SUCCESSFUL INTELLIGENCE AND METACOGNITIVE THINKING: THE MEDIATING EFFECTS OF SUSTAINABLE EDUCATIONAL DEVELOPMENT AMONG UNIVERSITY STUDENTS

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Abstract

This study investigates the direct effects of successful intelligence on metacognitive thinking and SED, the direct impact of SED on metacognitive thinking, and the indirect role of SED as a mediator between successful intelligence and metacognitive thinking. A quantitative analytical cross-sectional design was employed. A stratified-proportionate sample of 529 university students was selected. Standardized scales measuring successful intelligence, metacognitive thinking, and sustainable educational development were adapted and validated. Multiple regression analysis and structural equation modeling (SEM) were used to examine relationships among variables. The findings reveal that successful intelligence has a significant direct positive impact on both metacognitive thinking ($\beta = 0.505$, $p < 0.05$) and SED ($\beta = 0.347$, $p < 0.05$). Additionally, SED significantly enhances metacognitive thinking ($\beta = 0.461$, $p < 0.05$). The results confirm that SED partially mediates the relationship between successful intelligence and metacognitive thinking but indirectly. However, creative abilities had no significant effect on SED, and the economic dimension of SED showed a weaker impact on metacognitive thinking. This study underscores the crucial role of successful intelligence and sustainable educational development in fostering metacognitive thinking among university students. Universities should integrate successful intelligence strategies into curricula, develop metacognitive skill-building programs, and promote sustainability-focused education.

Keywords: Successful Intelligence, Metacognitive Thinking, Sustainable Educational Development, Higher Education, Analytical Thinking, Creative Abilities, Practical Intelligence, Cognitive Strategies, Learning Adaptability

1. Introduction

The university stage is one of the most critical stages of education, as it provides students with knowledge and specializations that enhance their ability to perform their social roles effectively. In this stage, students develop independence and self-confidence and undergo intellectual and creative growth, enabling them to bear social responsibilities. Accordingly, society's interest in university students is essential to foster their progress and development (Dallah, 2020). Sustainable educational development focuses on creating fair and comprehensive educational systems that meet the needs of current and future generations by integrating environmental, economic, and social dimensions, enhancing adaptation and flexibility, critical thinking, and problem-solving as well as improving teacher training and infrastructure and increasing community participation (Jusoh & Yan, 2021).

The theory of successful intelligence is an extension of Sternberg's theory of human intelligence, which is applied in educational programs to enhance students' analytical and applied abilities and support their development of imagination and creative and analytical thinking (Zahrani, 2020). According to (Sternberg and Grigorinko, 2007), focusing on successful intelligence enhances students' learning by exploiting their strengths, improving their weaknesses, and enhancing their motivation. This contributes to the development of memory, creative thinking, and the ability to adapt to the educational environment. It is

believed that the application of the theory of successful intelligence improves academic performance in creative and analytical assessments.

(Al-Dabbas, 2018) showed that critical thinking enhances understanding, links educational materials, enables individuals to use metacognitive strategies, and helps them succeed beyond simple memorization and indoctrination. Metacognitive thinking skills play a vital role in enhancing students' academic performance and skill development. Specifically, they improve communication, comprehension, reading, writing, and problem-solving skills (Al-Juid & Suleiman, 2023). In addition, these skills enhance students' awareness of their learning styles and methods, which reduces learning difficulties, especially for low-achieving students (Rawa, 2019). Moreover, metacognitive skills help students solve everyday problems efficiently, enhancing academic achievement and problem-solving (Veenman, & van Cleef, 2019). In this context, it was noted that successful intelligence is related to creative, analytical, and practical abilities. The aim of this study is to enhance successful intelligence by analyzing the factors affecting it. Metacognitive skills are essential for academic achievement, while sustainable educational development contributes to youths' environmental and technological readiness.

