

The impact of university coursework on students’ logical-mathematical intelligence: A cross-cultural study

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Abstract

This descriptive cross-cultural study aimed to identify the impact of university coursework on improving logical–mathematical intelligence (LMI) from the perspective of undergraduate mathematics students. A convenience sample of 431 undergraduate mathematics students at universities in Oman, Jordan, Qatar, Bahrain, and Algeria participated in this study. These participants responded to the LMI scale. The LMI scale consisted of 24 items distributed across 4 sub-dimensions: logical reasoning, mathematical problem solving, spatial reasoning, and data reasoning. Google Forms was used in designing the LMI scale, and its link was distributed to participants. The results showed that there was a high impact of coursework on LMI from the perspective of undergraduate mathematics students. The results also showed that there were statistically significant differences in the impact of university coursework on LMI according to the following study variables: gender, college, grade point average (GPA), year level, and country. The significant impact of university courses on LMI reflects the quality of academic programs, teaching methods, and activities offered to mathematics students at universities. Therefore, the study recommended improving the LMI of mathematics students in colleges of education. It also recommended promoting LMI for students with good or lower GPA averages, and students in academic levels of two years or less.

Keywords: Algeria, Bahrain, Cross-cultural study, Jordan, Logical–mathematical intelligence, Mathematics education, Multiple intelligences, Oman, Qatar, University courses.

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Contribution of this paper to the literature

The originality of this cross-cultural study lies in demonstrating the effective role of university courses in enhancing LMI among mathematics students in five Arab countries: Oman, Jordan, Bahrain, Algeria, and Qatar. This study may provide a research and academic foundation for improving pre-service mathematics teacher training programs in Arab universities, in addition to demonstrating the effectiveness of university mathematics programs and courses on LMI.

1. Introduction

The term human intelligence has long been a focus of attention for philosophers and psychologists. In the past, intelligence was defined as a single ability measurable by intelligence quotient (IQ) tests, which often focused on an individual's linguistic and logical skills. In 1983, theoretical innovations in the study of intelligence emerged when Howard Gardner proposed the theory of multiple intelligences (TMI). This theory clarified that intelligence is not a single, general mental ability, but rather a set of abilities and patterns of intelligence (Gardner, 1983). The TMI offers a modern perspective on human intelligence, moving beyond traditional definitions by understanding the patterns of these multiple intelligences.

Logical-mathematical intelligence (LMI) is one of the types of intelligences in the theory of multiple intelligences (Harb, El Hajj, Alyasin, & Nasser, 2025). This type of intelligence represents the ability of individuals to think logically and solve problems using mathematics and abstract thinking (Al-Zoubi & Al-Adawi, 2019), in addition to analyzing data, extracting patterns, and understanding the relationships between different mathematical definitions. LMI is a biological and psychological capacity for processing information that can be activated within a cultural environment to solve problems or produce products of value within that culture (Ghaznavi, Haddad Narafshan, & Tajadini, 2021). Gardner (1999) emphasized that an individual's ability to understand the fundamental principles that govern the physical and logical world through using logical-mathematical reasoning encompasses skills related to problem-solving, proof, classification, the use of symbols, and inference. Pehlivan (2017) defined LMI as the mental ability for deductive reasoning, logical analysis, working with numbers, discovering relationships, and recognizing patterns. Similarly, Arum, Kusmayadi, and Pramudya (2018) defined LMI as the skill of thinking with numbers, concluding, forming logical relationships, solving problems, thinking critically, dealing with abstract symbols such as numbers and geometric shapes, and connecting information. Individuals with a high level of LMI can understand abstract relationships, solve complex mathematical and scientific problems, and think in a systematic, analytical manner (Astuti, Jailani, & Subanti, 2019). Prastika, Riyadi, and Siswanto (2021) linked LMI to creative thinking and advocated for its development from an early age, as it is one of the higher-order thinking skills required in the 21st century.

Therefore, university courses contribute to raising the LMI of mathematics students in colleges of education and science. These courses are not limited to theoretical knowledge alone but also help develop critical and creative thinking skills. Furthermore, these courses enhance students' ability to approach mathematical problems with methods based on understanding and logic to arrive at correct solutions. This study aims to reveal the effects of university courses on the LMI of students in colleges of education and science.

2. Literature Review

2.1. Development of LMI

The development of LMI begins early in life, as children start to demonstrate LMI skills, evident in their abilities to count, compare quantities, and recognize shapes and numbers during the first three years of life (Petrou & Panaoura, 2022). In the early educational stages, LMI begins to emerge more clearly through solving simple mathematical problems, such as adding and subtracting numbers, and then gradually progresses to more complex issues, such as algebra, geometry, calculus, differential equations, and probability (Lagubeau, Tecpan, & Hernández, 2020). In this regard, Mannis and Berens (2024) showed that LMI is influenced by factors of heredity, environment, education and training, and self-motivation, as these individuals rely on setting their own goals and using effective problem-solving methods.

LMI plays a fundamental role in human life and is essential because logical thinking is a crucial ability for positive life change (Aini, Nurkamto, & Suparno, 2017). Therefore, logical-mathematical intelligence needs to be developed in various ways. Azinar, Munzir, and Bahrn (2020) listed several activities that stimulate the mind and promote critical thinking, such as solving mathematical puzzles, using math-based software, playing brain games, studying math-based sciences like physics and chemistry, and engaging in programming training. Furthermore, studies have indicated that LMI encompasses the ability to use numbers effectively, deductive reasoning, sequencing, classification, and the use of symbolic models in problem-solving (Gardner, 1999; Prastika et al., 2021). In this context, Ahmed (2018) emphasized that programming relies heavily on logical thinking, and programmers need to write logical code to solve problems and develop applications and programs. Therefore, data analysis and pattern extraction require advanced mathematical skills, making LMI fundamental to many scientific fields such as physics, chemistry, astronomy, and medicine (Majeed, 2018).

