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Improving the effectiveness of senior graders' education based on the development of mathematical intuition and logic: Kazakhstan's experience

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Mathematical learning in many developing nations is below average due to which students face difficulties in solving the equations and problems of mathematics as a result of limited understanding of the main concepts and reliance upon intuition as well as memorization. This study is focused on analyzing the effectiveness of senior graders' education based on the development of mathematical intuition and logic in the context of Kazakhstan's educational system. The quantitative research method and primary data sources were used for this research with a 147 sample size, which was selected by using a random strategy of sampling. With the use of IBM SPSS STATISTICS for data analysis, it was concluded that mathematical intuition and logic have a positive influence on the effectiveness of a student's education. Effective strategies, such as rote learning instructions, problem-based learning, RME approach, mathematical reasoning, etc., are essential for enhancing the capabilities of studies in learning mathematics. It is found that there is a significant and positive association between student effectiveness and the logical reasoning abilities of students. Additionally, a positive and moderate relationship is noticed between the critical thinking of students, problem-solving abilities of students, and student effectiveness. Nevertheless, the main limitation of this study is that with small sample size, the findings of the study cannot be generalized; therefore, a large sample size would increase the reliability of the results in the future research. However, in the context of Kazakhstan, this study potentially contributes to the existing literature by presenting conclusive findings in the context of mathematical logic and intuition and student effectiveness.

KEYWORDS

mathematics education, metacognitive teaching-learning approach, logic, mathematical intuition, learning outcomes

Introduction

Education is important for young generations for equipping them with important knowledge and skills. Effective learning allows acquiring knowledge and learning through creating ways of teaching. The former becomes an interesting activity through different techniques of teachers (Taranto and Buchanan, 2020). Mathematic education influences learners to become innovative and critical and cultivate strong reasoning and solution in problem-solving (Simamora and Saragih, 2019). Mathematics education is a continuous, dynamic and active process, and the activities in this type of education assist students in reasoning, and developing logical responses, thoroughly, critically, and systematically and adopting a goal and objective while addressing problems (Mendes and da Silva, 2018).

Mathematics learning in several developing countries is below average compared to countries like Singapore or China (Laurens et al., 2017). China, for example, in the past, has overtaken several western countries in achievement in mathematics, like International Mathematical Olympiads and PISA (Yuanita et al., 2018). However, changing the curriculum is one of the important challenges faced by teachers in teaching mathematics. The traditional teaching of mathematics still continues in secondary schools, and in case of a change in paradigm, the teacher must look for a learning and teaching approach that is constant with the constructivist approach (Donskikh, 2020; Mulenga and Marbán, 2020). Mathematical education and skills cannot be improved with the way it is being taught. The existing teaching approach hardly emphasizes creative, critical, systematic, analytical, and logical thinking among students. Instead, teachers rely more on textbooks (Mariani, 2019). With this kind of approach, students are left with the option to memorize formulas and different steps to answer math problems. Nevertheless, students face difficulties in attempting questions that require logic and critical thinking and not following textbook steps. The students memorize formulas and learn passively without comprehending what the actual question demands. Therefore, they lack understanding and fail to get the benefit of what they are being taught, as their entire teaching process is lacking logical, systematic and critical thinking approach, which is a must requirement for students (Darma et al., 2020; Sari, 2020).

Students often face problems in solving mathematical equations and questions because they have a limited understanding of the key concepts and rely more on memorization and intuition. Several problems can be addressed using comparison to help select contextual problems as an initial phase of the learning process, allowing students to develop their concepts, mathematical process and principles linked to the topic (Yuanita et al., 2018). Alsina and Mulà (2019) add that most of the papers comprise booklets and reports explaining inquiry-focused school projects that engage learners through

mathematics to explore different challenges. There is limited research that focuses on the key role of mathematics-based education in facilitating students to develop creative ways to meet their development needs efficiently, understanding the world, and our association with it, obtaining a significant understanding of technological advances and development or addressing complex problems through different approaches.

As per the World Bank's Systems Approach for Better Education Results (SABER) results, the education system of Kazakhstan is at a developing and emerging stage. The state's government has been committed to investing in human capital. Subsequently, the government has been focusing on increasing the quality of the education system and the learning outcomes for the students. However, the assessment of the classroom revealed that the education and learning in the majority of the schools in the country are based on rote learning instruction focused on the memorization of the content and the examination to test the students' ability in the subject areas of the curriculum (The World Bank, 2013). Rote learning primarily employs memorization, where teachers provide lectures and examples in class to allow students to follow problem-solving methods. It is an academic performance-based education system that focuses on student test scores rather than student learning processes and methods (Sassin, 2020; Bhattacharya, 2022). Rote learning has been criticized for content-based teaching whereby students memorize math formulas, rules, and principles which lacks logical and critical thinking (Iqbal and Ahmad, 2015). In general, this is one of the major laments pertinent to the educational community that is largely focused on memorization and rote learning and execution of the problems, which prevents the development of intuition which is important for the logic and reasoning skills of the students. This has given rise to the literature emphasizing the importance of conceptual learning and intuition development over procedural learning, memorization, and rote executions of the problems (Presmeg, 2020).