Studies on the influence of sustainable educational development as a mediating variable between successful intelligence and metacognition are limited. However, previous research confirms the role of these factors in promoting academic success. In addition, a study by (Vahidi and Baratali, 2017) showed that metacognitive skill development improves the academic performance of high school students. Furthermore, (Kaur et al., 2018) underscored the profound impact of metacognition and the learning environment on students' academic achievement, providing valuable insights for educators and policymakers.

The study by (Khalaf, 2019) not only revealed a statistically significant positive correlation between successful intelligence and decision-making skills but also offered essential implications for educational practices and policies. Similarly, (Shouman, 2019) demonstrated the practical effectiveness of a strategy based on the theory of successful intelligence in fostering achievement, metacognitive skill development, and critical thinking, inspiring potential applications in educational settings. (Azid and Md-Ali, 2020) found an influential relationship between successful intelligence and sustainable educational development, which supports the development of personal skills for university students in preparation for their professional future. In addition, a study by (McKim and McKendree, 2020) showed statistically significant relationships between metacognitive skills, systematic thinking, and problem-solving ability. It also indicated that metacognitive thinking skills enhance sustainable development's environmental and economic dimensions.

Another study (Murad, 2021) reported statistically significant positive direct effects of achievement motivation on metacognitive skills and analytical, practical, and innovative intelligence. Further, the results showed a positive indirect effect of achievement motivation on successful intelligence through metacognitive skills. Meanwhile, (Liu et al, 2022) found that students showed greater interest in the educational dimension of sustainable development than its social dimension. Female students also showed more positive attitudes towards the environmental and educational dimensions than male students, and students at higher academic levels show more positive attitudes towards the educational dimension compared to students at lower levels. In a study on accounting students, (Ebaid, 2022) revealed the need for a better understanding of sustainable development due to the weak integration of sustainable development issues into accounting education. Students also indicated a desire to enhance sustainable learning and integrate sustainable development issues into the curriculum.

Given the previous research, the research problem in this study addressed through the following questions: Does successful intelligence have a direct positive effect on metacognitive thinking? Does successful intelligence have a direct positive impact on sustainable educational development? Does sustainable educational development have a direct positive impact on metacognitive thinking? Is there a positive indirect and statistically significant impact of successful intelligence on metacognitive thinking in the presence of sustainable educational development as a positive mediator?

2. Theoretical Framework and Literature Review

2.1. Successful Intelligence

Modern education focuses on comprehensive learner development in preparation for a changing life, emphasizing practical skills as a basis for learning outcomes and shaping students' personalities and ability to adapt to life's challenges. In light of modern developments and easy access to information, the theory of successful intelligence (Sternberg, 2010) has emerged as a framework for providing students with the skills necessary to deal with life's challenges by developing their ability to distinguish, analyze, evaluate, and enhance creative and analytical thinking (Al Dossary, 2019). The theory of successful intelligence (Sternberg, 2010) is essential in helping students make the most of their talents and abilities. Successful intelligence encompasses an integrated system of abilities that contribute to students' success in life, supporting them in identifying their strengths and weaknesses and taking steps to improve them. Thus, students are better able to adapt to their environments using their analytical, creative, and practical abilities.

(Sternberg, 1984) proposed the theory of trilateral intelligence in the mid-1980s, which categorizes three main types of intelligence: analytical intelligence based on cognitive components, creative intelligence based on life experiences, and scientific intelligence based on social aspects. (Chan ,2008) specifically defined successful intelligence as a set of integrated practical, creative, and analytical abilities that allow individuals to achieve their goals and develop life and learning skills within a social and cultural framework that enables them to adapt to, choose, and shape the environment. Similarly, (Yan, 2023) defined successful intelligence as a person's ability to achieve goals based on three main characteristics: analytical, creative, and practical abilities. Analytical characteristics encompass analysis, evaluation, criticism, judgment, comparison, and contrast, as measured by traditional tests. Creativity is related to generating original and compelling ideas, while practical abilities relate to implementing ideas effectively. (Al-Otaibi, 2024) argued that successful intelligence is an integrated system of abilities necessary for success, allowing individuals to distinguish their strengths and weaknesses and adapt to their environments using their analytical, creative, and practical abilities. Accordingly, we hypothesized that employing the theory of successful intelligence in teaching would motivate students to improve their analytical, practical, and creative skills, thus positively impacting their academic performance.