Education is the cornerstone of societal development, preparing the next generation to engage with the realities of the present and overcome the nation's challenges and problems in the age of technological advancement. Therefore, education contributes to equipping students with the skills and requirements of the 21st century (Herlinawati et al.,

2024). Consequently, developing LMI in the next generation is a crucial focus of the teaching and learning process, enabling students to gain experience in using and applying knowledge and skills to solve problems they encounter in their daily lives. In this regard, Pehlivan (2017) pointed out that solving mathematical problems is an activity practiced by both teachers and students at all levels. Therefore, LMI helps students think logically when solving these mathematical problems. However, the LMI is the ability to think in an organized and logical way and to use numbers and relationships to solve problems (Shaban, Fikry, & Morsi, 2025).

2.2. LMI and University Courses

LMI is a crucial factor in the performance of university students, especially in scientific disciplines, as it is linked to higher-order thinking skills and problem-solving (Azinar et al., 2020). Within the context of university studies, LMI is considered a fundamental pillar of academic success, in addition to the positive relationship between LMI and self-regulation among university students (Hameed, 2025). University-level courses are a fundamental tool for developing LMI in mathematics students. These courses provide a learning environment that stimulates analytical thinking, mathematical reasoning, and the solution of complex problems (Wang & Abdullah, 2024). In other words, integrating practical exercises, projects, interactive activities, and teamwork enhances independent thinking skills, pattern recognition, and hypothesis formulation (Weigand, Trgalova, & Tabach, 2024). Therefore, designing courses diversely and practically contributes to the development of higher-order thinking skills and prepares students for academic and professional excellence in scientific and educational fields. The LMI can be integrated into mathematics and science courses because it helps reveal students' ability to work with numbers and logic, their skills in word and number processing, their use of logic and logical problem-solving, their ability to find formulas, and their capability to conduct scientific research. In this regard, Al-Jarrah (2013) indicated that there is an interactive correlation relationship between university courses and the LMI among Jordanian university students.

Understanding the impact of university courses on the LMI of mathematics students is not merely an academic matter; it is essential for developing young minds and stimulating the critical and analytical thinking that shapes the future of science and technology (National Council of Teachers of Mathematics, 2014). University courses are not merely content to be taught; they are a dynamic space where students investigate their skills and confront challenges that stimulate them to discover patterns, solve complex problems, and formulate hypotheses, all essential elements in mathematics education, particularly in LMI. In this context, comparative cultural studies gain significant importance, as they allow comparisons across the diversity of educational environments and demonstrate the extent to which social and cultural contexts affect the effectiveness of curricula and teaching methods. These studies are particularly valuable in Arab contexts, as they allow for the integration of perspectives from mathematics education students across Arab countries and universities. This provides a comprehensive and diverse view of how to design curricula and teaching methods to meet the varied needs of students. Based on this, this research becomes a bridge between theory and application, and between education and humanity. It contributes to the development of academic skills, in addition to cultivating minds capable of deep and creative thinking and active participation in a diverse knowledge society, both regionally and globally.

The current study aimed to identify the impact of academic courses on the LMI of mathematics students in some Arab universities. Therefore, understanding the impact of university courses on the LMI of mathematics students is a fundamental step in understanding the importance of these courses in developing analytical, critical thinking, and problem-solving skills. Examining this relationship allows universities and academics to identify the strengths and weaknesses of their courses and develop more effective teaching strategies that incorporate practical exercises, projects, and interactive activities. This examination also helps guide education toward fostering independent thinking, pattern recognition, and hypothesis formulation among students, thereby raising academic achievement and enhancing innovation. In other words, exploring the relationship between courses and LMI provides a reliable scientific database for designing future university courses that are more suited to students' cognitive needs and helps prepare a generation of teachers and researchers capable of meeting the challenges of knowledge and critical thinking in academic and professional environments.

3. Methodology

3.1. Study Design

The cross-cultural quantitative descriptive approach was used in the current study. Cross-cultural studies aim to examine the psychological and behavioral characteristics of two or more cultural groups to understand the influence of culture on these characteristics and to reveal the true differences between cultures (Matsumoto & van de Vijver, 2023). In other words, cross-cultural studies are a systematic approach to uncovering similarities and differences between societies. Despite the commonalities among Arab countries in terms of religion, language, and social values, higher education systems and educational policies may differ in universities of Oman, Jordan, Qatar, Bahrain, and Algeria. This makes a cross-cultural study potentially useful for uncovering the impact of courses on students' LMI in these five countries. This research approach provides a more in-depth image of LMI within the Arab context.

3.2. Participants

There were 431 university students majoring in mathematics education who participated in this study. These students were selected using convenience sampling. Convenience sampling is a type of non-probability sampling where participants are chosen based on their accessibility and willingness to collaborate in responding to the study instrument (Etikan, Musa, & Alkassim, 2016). Therefore, the results of this study cannot be generalized to all mathematics education students in Arab universities. Accordingly, a link to the LMI scale was distributed to all mathematics education students at some universities in Oman, Jordan, Algeria, Qatar, and Bahrain. Each author of this study distributed the link to mathematics students in universities within their respective countries. The scale included instructions for responding to the items, and participation was voluntary. The distribution of the scale took place from March to May 2025. Figure 1 shows the distribution of participants according to gender, year level, GPA, college, and country.