As discussed, the education system of the country and in general appears to be based on rote learning and content-based memorization, which has been criticized for flawed teaching methods in attempting mathematical questions that require logic and a critical approach. Therefore, this study has significance in terms of evaluating whether mathematical intuition and logic has a key role in enhancing the educational effectiveness of senior graders in the Schools of Kazakhstan. It is worth noting that previous research, i.e., Pirrone et al. (2018) add that cognition and critical thinking are closely related. Nevertheless, there also exists disagreement in the contemporary literature regarding the link between mathematic achievement and critical thinking. Critical thinking is a neglected topic in the literature associated with mathematics teaching (Kusaeri, 2019). Besides, a plethora of studies including Aminah et al. (2018), and Hirza and Kusumah (2017) have contributed to explaining the role of mathematical intuition and

logic in improving educational effectiveness, however, limited recent work is available in the context of Kazakhstan schools.

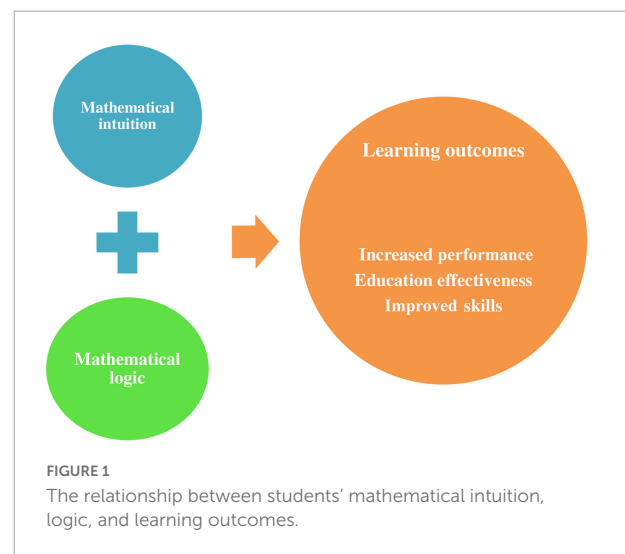
Literature in the context of mathematical intuition and logic showed that formal schooling has not provided students with structured opportunities to practice and develop creative and critical thinking in the subject of mathematics (Thibaut et al., 2018). Educators often believe that logical thinking is significant for learning math, while creativity is viewed to be less significant (Munawaroh, 2018). Nevertheless, mathematics is linked with science, and scholars apply creative thinking when confronted with new challenges (Pirrone et al., 2018). Overall, the findings of the study are likely to contribute to the existing limited empirical research in the context of mathematical intuition and logic in Kazakhstan School, and provide guidelines for policymakers and educationalists to work on improving the educational effectiveness of senior grade students thereby filling the research gap.

Literature review

The notion of intuition is found to be relevant to a variety of domains, with mathematics being on the top of the list in academics and education. A number of scholars, such as Bergson and Spinoza, have established a link between intuition and intuition, reason and logic, particularly in relation to the discipline of mathematics (Siagan et al., 2019). In the context of mathematics, intuition is concerned with the ability to conceptualize problems and understand the underlying logic contributing to the effective and efficient problem-solving ability of the students (Siagan et al., 2019). In simpler terms, mathematical intuition is the ability to understand the underlying logical reasoning and simultaneously find appropriate and rapid strategies for problem-solving. According to Simamora and Saragih (2019), the ability of the student to solve the mathematical problem can be described as his/her ability to comprehend the problem, plan different strategies linked to problem-solving, evaluate the selected strategies, and re-assess problem-solving to successively make solutions or develop problem-solving while students are faced with complex mathematical questions. Although mathematics is a major and significant subject in education and is linked to human life very closely, this subject is not appealing to students as it demands problem-solving abilities, reasoning, and logic which many students struggle with. The ability to solve the mathematical problem is found to be comparatively low in Asian students, i.e., Indonesian, compared to other developed regions of the world (Peranginangin et al., 2019; Siagan et al., 2019; Ulandari et al., 2019). Besides, it is observed, as per the investigation with teachers, that the word problem in math is difficult for many students, and students do not show much interest in mathematics as they find it complex, difficult and hard to understand (Verschaffel et al., 2020).

Figure 1 highlights that mathematical intuition and logic are positively correlated with learning outcomes in students by increasing their performance, education effectiveness and improving skills. However, previous literature, i.e., Sabirovich (2005) in the context of Kazakhstan focused on the process the examines the link between logic and intuition in teaching mathematics and argues, argues that different factors are established that do not rely on teaching; for instance, determined by socioeconomic factors defining mutual goals, when developing an idea, *via* in the fluence of parents, and relying on the subjective experience of learners. It is added that effective of teaching maths is because of its deductive nature, depending on the suitable choice of logical rigor of presenting educational material and determining the optimal percentage of logical and intuitive reasoning in the cognitive action of students. Toybazarova and Nazarova (2018) added that the attitude and behavior of students toward learning are strongly associated with surrounding conditions, which influence the student to learn what is being taught, or in many cases, they lose interest in learning activities. The surrounding conditions such as school premises, comfort, cleanliness, ambiance, and interactive environment is all that motivate studies, reduce mental stress and stimulate their cognitive activity. In addition, the logical reasoning in a subject like mathematics is comparatively less, and it all depends on the teaching methods and the cognitive ability of students; however, more or less, students rely on their intuition to solve math problems. Therefore the role of a favorable surrounding environment is critical in increasing learning activities and cognitive capabilities and skills in students so that they rely on logical answers instead of focusing on their intuition.