In particular, Sternberg's theory of triadic intelligence, comprising "analytical intelligence, creative intelligence, and practical intelligence," is instrumental in comparing students' interests and academic performance. This theory, has significant practical implications for education (Sternberg, 2003).

Analytical intelligence includes three main components:
1. Metacognitive components, such as planning, monitoring, and evaluating cognitive processes.
2. Performance components related to implementing strategies.
3. Knowledge acquisition components, including using knowledge to solve problems.

According to (Al-Sharawy, 2024), analytical intelligence also includes analysis, evaluation, and judgment and is usually measured through tests that include problem-solving skills and logical and critical thinking.

Creative intelligence, a crucial aspect of successful intelligence, refers to the ability to navigate new situations using past experiences and current skills. It involves innovative thinking and generating new ideas, such as imagination, originality, and adaptability (Sternberg, 2000). Meanwhile, (Sternberg, 2020) defined practical intelligence as the ability to adapt to daily life by applying knowledge and managing oneself and others effectively. It requires a balance between analytical, creative, and practical abilities to achieve goals, overcome challenges, and contribute meaningfully to society. Analytical skills are useful for evaluating and identifying creative ideas appropriate to the educational situation. Analytical intelligence encompasses inference, memorization, application, interpretation, comparison, planning, criticism, judgment, evaluation, classification, and decision-making.

Dağtan and Bulut (2022) listed several distinctive characteristics of successful individuals, including analytical intelligence, creative intelligence, practical intelligence, and self-organization. Successful individuals can also deal with others, have strong personal skills, and are able to adapt and learn continuously throughout life.

2.2. Metacognitive Thinking

The concept of metacognition, which emerged in the 1970s thanks to John Flavell, is not just a theoretical construct. It is a practical tool that provides knowledge and awareness about cognitive phenomena, including knowledge of cognitive processes and their organization. (Mazen, 2011) developed this concept to include learners' understanding of themselves and how they acquire knowledge. Since the 1980s, this concept has continued to be of interest in education and learning, both theoretically and practically. According to (Schraw and Dennison, 1994), metacognition refers to awareness and perception and their organization, including self-knowledge, strategies and reasons for using them as well as organization involving the planning, monitoring, and evaluation of cognitive activities. Similarly, (Pintrich, 2002) defined *metacognition* as the awareness and control of cognitive processes, involving the organization of individual thinking and learning, including the planning, monitoring, and evaluation of strategies. (Abdulaziz, 2016, p. 35) elaborated on metacognition, describing it as "The student's thinking about the cognitive and mental processes he performs and the awareness and monitoring of learning processes and problem solving." (Al-Hashemi and Al-Dailami, 2018) stated that it refers to procedures and practices that include methods and means for achieving goals. According to (Pasigon, 2024), individuals with high levels of metacognitive thinking have vital characteristics such as self-awareness, self-regulation, and strategic thinking. They also evaluate and improve their thinking and show flexibility in adapting strategies to different situations.

In sum, metacognitive thinking skills enable individuals to understand and control their cognitive processes and develop knowledge, organization, and strategies. These skills are essential for lifelong learning and personal growth and increase problem-solving effectiveness.

2.3. Sustainable Educational Development

Sustainable educational development enhances students' motivation to learn about specific practices and deepens the learning impact, guiding them towards sustainability challenges and the importance of conserving resources and the environment (Baber et al., 2024, p. 393). (Thurm et al, 2024) noted that sustainable educational development involves integrating sustainability principles into education systems, seeking to prepare learners to face the challenges and opportunities of the twenty-first century. Importantly, sustainable educational development focuses on practical engagement and an active approach rather than simply

transferring knowledge, emphasizing the seriousness of environmental problems and deepening students' environmental understanding (Jiajun & Abidin, 2024, p. 20). Defined (bautista-Puig and Sanz-Casado, 2021) defined sustainable educational development as "Knowledge, attitudes, and behaviours that support sustainability, reduce the negative environmental, economic, social, and health impacts resulting from the use of resources, to meet the needs of society towards sustainable lifestyles." Sustainable educational development encompasses learners' environmental, social, ethical, technological, and economicbehaviors, knowledge, and attitudes.