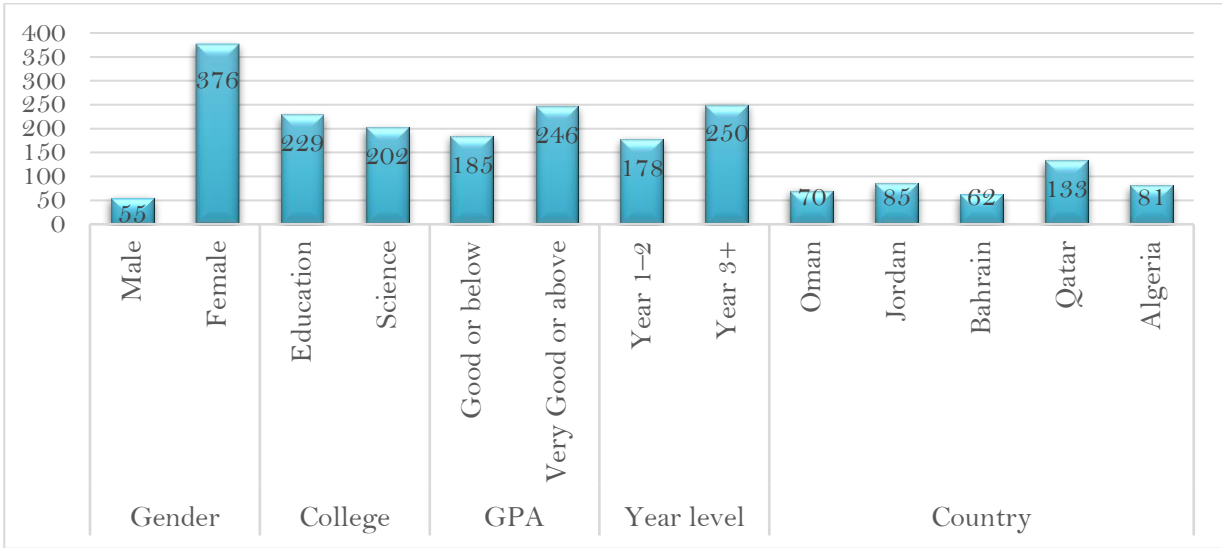


Figure 1. Distribution of participants by demographic variables.

3.3. Data Collection

The development of the LMI scale is based on TMI (Gardner, 1983) and related research and studies (Al-Onizat, 2014; Khodadady, 2016; Shearer, 1996; Suryani, Kartowagiran, & Jailani, 2017). The first draft of the LMI scale consisted of 29 items distributed across 4 domains: Logical reasoning, mathematical problem solving, spatial reasoning, and data reasoning. To examine the psychometric properties of the LMI scale, it was reviewed by 9 experts in psychology and mathematics education in Oman and Jordan. These experts provided suggestions and feedback on the scale's domains and items. Consequently, the final draft of the LMI scale consisted of 24 items distributed as follows: Logical reasoning (1–6), mathematical problem solving (7–12), spatial reasoning (13–18), and data reasoning (19–24). The scale items were answered using a three-point Likert scale: Agree (3), Neutral (2), and Disagree (1). To analyze the results of the current study, the following criteria were used for calculating the means: low (1.00–1.67), average (1.68–2.34), and high (2.35–3.00) (Al-Hadabi, Al-Zoubi, & Al-Zoubi, 2024; Ling & Yamat, 2020). The reliability of the LMI scale was also examined by applying a pilot sample of 82 mathematics students in the five Arab countries. Cronbach's alpha coefficients for the four domains of the LMI scale showed the following: Logical reasoning (0.83), mathematical problem solving (0.78), spatial reasoning (0.75), and data reasoning (0.86). The results of Cronbach's alpha coefficient show that the study scale had alpha values ranging between 0.75 and 0.86, which means that there is internal consistency between the items and the scale has good reliability that can be used in the current study. Therefore, values (≥ 0.70) are an acceptable reliability, and values (> 0.80) are a good reliability (Taber, 2018).

3.4. Procedures

This study aims to identify the impact of university courses on the LMI of university mathematics students in five Arab countries: Oman, Jordan, Qatar, Algeria, and Bahrain. The LMI scale was developed after a review of the theoretical literature. The final draft of the LMI scale was distributed electronically to participants by the authors of this study, who were responsible for data collection and contact with students and colleges of education and sciences at their respective universities and countries. The distribution of the scale took place from March to May 2025. Finally, the data were downloaded from Google Forms and processed using Cronbach's alpha, Shapiro-Wilk, and Kolmogorov-Smirnov tests, means, standard deviations, t-test, one-way ANOVA, and post-hoc comparisons (LSD).

4. Results

4.1. Results of the First Question

What is the impact of courses on the LMI of undergraduate students?

To answer this question, the means (M) and standard deviations (S.D.) were calculated. Table 1 shows these results.

Table 1. Means and standard deviations according to domains of the LMI scale (N = 431).

Scale's domains	M	S.D	Level
Mathematical Problem Solving	2.63	0.435	High
Data Reasoning	2.59	0.486	High
Logical Reasoning	2.58	0.437	High
Spatial Thinking	2.51	0.524	High

Table 1 shows that the means ranged between 2.63 and 2.51. The domain of mathematical problem-solving ranked first (M = 2.63), while the domain of spatial thinking ranked last (M = 2.51). However, the impact of the courses on the LMI was high across all dimensions of the LMI scale from the perspective of undergraduate mathematics students. Figure 2 provides a visual representation of the impact of university courses on LMI.

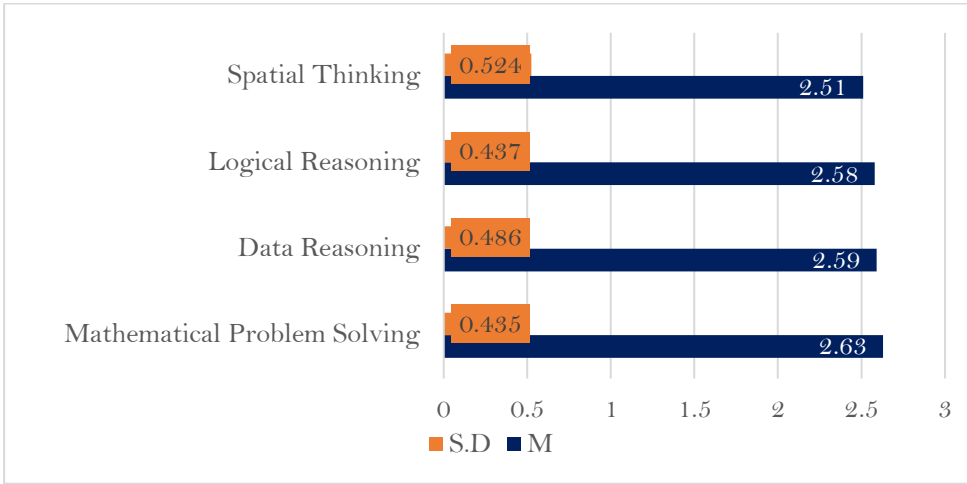


Figure 2. Domains of the LMI scale.

