increases the student's capability. Moreover, it increases the collaborative capability of the student. Similarly, the visualization tool to build the graph in different mathematical equations and theories increases the understanding of the student [50]–[53]. In a recent study, Rabi *et al.* [54] studied the impact of advanced mathematical visualization tools on the academic skills of the students and found a positive impact of the visualization tool on the student's mathematical skills development. Consequently, information and communication technology tools in mathematical literacy are crucial and help in building the development of algorithmic competence in students. The importance of technology becomes more important for secondary school students, as the use of technology in an early stage will help them increase their motivation toward technology [55]. Meanwhile, the use of IT tools has significantly increased during the COVID-19 pandemic

[56]. The importance of IT has increased in recent times due to the association of different economic functions with technology use. To advance the education system for future development and progress, the importance of the implementation of technology in schools cannot be ignored. The findings from this study also suggest the positive impact of IT on the effective learning outcome of the student. Therefore, the potential utilization of IT in the education system, particularly in school education, has become more important. Successful transformations to IT use need effective training, the understanding of the complexion in adaptation, and efficient observation ability. Moreover, some environmental factors such as user asses, communication safety, user knowledge, and dependence on technology use also contribute to the use of IT in the education system.

5.4. Learning outcome and distance learning

During the COVID-19 pandemic, the adaptation of different online learning tools increases significantly [57] to avoid the COVID-19 epidemic spread chains. Consequently, this study also examines the association between DL and the effective learning outcome of the student. The findings from the study suggest a positive association of DL with student learning outcomes. The potential factors that attract students toward DL include the interesting appearance of the content, well-organized content, and flexibility of communication through different learning tools, assignments, and discussion facilities [58]. Selvaraj *et al.* [59] suggested that student preference toward the traditional learning method is more likely compared to DL. This difference might occur due to structural changes in research methodology and geographical differences. Blaskó *et al.* [60] documented the loss in learning outcomes of students in European countries during DL.

Using the regression analysis, this study also provides evidence for the positive impact of DL on the effective learning outcomes of students. These results are similar to the finding of Stojanović *et al.* [39] where they discuss the positive aspect of the online learning tool on the mathematical understanding of the student. This positive association indicates the advanced technology in DL that enables the student to explore mathematical concepts and theories. Moreover, it enables them to develop critical views in the problem-solving process. Besides the advantages of online learning, some challenges increase the risk of loss of learning outcomes for the student. These challenges include internet connection problems and power interruptions [61]. The other challenges in DL use include insufficient knowledge of various learning tools that affect the students of primary and secondary levels [62]. The transformation of mathematics education from a traditional learning tool to advanced technology tools can also provide effective help in organizing student data and records [63], [64]. Besides, the performance evaluation of student performance has also become easier. However, it is also important to provide sufficient knowledge regarding the technology used for efficient access to online learning tools. Thus, successful adaptations of the online learning tool require guidance for the student and the teachers.

6. CONCLUSION

This study has provided valuable insights into the factors influencing ML and their impact on students' achievements and understanding of mathematical concepts. The findings highlight the significance of LR and CT in promoting students' analytical skills, problem-solving abilities, and conceptual understanding. Furthermore, the integration of IT and DL has shown positive effects in enhancing engagement, problem-solving skills, and access to diverse learning resources. Educators and policymakers can use these insights to develop instructional strategies, design curricula and integrate technology tools that enhance ML outcomes. It is crucial to foster an environment that nurtures LR, encourages CT, and provides access to relevant and interactive digital resources.

Based on the findings of this study, several practical recommendations can be made to enhance ML and promote optimal educational outcomes: i) strengthen the development of LR skills: educators should focus on fostering LR abilities among students. This can be achieved through activities that encourage pattern recognition, error identification, and the application of logical strategies to problem-solving tasks; ii) foster CT in mathematics education: it is essential to integrate CT skills into mathematics instruction. Encourage students to ask questions, evaluate evidence, consider alternative solutions, and think critically about mathematical problems and concepts. CT enables students to approach mathematical challenges from different perspectives and develop their own strategies for solving problems; iii) integrate IT into mathematics instruction: leverage the power of IT tools and use interactive software, online platforms, and digital resources that provide engaging and dynamic learning experiences. These technologies can facilitate visualization of mathematical concepts and offer interactive learning environments that promote student engagement and problem-solving skills; and iv) consider blended learning approaches: DL showed a significant impact on this study. This hybrid approach offers the benefits of personalized instruction, anytime-anywhere learning, collaborative online tools, and access to a vast array of digital resources and interactive activities. Considering the area of the study, the sample size (which is 100) tends to be smaller. Thus, an increase in the sample size may provide more understanding and in-depth outcomes of mathematical thinking and LR.

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