In a similar context, the ability to conceptualize problems and understand the underlying logic due to the development



of mathematical intuition and logic has been discussed in relation to improving the effectiveness of education and learning for the students. As per Deniz and Uygur-Kabael (2017), students usually intuitively understand mathematical problems before they are introduced to formal classroom learning. This demonstrates the importance of the development of mathematics education whereby the students are able to establish the application of their mathematical skills such as reasoning and logic to problem-solving (Sumirattana et al., 2017). Students are able to develop mathematical intuition by interacting with real-world problems, which ultimately enable them to demonstrate greater critical thinking and reasoning ability in problem-solving in other disciplines as well (Bray and Tangney, 2016; Laurens et al., 2017). In this context, Su et al. (2016) have conducted a study to draw a link between the effective mathematic teaching strategies that helps students in developing critical thinking and treading and the students' problem-solving abilities. The findings of the study revealed that effective methodical learning enables the students to improve their critical thinking and logical reasoning ability. Students are able to acquire these skills when confronted with math problems while they are required to identify possible solutions and assess and justify the reasons for the result. These critical thinking and logical reasoning abilities allow the students to apply their mathematical discipline skills to exercise logical thinking when solving problems. This discipline of reasoning results in students who develop the ability with focused on thinking, planning, and strategizing, which have been identified as key aspects of organizational success, decision making, and life choices. Thus, these studies demonstrate the importance of mathematics education for the development of students' problem-solving ability.

Nevertheless, earlier studies have presented different models and approaches linked to mathematics that are considered helpful in improving the educational effectiveness and learning ability of students. For instance, the metacognitive teaching-learning approach (MLTA) comprises a method that focuses on promoting awareness of students toward their efficiency and capabilities *via* accustomization to take metacognitive problems or queries that enclose involve an understanding of problems and concepts of mathematics to enhance the connection among both previous and new knowledge; using appropriate strategy, and reflect outcome and process (Aminah et al., 2018). Studies have shown that MLTA was a challenging task for senior grade students. Also, it was challenging and complex for even tertiary students too (Martin et al., 2021). In several cases, the high-grade student cannot logically present the required response in the reasoning case; however, as per the understanding of a few researchers, low-grade students were more logical in their responses *via* fake premises or abstracts. Nevertheless, this sort of reasoning was not easy for senior students (Aminah et al., 2018). Besides the address the difficulties faced by students, it is important to

develop an innovative-teaching-learning method that provides an opportunity for students to be logical in their responses. MTLA is one such approach/method that can help and facilitate students and comprises three key steps, including class and group discussion, pairs discussion, and metacognitive scaffolding (Martha et al., 2019; Sugandi et al., 2019). Students in MLTA are stirred up for assessing and controlling their thought process *via* posing questions and later attempting to address them with appropriate reasoning for relating the new knowledge to the old one. By working on those activities, there is high anticipation that students will be motivated to think more rationally and logically (Aminah et al., 2018).

Besides, it is observed that the Realistic Mathematics Education (RME) approach is found to increase the motivation and learning activities of students. Trisnawati et al. (2018), in this reference, add that applying the RME approach with a mathematical learning model can facilitate improving the mathematical and problem-solving skills of students. The key aspects of this approach are appropriate to the context of mathematical models, integration of the subject under discussion and the method of student interaction. Through this, it is likely that students can efficiently flow the process of learning. Besides the RME approach, scholars in the context of mathematics learning have also assessed different innovative learning models, which include the Problem Posing (PP) model. The framework of PP comprises the abilities that exhibit the explanations and knowledge of students in problem-solving, like when students evaluate their metacognitive process (Chasanah and Usodo, 2020). The PP model, according to Retnowati et al. (2018), helps students in developing several problems *via* information they acquired to be addressed immediately (Unver et al., 2018). Likewise, the studies including Ozgen and Bayram (2019) have shown that there is a link between learning strategies and models and noted that PP is effective compared to other models yet is more appropriate in group learning. This particular model is quantitatively tested and showed positive outcomes and has been recommended for problem-based learning and to boost the confidence of students. Besides, it is concluded that the use of PP can affect the learning achievement of mathematics students and help improve their education if combined with group activities in class that motivate learners to learn. Moreover, it is noted that students through the PP model are able to acquire much learning experience and problem-solving abilities (Calabrese et al., 2019).

Materials and methods

Research approach

This study applied a quantitative approach that focuses on statistical, objective measurement and numerical and

mathematical analysis of data collected through surveys, polls, and questionnaires or by controlling pre-existing stats-based data through computational techniques (Taguchi, 2018). The quantitative approach, unlike other, i.e., qualitative approach (relying on non-statistical and numerical data for data analysis) (Biereenu-Nnabugwu, 2019), is appropriate for this study in accomplishing the purpose, as this approach relies on using statistical evidence, which is required in this study to assess the effectiveness of senior grades' education.

Research design

Similar to the quantitative approach, descriptive design is used, which is one of the types of research design that help acquire information/data to systematically explain a population, situation, or phenomenon. In addition, it helps to address the answer linked to how, where, when, and what questions related to the problem statement, instead of "why" (Bloomfield and Fisher, 2019). These include different types of descriptive design strategies, such as survey, observational, and case study design (Atmowardoyo, 2018).