4.2. Results of the Second Question

Are there statistically significant differences in the participants’ responses attributable to gender? Before statistical analysis, the normality of the data distribution by gender was verified. Table 2 shows the Shapiro–Wilk test and the Kolmogorov–Smirnov test.

Table 2. Normality of the data by gender.

Gender	N	Shapiro-Wilk	p-value	Kolmogorov-Smirnov	p-value	Normality
Male	55	0.975	0.162	0.973	0.200	Normal
Female	376	0.992	0.056	0.988	0.080	Normal

Table 2 shows the results of the Shapiro-Wilk and Kolmogorov-Smirnov tests on the LMI scale. The table indicates that all p-values are normally distributed between male and female students. This means that all values are above 0.05 ($p > 0.05$). This allows for the use of parametric tests to answer the second study question. Therefore, a t-test was used to answer the second question. Table 3 shows the results.

Table 3. Results of t-test according to gender (N = 431).

Scale's domains	Gender	N	Mean	S.D	t	df	Sig.
Logical Reasoning	Male	55	2.66	0.45	1.537	429	0.06
	Female	376	2.57	0.43			
Mathematical Problem Solving	Male	55	2.73	0.33	2.291	429	0.01*
	Female	376	2.61	0.44			
Spatial Thinking	Male	55	2.59	0.52	1.222	429	0.11
	Female	376	2.50	0.52			
Data Reasoning	Male	55	2.75	0.37	3.370	429	0.00*
	Female	376	2.56	0.49			

Note: * ($\alpha \leq 0.05$).

Table 3 indicates that there are statistically significant differences in the dimensions of mathematical problem solving and data reasoning according to gender, favoring male students. However, there are no differences in the dimensions of logical reasoning and spatial thinking. Figure 3 illustrates the statistical differences in favor of male students in mathematical problem solving and data reasoning.

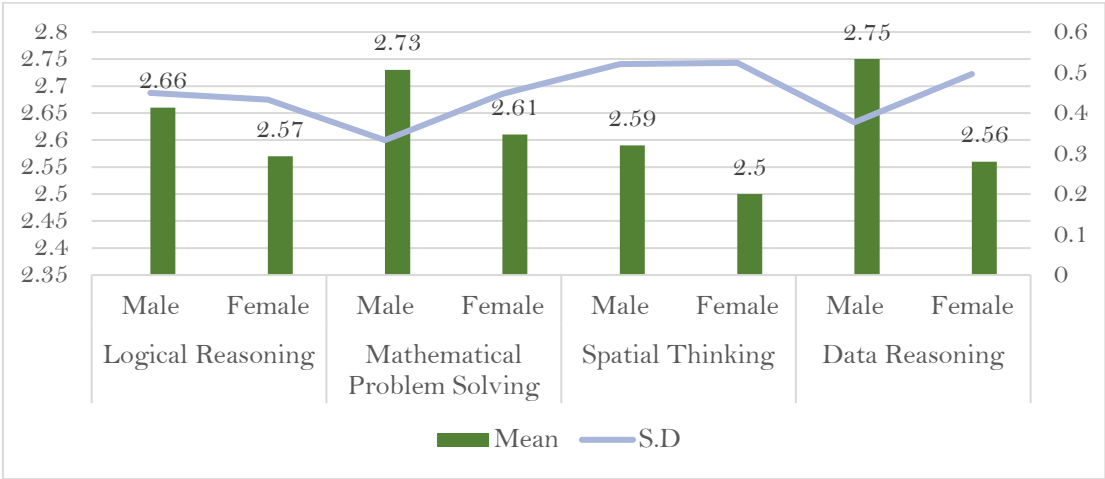


Figure 3. The statistical differences in favor of male students.

4.3. Results of the Third Question

Are there statistically significant differences in the participants’ responses attributable to college (Education vs. Science)? Table 4 shows the results of the t-test according to college.

Table 4. Results of t-test according to college (N = 431).

Scale's domains	College	M	S.D	t	df	Sig.
Logical Reasoning	Education	2.54	0.47	-2.02	429	0.02*
	Science	2.62	0.38			
Mathematical Problem Solving	Education	2.60	0.46	-1.75	429	0.04*
	Science	2.67	0.39			
Spatial Thinking	Education	2.44	0.54	-0.61	429	0.26
	Science	2.52	0.49			
Data Reasoning	Education	2.52	0.52	-3.04	429	0.00*
	Science	2.66	0.42			

Note: * ($\alpha \leq 0.05$).

Table 4 indicates that there are statistically significant differences in the dimensions of logical reasoning, mathematical problem solving, and data reasoning according to college. These differences favor the students at the College of Science. Figure 4 demonstrates these results.

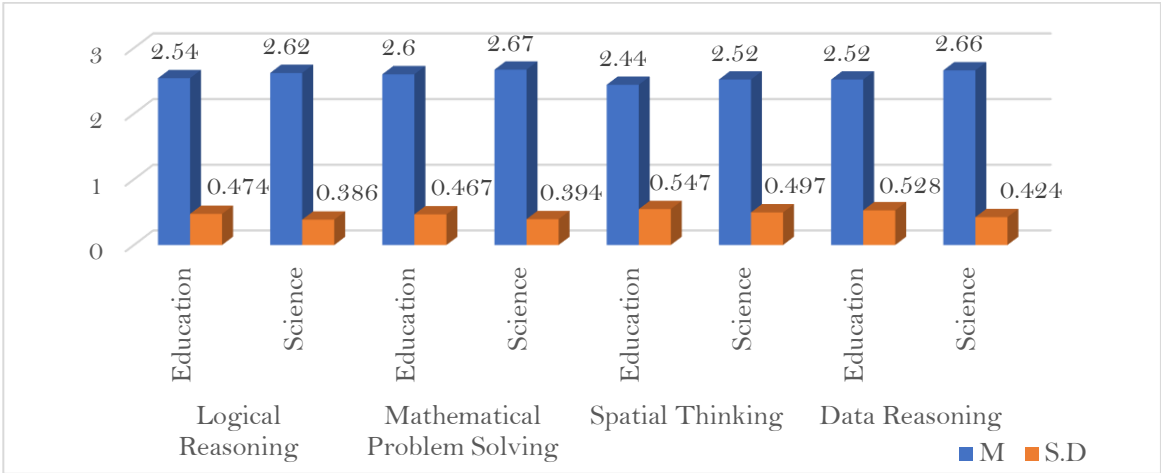


Figure 4. The statistical differences in favor of students in the College of Science.