(Shafiei and Maleksaeidi, 2020) noted that promoting environmental behavior among students requires increasing their awareness through university courses and campaigns, positive attitudes, self-efficacy, and institutional support (policies and leadership initiatives). (Getahun, 2023) also noted that socially appropriate behaviors are influenced by individual factors like empathy and conscience, social factors like peers and cultural norms, and situational factors like volunteer opportunities. (Haron et al., 2024) argued that ethical behavior, including honesty and integrity, is influenced by individual, social, and situational factors, and university policies and an ethical climate play a vital role in promoting a commitment to such behavior. (Cohen et al. 2022) suggested that technology can enhance the university experience by improving learning and communication through a variety of tools, such as Blackboard, distance learning through Zoom, and programs like SPSS support research. In addition, tools like Google Scholar contribute to research engagement. Applications like WhatsApp contribute to communication, and tools like Headspace support well-being. To promote the healthy use of technology, universities should set boundaries, encourage physical activity, support mental health, and teach students about the effective use of technology (Chandrasekaran et al., 2020). (Nousheen et al., 2020) argued that sustainable economics involves focusing on environmental and social sustainability and economic viability while enhancing students' awareness and understanding of sustainability concepts and sustainable economic practices and policies. It also involves integrating sustainability courses into academic curricula using an interdisciplinary approach.

The Study Context
Higher education is a critical stage in shaping students' cognitive and intellectual abilities, equipping them with the skills necessary for lifelong learning and professional success. In this context, successful intelligence is essential for problem-solving and adaptability in academic and real-world settings. Additionally, metacognitive thinking skills are fundamental to effective learning and knowledge application (Ahmed, 2024; Nykyporets & Chopliak, 2023). However, despite the well-established importance of successful intelligence and metacognition, little research has explored the mediating role of sustainable educational development (SED) in this relationship. SED integrates environmental, social, ethical, technological, and economic dimensions into education, fostering critical thinking and long-term problem-solving skills (Almulla & Al-Rahmi, 2023). Given Saudi Arabia's Vision 2030, which prioritizes education reform, sustainability, and skill-based learning, understanding how SED influences students' intellectual growth is crucial (Al Thehli, 2023; Kayyali, 2024; Quamar, 2020). Therefore, the study seeks to fill this gap by examining the direct effects of successful intelligence on metacognitive thinking and SED, the impact of SED on metacognitive thinking, and whether SED serves as a mediator between successful intelligence and metacognitive thinking. Addressing this research problem is essential for informing higher education policies, curriculum development, and student skill enhancement strategies, ensuring that universities in Saudi Arabia cultivate well-rounded, future-ready graduates.

Research Objectives

1. To examine the effect of successful intelligence on metacognitive thinking among university students in Saudi Arabia.
2. To assess the direct impact of successful intelligence on sustainable educational development (SED) and its dimensions (environmental, social, ethical, technological, and economic).
3. To analyze the influence of SED on metacognitive thinking, determining its role in fostering students' cognitive development.
4. To investigate the mediating role of SED in the relationship between successful intelligence and metacognitive thinking.

3. Study Methodology

This study employed a quantitative approach, specifically, analytical cross sectional design. This design was appropriate for this study because data on both independent (e.g., successful intelligence) and dependent variable (e.g., metacognitive thinking) are collected at a single point in time to examine their associations and how sustainable educational development mediates this relationship (Wang & Cheng, 2020).