Research strategy

For this study, a survey strategy was applied, which is a quantitative way of collecting data from different participants through a questionnaire. The process comprises of recruitment of respondents, data collection, categorization and then analysis (Stockemer, 2019). The use of a survey strategy is helpful in assessing the effectiveness of education for senior graders through mathematical intuition and logic.

Data collection

In the context of the quantitative approach, a primary data source is used for collecting data from participants, as this source of data collection relies on gathering first-hand, latest and updated information about a subject or topic, unlike the secondary source in which outdated, published data is used, transform and molded to achieve research objectives (Aspers and Corte, 2019). Therefore, using a survey strategy, the required data can be collected to achieve research objectives. In terms of the data collection process, 5-Likert-scale was used to assess the responses and to measure the mathematical skills of the participants. The data was collected through an online questionnaire survey which is less time-consuming and can be used for collecting a required sample of data. Considering the ethical principle, the participants (senior grade students) are informed about the research purpose, and their formal approval is taken. The overall length of the data collection process was

approximately 8 weeks, and the questionnaire was filled out by the participants themselves.

Target population and sample size

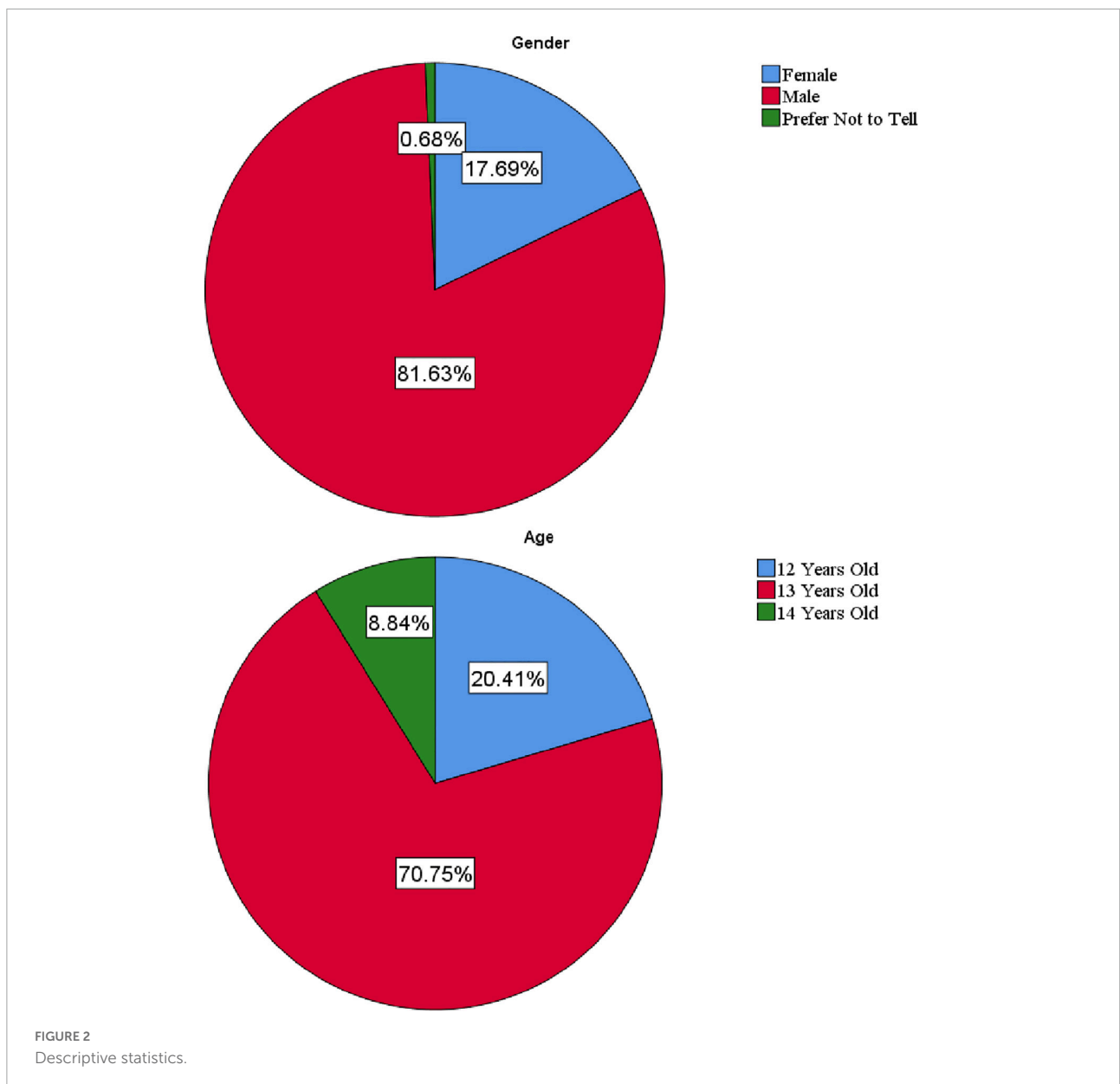
The target population was 7th-grade students at Nazarbayev Intellectual school of Chemistry and Biology in Shymkent. The research used a sample size of 147 students using a random sampling strategy which was proven significantly useful for this research in terms of selecting a sample with each one having an equal chance of getting selected. Besides, a pedagogical experiment was also performed comprising of different steps, including pre-text, post-test, educational text, and questionnaire. This experiment is useful in determining the level of knowledge of the participants (Asad et al., 2022). Approximately 20 min were given to address the first section (pre-text), and overall 45 min to address other sections.