4.4. Results of the Fourth Question

Are there statistically significant differences in the participants' responses attributable to GPA? Table 5 and Figure 5 show the results of the t-test according to GPA.

Table 5. The results of the t-test according to GPA (N = 431).

Scale's domains	GPA	Mean	S.D	t	df	Sig.
Logical Reasoning	Good or Less	2.47	0.50	-4.41	429	0.00*
	V. Good or above	2.66	0.35			
Mathematical Problem Solving	Good or Less	2.53	0.48	-3.94	429	0.00*
	V. Good or above	2.70	0.37			
Spatial Thinking	Good or Less	2.38	0.56	-4.21	429	0.00*
	V. Good or above	2.60	0.46			
Data Reasoning	Good or Less	2.49	0.54	-3.468	429	0.00*
	V. Good or above	2.66	0.42			

Note: * ($\alpha \leq 0.05$).

The results in Table 5 indicate that there are statistically significant differences in all dimensions of the LMI scale in favor of students with a very good GPA and above.

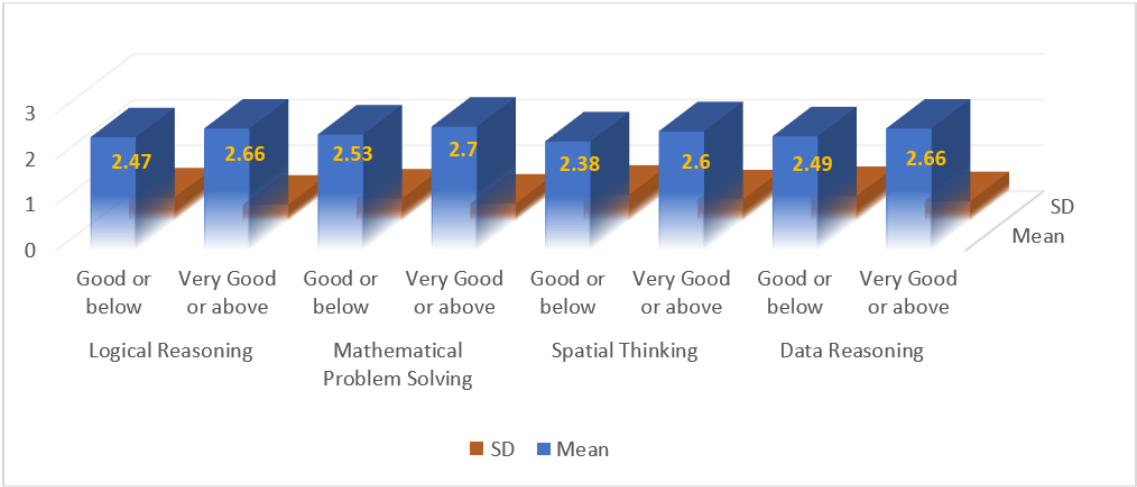


Figure 5. The statistical differences in favor of students with a very good or above.

4.5. Results of the Fifth Question

Are there statistically significant differences in the participants' responses attributable to year level? Table 6 and Figure 6 show the results.

Table 6. The results of the t-test according to year level (N = 431).

Scale's domains	Year level	M	S.D	t	df	Sig.
Logical Reasoning	Year 1-2	2.48	0.48	-3.80	429	0.001*
	Year 3+	2.65	0.38			
Mathematical Problem Solving	Year 1-2	2.59	0.46	-1.31	429	0.095
	Year 3+	2.65	0.41			
Spatial Thinking	Year 1-2	2.45	0.54	-1.74	429	0.040*
	Year 3+	2.54	0.51			
Data Reasoning	Year 1-2	2.51	0.53	-2.53	429	0.006*
	Year 3+	2.64	0.44			

Note: * ($\alpha \leq 0.05$).

Table 6 shows that there are statistically significant differences across all scale dimensions except for mathematical problem solving. These differences favor students at the 3-year and above. Figure 6 provides a visual representation of means according to the years of study.

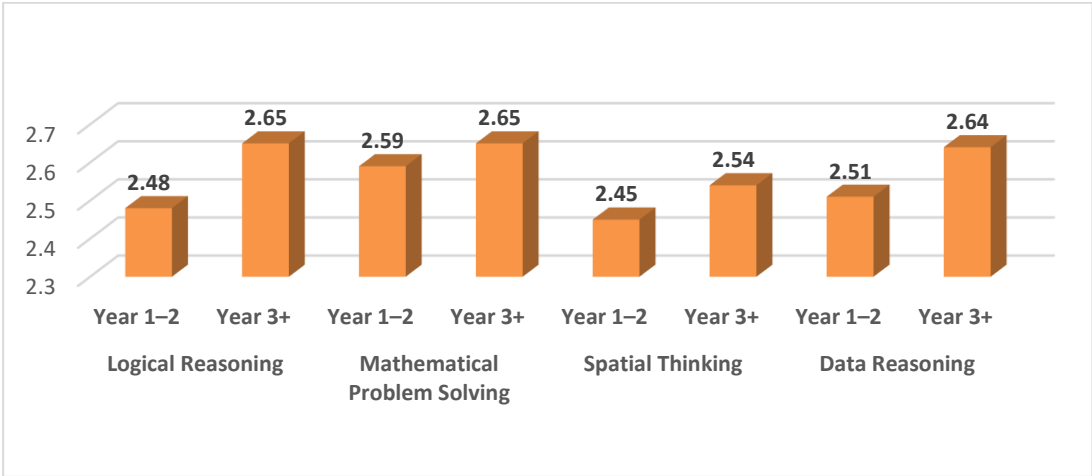


Figure 6. Distribution of means according to the years of study.

4.6. Results of the Sixth Question

Are there statistically significant differences in the participants’ responses attributable to the country? The figure shows the means and standard deviations on the overall scale according to the country.

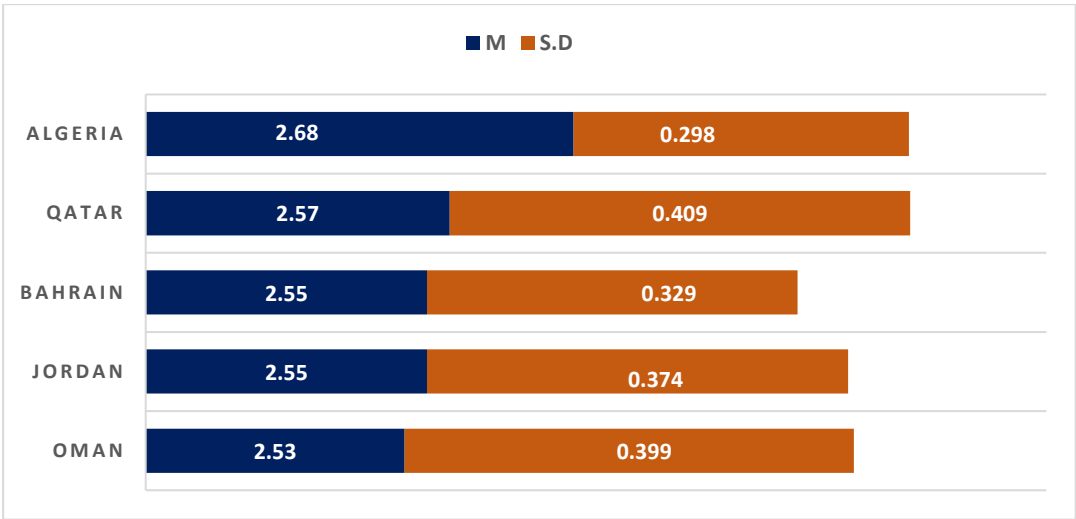


Figure 7. Means and standard deviations according to the students' country.

Figure 7 shows differences in the means by country. Algeria has a high mean (M=2.68), and Oman has the lowest (M=2.53). To determine if these differences are statistically significant, one-way ANOVA was used. Table 7 shows these results by student’s country.

Table 7. Results of one-way ANOVA by student's country.

Scale's domains	Country	Source of Variance	SS	df	MS	F	Sig.
Logical Reasoning	Oman	Between groups	2.098	4	0.525	2.799	0.026*
	Jordan	Within groups	79.832	426	0.187		
	Bahrain	Total	81.93	430			
	Qatar						
	Algeria						
Mathematical Problem Solving	Oman	Between groups	1.675	4	0.419	2.236	0.064
	Jordan	Within groups	79.787	426	0.414		
	Bahrain	Total	81.462	430			
	Qatar						
	Algeria						
Spatial Thinking	Oman	Between groups	1.5	4	0.375	1.372	0.243
	Jordan	Within groups	116.449	426	0.273		
	Bahrain	Total	117.949	430			

Scale's domains	Country	Source of Variance	SS	df	MS	F	Sig.
Data Reasoning	Qatar					1.574	0.180
	Algeria						
	Oman	Between groups	1.481	4	0.370		
	Jordan	Within groups	100.227	426	0.235		
	Bahrain	Total	101.708	430			
	Qatar						
	Algeria						

Note: * ($\alpha \leq 0.05$).

Table 7 shows that there are statistically significant differences in the logical reasoning domain, while there are no differences in the other domains of the LMI scale according to the country. To identify these country-specific differences, LSD post-hoc comparisons were used. Table 8 presents the results by country.

Table 8. LSD on logical reasoning domain by the students' country.

Country	Jordan	Bahrain	Qatar	Algeria
Oman	0.303	0.210	0.148	0.210
Jordan	—	0.752	0.730	0.017*
Bahrain	—	—	0.975	0.012*
Qatar	—	—	—	0.003*

Note: * $\alpha \leq 0.05$ indicates statistical significance.
Significant differences were found between Algeria, Jordan, Bahrain, and Qatar.
No significant differences were found between Algeria and Oman.

Table 8 shows that Algerian students scored significantly higher than students from Jordan, Bahrain, and Qatar, while no significant difference emerged between Algeria and Oman. No additional pairwise comparisons were statistically significant, confirming that the effect of the overall analysis of variance was primarily driven by Algeria's relatively stronger performance in logical reasoning tasks.

5. Discussion

This study aimed to investigate the effect of university courses on the LMI of mathematics students in different universities in the Arab world. The study results will be discussed below.

5.1. The Impact of Courses on LMI among Mathematics Students

The current study revealed a high level of LMI among students, with outstanding performance across all four dimensions of the LMI competence scale: mathematical problem solving, data reasoning, logical reasoning, and spatial thinking. This comprehensive report provides compelling evidence that university courses, particularly in mathematics-related disciplines within faculties of education and science, effectively contribute to LMI in Arab universities. Students' ongoing engagement with symbol manipulation, evidence-based reasoning, and justification-based assessment is likely to foster disciplined analytical thinking and rule-based decision-making. Therefore, the observed high levels appear to reflect not only individual aptitude but also cumulative educational experience and rigorous cognitive demands embedded within mathematics courses.