Data analysis

For data analysis, correlation, regression, and descriptive analysis were used. The correlation analysis helped in assessing the strength between the variables, including (the effectiveness of education and mathematical intuition and logic), while the regression analysis was significant in determining the relationship between the dependent and independent variables. Similarly, descriptive analysis was performed to quantitatively summarize or describe features from the collected data and analyze the statistics.

Results

This section analyzes the results of the study. Basically, the study aimed to examine the development of mathematical intuition and logic, critical thinking of students, and problem-solving abilities of students to improve the effectiveness of senior graders' education. Moreover, the study intends to identify the relationship between mathematical intuition and logic, critical thinking of students, problem-solving abilities of students, and student effectiveness. For this purpose, the article has collected data from 147 participants. Later, the study analyzed such data using IBM SPSS STATISTICS to accomplish the objectives. It is found that there is a significant and positive association between student effectiveness and the logical reasoning abilities of students. Additionally, a positive and moderate relationship is noticed between the critical thinking of students, problem-solving abilities of students, and student effectiveness. On the other hand, the result indicates a positive and significant influence



of mathematical intuition and logic, critical thinking of students, and problem-solving abilities of students on student effectiveness.

Demographic statistics

These statistics help in generating the profile of the participants. In the current study, Figure 2 and Tables 1–9 summarize the demographic characteristics of the participants. Table 1 presents the demographic characteristics of the study which comprised of the gender and age.

As shown in Figure 2, the study respondents comprised of 81.6% of the males and 17.6% of the females while

the remaining population preferred not to disclose their gender.

Figure 2 showed that 70.75% participants were responded were at the age 13 years old, 20.41% were at the age of 12 years old, and those who did not responded were 8.84% with 14 years of age.

As depicted in Table 2, when respondents were asked regarding problem-solving abilities of the students, all of the responses had an average mean of more than 4 which depicts high agreements with the statement with standard deviation less than 1 indicating that there was limited dispersion among the responses.

As indicated in Table 3, when respondents were asked in response to critical thinking of students, all of the responses had

TABLE 1 Demographic characteristics.

		Frequency	Percent	Valid percent	Cumulative percent
Gender					
Valid	Female	26	17.7	17.7	17.7
	Male	120	81.6	81.6	99.3
	Prefer not to tell	1	0.7	0.7	100.0
	Total	147	100.0	100.0	
Age					
Valid	12	30	20.4	20.4	20.4
	13	104	70.7	70.7	91.2
	14	13	8.8	8.8	100.0
	Total	147	100.0	100.0	

an average mean of more than 4 which depicts high agreement with the statement with standard deviation less than 1 indicating that there was limited dispersion among the responses.

In the similar manner, [Table 4](#) also depicted that responses agreed to logical reasoning of the students as the average mean was between 3.63 and 4.22 while the standard deviation was also less than or equal to 1.

Similar findings were analyzed in [Table 5](#) with high mean value ranging between 3.63 and 4.3 and standard deviation less or equal to 1 depicting that there was high student effectiveness.

The reliability and validity in [Table 6](#) indicated a Cronbach's Alpha value of 0.78 indicating that data is reliable as value less than 1 is considered significant.

Correlations was presented in [Table 7](#). It is found that there is a significant and positive association between student effectiveness and the logical reasoning abilities of students. Additionally, a positive and moderate relationship is noticed between the critical thinking of students, problem-solving abilities of students, and student effectiveness.

The regression was presented in [Table 8](#) where the value of R square was found to be 0.69 meaning that there was 69% variance in the study while the adjusted R square value was 0.69 indicating that the research variables had a significant and positive impact on one another.

As indicated in [Table 9](#), the result indicates a positive and significant influence of mathematical intuition and logic, critical thinking of students, and problem-solving abilities of students on student effectiveness.

Discussion

The given study aims to evaluate mathematical intuition and logic development in order to enhance the senior graders' education effectiveness within the context of Kazakhstan's education system.

The results of the analysis using regression and correlation find that mathematics education positively influences the students' effectiveness as it is important in improving the performance of senior students' education. Worldwide, mathematics is recognized as a valuable subject within the curriculum of school because technological along with scientific knowledge is based upon it, which significantly contributes to the nation's socio-economic development. With the help of mathematics education, students in Kazakhstan can increase their understanding of mathematical thinking and ability to specify the matter of subject involved within the particular topic of mathematics ([Verschaffel et al., 2020](#)). It is highlighted by a number of stakeholders that the nations must enhance their proficiency as well as skills of mathematics for the students due to the fact that it solves various issues related to other fields, such as computer science, medicine, physical sciences, and engineering ([Gebremichael, 2018](#)). The usefulness and worth of mathematics education are possibly being communicated with the help of a classroom curriculum. The study of [Fitzmaurice et al. \(2021\)](#) elaborates that mathematics education is designed and delivered in a way that helps students in solving their course-related problems and everyday-life situations. When the real-world contexts are embedded within mathematics, it potentially highlights its significance to teachers as well as students and boosts interest, motivation, and achievement. Although mathematics education is perceived by many students to be difficult and complex, it enables them to possess the knowledge to solve problems of everyday life, make day-to-to operations and required calculations, and think logically ([Verschaffel et al., 2020](#)). It further makes the students capable of developing mathematical inquiry, conceptualization, and communication skills and using different concepts and techniques to solve and formulate problems.