At the dimensional level, mathematical problem-solving scored the highest average ($M = 2.63$), indicating a high ability to choose appropriate strategies, implement multi-step solution procedures, and monitor the validity of the solution. This result reinforces the view that problem-solving is a central behavioral aspect of LMI in higher education; learning expectations focus on procedural competence, accuracy, and reflective reasoning. In this regard, Majeed (2018) and Sabiila, Susongko, and Munadi (2025) demonstrated that competence in solving mathematical problems is closely linked to core LMI. Pattern detection and logical evaluation are key aspects of this dimension. Therefore, the dominance of this dimension is attributed to university learning environments that demand systematic thinking in addressing non-routine problems. High performance in data analysis suggests that courses are designed to require advanced analytical skills, enhancing students' ability to interpret quantitative evidence. This finding is particularly significant given the increasing integration of statistics, mathematical modeling, computational tools, and other related fields into mathematics programs, areas that necessitate systematic data processing and the evaluation of numerical relationships. This interpretation supports the findings of Aziz, Rahayu, and Sugiman (2020), who demonstrated that integrating programming skills, statistical analysis, and comparative modeling into university courses can significantly enhance symbolic analytical thinking. Consequently, the high average score for data analysis in this study likely reflects university courses' features that promote evidence-based reasoning and quantitative decision-making.

The high level of logical reasoning confirms that students in mathematics-related disciplines tend to develop consistent abilities for deduction, reasoning, and evaluating arguments. This result is consistent with Multiple Intelligences Theory, which defines LMI as the ability to work through logical relations, organized chains of reasoning, and to solve problems systematically (Gardner, 1983). University mathematics courses typically enhance these competencies through frequent engagement in formal reasoning practices, including verifying assumptions, defending the logic of a solution, and establishing consistency between representations and conclusions.

Although spatial thinking achieved the lowest average score ($m = 2.51$), it remained within the high end, indicating strong spatial competence, but with relatively weaker development compared to the symbolic-analytical dimensions. This pattern aligns with evidence suggesting that spatial reasoning receives less explicit attention in programs that primarily focus on abstraction and symbolic operations. Arum et al. (2018) observed that mathematical-logical skills are developed through instructional focus, and that representational competencies may remain underdeveloped if not systematically emphasized. From an educational perspective, this indicates the need to enhance spatially rich courses with visualization, modeling, and representational tasks (such as dynamic geometry and simulation-based activities) to ensure balanced LMI growth.

The present results align with prior research reporting high LMI levels among university students in mathematics-related contexts. Shirawia et al. (2023) documented high LMI among pre-service mathematics teachers. Prastika et al. (2021) demonstrated that higher LMI is associated with enhanced creative mathematical thinking. Collectively, these results lend support to the claim that intensive academic engagement in mathematics promotes advanced cognitive dispositions underpinning LMI. Nonetheless, the current findings diverge from evidence of moderate or low LMI in other contexts (Azinar et al., 2020; Hameed, 2025). These differences in the results of these studies may be attributed to course content, curriculum, instructional quality, and assessment methods. These differences may affect the level of students' acquisition of LMI skills in university academic programs. Overall, the results provide cross-cultural evidence that university coursework contributes positively to sustaining high LMI among mathematics majors.

5.2. The Impact of University Coursework on LMI by Study Variables

Gender: Results indicated that there were statistically significant differences in the dimensions of mathematical problem solving and data reasoning in favor of male students. One possible explanation is that the observed differences reflect variations in educational experiences and academic engagement, rather than innate abilities. Dimensions in the applied domain, such as mathematical problem-solving and data reasoning, are typically enhanced through courses that include statistical interpretation, computational reasoning, and structured reasoning tasks. In this context, Aziz et al. (2020) reported that integrating programming, statistical analysis, and modeling activities into the curriculum can improve symbolic analytical thinking, skills closely related to problem-solving and data reasoning. Therefore, gender gaps in these dimensions likely arise from differing exposure to or practice of different mathematical tasks in different educational contexts.

The current results are consistent with studies reporting males outperforming in analytical and problem-solving outcomes, e.g., (Al-Jarrah, 2013; Prastika et al., 2021; Sabilila et al., 2025). However, they diverge from evidence showing low or non-significant gender effects in the LMI (Azinar et al., 2020; Hameed, 2025). This reinforces the argument that gender differences are influenced by context, educational circumstances, and methodology. This interpretation aligns with what (Shirawia et al., 2023) documented regarding an increase in the LMI among female pre-service mathematics teachers; this suggests that females are capable of achieving similarly high results when learning environments provide opportunities that require cognitive effort. Logically, given the small magnitude of the practical differences in this study, the findings highlight the urgent need for instructional designs that ensure access to inquiry-based problem-solving tasks, data justification, and modeling, thereby supporting balanced LMI development across genders.

College: The results showed that the courses had a positive effect on the LMI of mathematics students in science colleges compared to mathematics students in education colleges, particularly in logical reasoning, mathematical problem solving, and data reasoning. A possible explanation is that the sciences require ongoing engagement with quantitative analysis, evidence-based reasoning, and formal justification, which may enhance the applied analytical dimensions of LMI, particularly data reasoning. This interpretation is consistent with Aziz et al. (2020), who showed that integrating programming, statistics, and modeling into university courses can enhance symbolic analytical thinking and data-based reasoning. In contrast, education programs often prioritize educational theories and reflective practice, providing less structured opportunities for quantitative reasoning compared to science programs. These findings are consistent with research highlighting the role of continuous reasoning practice in promoting LMI (Majeed, 2018; Sabilila et al., 2025) and are generally consistent with evidence of strong LMI in mathematically intensive university contexts (Shirawia et al., 2023). However, the lack of differences in spatial thinking suggests that this dimension may not develop incidentally through program type, especially when visual perception-based learning is not the primary objective, a finding consistent with Arum et al. (2018). Overall, the results indicate that university specialization has a limited but consistent impact on learning and comprehension skills, giving science students an advantage in dimensions requiring deep thinking. From a curriculum perspective, strengthening teacher preparation programs with subjects that focus on data interpretation, modeling, and inquiry-based problem-solving could contribute to a more balanced LMI development across disciplines.