The research work of [Su et al. \(2016\)](#) also discovered a positive association between mathematics education and students' effectiveness in primary grades. It was explored that effective strategies for teaching mathematics, such as rote learning instruction, will be helpful for Kazakhstani students in developing their problem-solving abilities and critical thinking. They will become capable of implementing skills of mathematical discipline toward exercising logical thinking when the problems are solved by them. According to the study by [Cresswell and Speelman \(2020\)](#), the mind is disciplined by mathematical training, and it develops critical as well as logical reasoning along with problem-solving and analytical skills within the students. Most schools design the course of mathematics in a way that it forms deep analytical thought, creative thinking, mathematical fluency as well as understanding, and logical reasoning not in primary grades students but also in the students in secondary grades. [Alreshidi \(2016\)](#) explored problem-based learning strategy as superior in comparison with other traditional methods of teaching for the retention of knowledge as it is helpful in increasing the

TABLE 2 Problem-solving abilities of students: descriptive statistics.

	<i>N</i>	Range	Minimum	Maximum	Mean	Std. deviation	Variance
Descriptive statistics							
E1	147	4	1	5	4.68	0.64	0.41
E2	147	3	2	5	4.71	0.61	0.38
E3	147	4	1	5	4.36	0.87	0.76
E4	147	3	2	5	4.24	0.85	0.73
Valid N (listwise)	147						

TABLE 3 Critical thinking of students: descriptive statistics.

	<i>N</i>	Range	Minimum	Maximum	Mean	Std. deviation	Variance
Descriptive statistics							
E5	147	3	2	5	4.31	0.78	0.61
E6	147	3	2	5	4.41	0.81	0.66
E7	146	4	1	5	4.30	0.89	0.80
E8	147	4	1	5	4.17	1.01	1.03
E9	146						

TABLE 4 Logical reasoning of students: descriptive statistics.

	<i>N</i>	Range	Minimum	Maximum	Mean	Std. deviation	Variance
Descriptive statistics							
E9	147	3	2	5	4.40	0.82	0.68
E10	147	4	1	5	3.63	1.10	1.22
E11	147	4	1	5	4.22	0.98	0.96
E12	147	4	1	5	4.06	1.08	1.18
Valid N (listwise)	147						

TABLE 5 Student effectiveness: descriptive statistics.

	<i>N</i>	Range	Minimum	Maximum	Mean	Std. deviation	Variance
Descriptive statistics							
E13	147	3	2	5	4.23	0.86	0.74
E14	147	3	2	5	4.71	0.61	0.38
E15	146	4	1	5	4.30	0.89	0.80
E16	147	4	1	5	3.63	1.10	1.22
Valid N (listwise)	146						

periods of retention for learning, specifically if there is an enthusiasm in students regarding a fact or concept, which they revealed by themselves. Along with that, [Gravemeijer et al. \(2017\)](#) narrated that effective mathematics understanding offers a number of valuable skills to the students, such as analytical skills, representation, reasoning, interpretation, and problem-solving skills. All these skills would help them in their post-secondary education within different disciplines, such as finance, business, and engineering. As noticed above, several prior studies explored the impact of mathematical intuition and logic on primary grade students as well as university students in comparison with traditional methods,

TABLE 6 Reliability and validity: reliability statistics.

Reliability statistics	
Cronbach's alpha	N of items
0.78	16

whereas the present study specifically provides evidence through its findings to improve the efficiency of senior grade students as they face more difficulty in understanding the mathematical concepts.

TABLE 7 Correlations.

		PSAM	CTM	LGM	SEM
Correlations					
PSAM	Pearson correlation	1	0.14	0.41**	0.44**
	Sig. (2-tailed)		0.09	0.00	0.00
	N	147	147	147	147
CTM	Pearson correlation	0.14	1	0.35**	0.58**
	Sig. (2-tailed)	0.09		0.00	0.00
	N	147	147	147	147
LGM	Pearson correlation	0.41**	0.35**	1	0.74**
	Sig. (2-tailed)	0.00	0.00		0.00
	N	147	147	147	147
SEM	Pearson correlation	0.44**	0.58**	0.74**	1
	Sig. (2-tailed)	0.00	0.00	0.00	
	N	147	147	147	147

**Correlation is significant at the 0.01 level (2-tailed).

TABLE 8 Regression.

Model	R	R square	Adjusted R square	Std. error of the estimate
Model summary				
1	0.83a	0.69	0.69	0.28197

a Predictors: (Constant), LGM, CTM, PSAM.

TABLE 9 Coefficients.

Model	Unstandardized coefficients		Standardized coefficients	T	Sig.
	B	Std. Error	Beta		
Coefficients					
1 (Constant)	0.26	0.24		1.07	0.28
PSAM	0.16	0.04	0.17	3.40	0.00
CTM	0.31	0.04	0.36	7.48	0.00
LGM	0.46	0.04	0.54	10.10	0.00

Dependent variable: SEM.

Further, the results produced by regression and correlation analysis revealed that the influence of mathematical intuition and logic on the students' problem-solving ability is positive and moderate. Intuition is a mental and cognitive procedure to understand the information within the form of exposing, capturing, and uncovering knowledge or ideas based upon subconscious feelings, mixed with immediate experience and prior knowledge (Arwanto et al., 2018). In today's world, students live within a technology and information-based society where they must have the ability to critically and logically think regarding complex problems and new situations. In

mathematics education, the effective strategies of teaching are not enough to teach how the problems must be solved. Rather, the capability of the students to create efficient and effective ideas is essential for solving mathematical problems.

According to Hirza and Kusumah (2017), in order to create these notions or ideas, the students are required to have intuitive skills. Mathematics intuition plays an important role in providing access to the students toward economic and educational opportunities and developing problem-solving strategies along with processes (Lester, 2018). It helps the students to deal with problem-solving situations in an effective manner; for instance, when difficult situations are faced by the students in logical thinking, considering their mathematics intuition is important (Hirza and Kusumah, 2017). An important role is played by intuition to find the problem solution and problem content's comprehension. Usually, problem presentation with the help of an intuitive or figure method leads to collecting and facilitating associated information. Therefore, the current study findings, particularly related to the connection between mathematical intuition and problem-solving capabilities of the students, will help senior graders in enhancing their overall intuitive skills, and teachers formulate the teaching methods in accordance with the needs of the students.

As depicted in the results of the study, a one-percent change in the problem-solving capability of the Kazakhstani students due to mathematical intuition and logic could bring over 16 percent changes in their effectiveness. This represents that the impact of mathematics intuition is noteworthy on the problem-solving ability of the students as it makes them capable of understanding mathematics operations, facts, principles, and concepts intuitively and analytically. Also, Sujadi and Masamah (2017) explore that mathematics intuition has helped the students in universities and schools to solve their problems relating to scientific and reasoning considerations.

Furthermore, the study results of Deniz and Uygur-Kabael (2017) are also similar to the given research findings, which depicted that the problem-solving capability of students is developed and enhanced due to mathematical intuition, and they intuitively understand the problems before their introduction to the formal learning in the classroom. Thus, with the help of mathematical intuition, the students establish and implement various mathematical skills, including logic as well as reasoning to problem-solving. The study of Babaei et al. (2019) further discovered that problem-solving of mathematics through intuition positively impacts the overall performance of the students. One of the approaches associated with the development of mathematic intuition skills is RME (Realistic Mathematics Education). This enables the students to enhance their strategies as well as techniques of mathematical problem solving (Hirza and Kusumah, 2017). Furthermore, Trisnawati et al. (2018) explored that the RME approach has increased the learning activities along with motivation of students and

the implementation of this approach with the model of mathematical learning, which facilitated the improvement of problem-solving as well as mathematical skills of the students.

Additionally, by using regression and correlation analysis, the findings presented in the study reveal the positive and significant impact of mathematical intuition and logic on students' critical thinking and overall effectiveness. Critical thinking is an essential success characteristic, which the students are required to learn so as to attain the greatest potential within society. It is disclosed by [Çelik and Ozdemir \(2020\)](#) that critical thinking helps students to think regarding making decisions, problem-solving, calculating probabilities, and formulating inferences as it is objective, logical, and purposeful. The skills of critical thinking have been considered valuable in recent years as they are important for the future success of students.

Further, the research of [Chukwuyenum \(2019\)](#) mentioned that these skills could be helpful for the students in making decisions, managing lives, and solving problems. As per the research of [Facione \(2020\)](#), the skills of critical thinking include rational, reflective thinking by the procedure of judgment or evaluation to interpret, inference, and analyze with the use of inductive or deductive reasoning in order to make decisions relating to the problems considered. Further, it is mentioned by [Ennis \(2018\)](#) that these skills are required by practiced in primary as well as secondary schools. Mathematic intuition is helpful for the students in letting them critically think about a specific problem not only related to mathematics but also in other fields. This critical thinking further enables students to understand the issue, and on the basis of this understanding, strategies for problem-solving can be devised by them ([Cresswell and Speelman, 2020](#)). In addition to that, the appropriate solutions, as well as ideas, are explored by the students, which helps them to make effective strategies for solving the problems.

The findings of [Bray and Tangney \(2016\)](#) and [Laurens et al. \(2017\)](#) provide justification for that as, according to them, with the help of mathematical intuition, students become capable of interacting with the problems in the real world that make them able to represent greater reasoning ability and critical thinking in problem-solving. Moreover, a positive relation between mathematical intuition and the critical thinking of students is also explored by [Su et al. \(2016\)](#), which explained that critical thinking skills are developed in the students due to effective strategies and techniques of mathematical intuition implemented by teachers. Further, they discussed that the ability of critical thinking is enhanced within students with the use of effective methodical learning. These abilities in students could be helpful at the time of starting a career as the skills of critical thinking are highly-valuable attributes that are sought by employers within job candidates. It is further indicated by [Elder and Paul \(2020\)](#) that few negative events of life are experienced by critical thinkers, which is why the development of these skills is

significant at the school stage. As explored in the present study findings, the formation of critical thinking with mathematical intuition helps students to solve problems of mathematics, specifically to predict the right answers and explore the issues through identifying mathematical formulas or concepts involved within them.