GPA: The results showed statistically significant differences in all dimensions of the LMI scale in favor of students with a very good GPA or above. This result confirms that the GPA is a strong indicator of mathematical logic competence and LMI in this study. The plausible interpretation is that the relationship between GPA and LMI is reciprocal and reinforces each other. Students with stronger mathematical reasoning abilities are more likely to succeed in courses and assessments that require advanced mathematical skills. This explanation converges with Majeed (2018), who stated significant relations between LMI and procedural mathematical knowledge, and with Sabilila et al. (2025), who emphasized LMI as a key interpreter of mathematical problem-solving performance. The finding is also consistent with Prastika et al. (2021), who connected higher LMI with stronger creative mathematical thinking. This means that high-achieving students may possess more sophisticated cognitive structures that support both analytical accuracy and mathematical flexibility.

Notably, the impact of (GPA) extends to spatial reasoning, suggesting that higher academic achievement is not only linked to symbolic reasoning but also to competence and the ability to mentally manipulate mathematical structures. This adds further nuance to the broader pattern of the study, where spatial reasoning was generally the least relevant, indicating that spatial development may depend on the depth of academic engagement. In line with this, Shirawia et al. (2023) stated that high LMI among the trainee mathematics teachers with outstanding academic standing. In this regard, Aqtait (2023) showed that high-achieving students possess stronger mathematical communication skills, abilities that develop in parallel with reasoning and logic. However, some studies have indicated weaker relations between academic achievement and LMI, e.g., Hameed (2025). These discrepancies may reflect contextual differences in the rigor of curricula and the focus on assessment.

Overall, the results provide important cross-cultural evidence that GPA is closely related to LMI across all domains. Pedagogically, this underscores the need for targeted support for low-achieving students, particularly in

structured problem-solving, supported data-reasoning tasks, and clear visualization training, to reduce achievement gaps and promote equity in LMI development.

Year of Study: Results indicated that year of study is implicitly related to LMI, with year 3+ students obtaining significantly higher scores than year 1–2 students on all dimensions of LMI, except mathematical problem solving, which did not reach statistical significance ($p = 0.05$). This suggests similar performance across academic levels in this dimension.

A plausible explanation for the benefits of advanced undergraduate years is exposing students to higher cognitive and epistemological demands, including increased abstraction, evidence-based reasoning, formal modeling, and data-driven analysis, experiences that directly strengthen Logical Reasoning and Data Reasoning. This interpretation converges with Al-Jarrah (2013), who reported higher LMI among graduating students compared with first-year students, and with Majeed (2018), who emphasized that engagement in structured mathematical tasks enhances reasoning sophistication over time. The observed gains in spatial thinking further suggest that cumulative exposure to advanced representations and structural relationships may gradually strengthen visualization and representational competence, particularly within mathematics and science programs.

The absence of significant differences in mathematical problem solving implies that core problem-solving competence may stabilize earlier in students' academic trajectories and may depend more on individual strategy use and prior preparation than on seniority alone. This aligns with Prastika et al. (2021), who linked problem-solving-related outcomes to deeper cognitive dispositions and creative mathematical thinking rather than to academic stage. Collectively, these findings support the conclusion that university progression tends to strengthen reasoning, representation, and evidence-based justification more consistently than it strengthens problem-solving performance. Accordingly, curricula should distribute reasoning-rich, visualization-based, and data-justification tasks across all years, particularly in early stages, to accelerate balanced LMI development and minimize gaps between lower- and higher-year students (Shirawia et al., 2023).

Country: Results indicated that cross-country differences in the LMI were generally minimal across Oman, Jordan, Bahrain, Qatar, and Algeria. But the one-way ANOVA revealed statistically significant variation only in logical reasoning. In contrast, the differences in mathematical problem solving, spatial thinking, and data reasoning were not statistically significant. Thus, within this cross-cultural sample of mathematics majors, the LMI appears broadly comparable across Arab countries, with country operating as a weak differentiating variable rather than a systematic determinant.

LSD showed that Algerian students scored significantly higher in logical reasoning than students from Jordan, Bahrain, and Qatar. This selective pattern suggests that any cross-national variation is concentrated in formal reasoning skills rather than in applied competencies. A plausible interpretation is that logical reasoning is particularly sensitive to curricular emphasis on deductive thinking, proof-oriented tasks, and structured justification practices, elements that may vary modestly across educational systems. This interpretation aligns with Majeed (2018), who emphasized that reasoning outcomes strengthen when curricula foreground logical structure and multi-step justification. Conversely, the absence of differences in problem solving, data reasoning, and spatial thinking suggests that these competencies may be more uniformly cultivated within university mathematics programs across Arab countries, reflecting shared disciplinary standards and comparable course-related cognitive demands.

Overall, the results related to study variables provide strong cross-cultural evidence of convergence in the LMI among mathematics undergraduates, with only modest national variation in logical reasoning. Educationally, the results highlight the value of embedding proof-based reasoning, structured argumentation, and justification-rich tasks across curricula to strengthen formal reasoning competencies in diverse higher-education contexts (Sabiila et al., 2025; Shirawia et al., 2023). Overall, the findings suggested that variation in the LMI is shaped primarily by academic and curricular factors rather than demographic context. While gender and college effects were statistically significant, they remained modest and dimension-specific; in contrast, GPA showed the strongest and most consistent association across all the LMI dimensions, and senior students (Year 3+) outperformed juniors in logical reasoning, spatial thinking, and data reasoning. Cross-country differences were largely negligible, with significance limited to logical reasoning and a very small effect size. Collectively, the results highlight the importance of reasoning-rich coursework and assessment practices that systematically develop analytical, data-based, and visualization competencies across mathematics students.

6. Conclusion

This cross-cultural study examined undergraduate students' LMI across four dimensions: mathematical problem solving, data reasoning, logical reasoning, and spatial thinking. Tested differences attributable to gender, college type, GPA, year of study, and country. Overall, the results indicated a high level of the LMI, suggesting that mathematically intensive university coursework supports the development of higher-order reasoning competencies. Variations in the LMI were explained primarily by academic and curricular factors, particularly GPA, followed by college type and year of study, whereas gender and country effects were limited and dimension-specific. This study recommends including logical reasoning, spatial thinking, and data analysis skills in university curricula and courses, and providing targeted support for lower-achieving students in strategic mathematical problem solving.

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