The current study, with the help of regression and correlation analysis, explored a positive relation between mathematical intuition and students' logical reasoning along with their overall effectiveness. [Su et al. \(2016\)](#) conducted their study to explore the view of Kazakhstani students and revealed that mathematical knowledge and the capability of the students toward solving quantifiable issues and utilizing critical thinking would enhance their capacities to think and make effective decisions. Mathematical reasoning is one of the critical skills by which the students become capable of making use of other skills of mathematics. According to [Resnick \(1987\)](#), in mathematics, logical reasoning helps the students to recognize the understanding and sense of mathematics as they learn to opt for appropriate strategies for solving the problem, describe as well as develop a solution, evaluate the situation, and draw logical conclusions. The study of [Abishev et al. \(2016\)](#) discovered that Kazakhstani students within higher education need to develop certain reasoning, creativity, and intuition in choosing mathematical tools in order to effectively understand the concepts and problems. Furthermore, the reasoning power helps students become independent thinkers of mathematics and self-reliant, which makes them capable of making sensible choices and reaching decisions. As per the study of [Simamora and Saragih \(2019\)](#), mathematic intuition is valuable in developing and cultivating problem-solving and strong reasoning skills among students.

The findings of the study are similar to the research work of [Uyen et al. \(2021\)](#), which discovered that mathematical intuition positively impacts the effectiveness of grade seven students by enhancing their logical Thinking, Critical Thinking, synthesis, and Creative Thinking. It makes the students more interested in implementing techniques and concepts of mathematics to solve complex issues by considering the mathematical ideas that are associated with real-life situations. The development of logical reasoning creates an intimate relationship between the practice of the students and mathematics intuition, which motivates them to learn more about the problems and its solution. Reflective thinking is one of the essential aspects that the students are required to develop as the problems facing them cannot be immediately solved. Thus, the need for awareness toward predicting, thinking, seeking simple formulas, and proving the truth is noteworthy. In this context, the study of [Yuanita et al. \(2018\)](#) also explored the positive influence of the RME approach on developing the skills of logical reasoning, Critical Thinking, and problem-solving in students within the mathematical representation. It is discussed

in their study that favorable conditions are created by RME for developing mathematical communication capabilities as well as reasoning. When the logical reasoning skills of students are developed, it helps them to establish the capabilities of focused planning as well as thinking, which are considered important aspects of life choices, organizational success, and decision making.

Conclusion

In the end, it can be concluded that mathematical intuition and logic have a significant influence on the effectiveness of a student's education. This study examined different aspects of students' education like problem-solving, critical thinking, and logical reasoning to assess the impact of mathematical intuition and logic. It was noted that all these aspects are positively affected by mathematical intuition and logic. During the literature review and analysis of the results, this study found a link between mathematics instruction and student effectiveness. It was discovered that successful teaching tactics for mathematics aid pupils in strengthening their problem-solving skills and critical thinking. When they answer problems, they get the ability to use mathematical discipline abilities toward practice logical thinking. Hence, it is important that mathematical intuition and logic are majorly focused on enhancing the effectiveness of education for the students. In addition to this, the study has noted that mathematics intuition has a significant influence on students' problem-solving abilities because it allows them to intuitively and analytically comprehend mathematical operations, facts, principles, and ideas. Various scholars have also found that mathematical intuition has aided students in schools in solving challenges linked to scientific and reasoning concerns. Similarly, students benefit from mathematical intuition since it allows them to think about a topic not only in mathematics but also in other subjects critically. Students can use critical thinking to better comprehend the situation and design problem-solving solutions based on that understanding. Therefore, it can be stated based on these findings that mathematical intuition and logic are highly critical aspects of education effectiveness that must be targeted by all institutions to optimize their outcomes. This study has been able to accomplish its aims successfully; however, there are certain limitations that can be improved in future research. One of the major limitations of this study is that it used a smaller sample size, which could have caused bias and inaccuracy in the results. In the future, a study with a larger sample size can be conducted to enhance results reliability. Besides this, this research has relied majorly on primary data, which could be biased based on the location and experience of the respondents. Therefore, future research should be conducted

with a versatile data collection process to enhance the reliability and credibility of the results.

Recommendations

Mathematical intuition and logic are found to have a significant impact on learning outcomes in students, increasing their logical reasoning, critical thinking and problem-solving skills. Hence, it is recommended to Kazakhstan high school administration and mathematic teachers to focus on developing mathematical intuition and logic among students by involving them in exercises that require critical and problem solving skills. Provide additional sessions and training courses to students to understand logical reasoning when solving maths problems.

Limitations

The size of the sample is relatively small considering the scope of this study; therefore, increasing the sample size and incorporating qualitative interviews with mathematics teachers inquiring about the use of mathematical logic and intuition to increase student's education effectiveness and learning outcomes may provide a comprehensive, in-depth and more reliable and generalized findings, and is likely to fill the knowledge gap identified in previous literature.

Data availability statement

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

YP was responsible for the conceptualization, in charge of the methodology, and supervised the research process. MA was responsible for the conceptualization and sought and provided the resources. NY performed the data curation and conducted the investigation. YT carried out the formal analysis and performed the validation. GO wrote

the original draft, reviewed, and edited it. All authors contributed to the manuscript revision, read, and approved the submitted version.

Conflict of interest

NY was employed by JOO High Schools Management, Limited.

The remaining authors declare that the research was conducted in the absence of any commercial or financial

relationships that could be construed as a potential conflict of interest.

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