3.1. Study Sample

The study community consisted of all university students registered in the academic year 2024.Out of the many, 529 respondents were sampled using stratified-proportionate procedure. The choice for selecting the respondents using stratification was to ensure each one had equal chance to be part and to present issues among the respondents fairly. Having considered the diverse nature of the university system, the procedure was appropriate.In doing this, the process **considered** specializations (theoretical and scientific), academic years, and gender, the sample was reflective in this way of the greater population.

3.2. Sample Characteristics

Regarding academic year, the first-year student group had the highest representation (56.7%), followed by the second-year (30.4%), third-year (10.2%), and fourth-year student groups (2.6%). In terms of gender, the study maintained a balanced representation, with females and males each accounting for 45.6%. Regarding academic specialization, theoretical specializations were by far the most common (96.6%), while a few students had practical specializations (3.4%).

3.3. Study Tools

The study adapted already existing scales because the variables under investigation are well established and standardized. In making the scales suitable for the current study, a survey sample of 75 respondents from a different university in the chosen community was used.

3.4.1. Successful Intelligence Scale for University Students

This was –item scale, developed by Al-Otaibi (2016) with three axes: analytical abilities, creative abilities, and practical abilities. The scale was adapted and its validity was calculated using the internal consistency (construct) method and as well, correlation was performed to test the composite variable and its dimensions [e.g., values showed statistical significance at the 0.01 and 0.05 levels] (Shi et al., 2012). Table 1 and 2 present the results on the scale validation.

Table 1

Pearson's Correlation Coefficients between the Scores of the Statements of Each Axis and the Total Score of the Axis (*)

Analytical capabilities		Creative abilities		Practical capabilities	
Phrase	modulus	Phrase	modulus	Phrase	modulus
1	0.564**	9	0.626**	17	0.593**
2	0.609**	10	0.640**	18	0.614**
3	0.650**	11	0.735**	19	0.699**
4	0.613**	12	0.639**	20	0.723**
5	0.679**	13	0.696**	21	0.736**
6	0.414**	14	0.706**	22	0.732**
7	0.613**	15	0.720**	23	0.725**
8	0.616**	16	0.735**	24	0.743**

** p=0.01   * p=0.05

As shown in Table 1, the correlation coefficients for the scale statements ranged from 0.414 to 0.743, indicating an appropriate level of internal consistency.

Scale Stability. The scale stability coefficient was calculated on a sample of 75 individuals using the Cronbach's alpha equation, and the results are shown in Table 2.

Table 2

Cronbach's Alpha Stability Coefficients for Scale Axes and Total Degree

Domain	Number of paragraphs per dimension	Alpha value
Analytical capabilities	8	0.724
Creative abilities	8	0.835
Practical capabilities	8	0.844
The scale as a whole	24	0.801

The alpha coefficients ranged between 0.724 and 0.844, and the general stability of all scale axes was 0.801, indicating adequate stability.

3.4.2. *Metacognitive Thinking Scale for University Students*

This scale was adapted –items and happened to be developed by (Al-Obaidi & Al-Ghamdi, 2021) with three axes: planning, monitoring, and evaluation. The scale was adapted and its validity was calculated using the internal consistency (construct) method and as well, correlation was performed to test the composite variable and its dimensions [e.g., values showed statistical significance at the 0.01 and 0.05 levels] (Shi et al., 2012). Table 3 and 4 present results on the validation process.

Table 3

Pearson's Correlation Coefficients between the Scores of the Statements of Each Axis and the total Degree of the Axis (*)

Planning		Monitoring		Calendar	
Phrase	Modulus	Phrase	Modulus	Phrase	modulus
25	0.400**	32	0.669**	39	0.734**

26	0.558**	33	0.573**	40	0.612**
27	0.524**	34	0.628**	41	0.550**
28	0.460**	35	0.628**	42	0.610**
29	0.509**	36	0.614**	43	0.717**
30	0.560**	37	0.510**	44	0.640**
31	0.703**	38	0.371**	45	0.705**

** p=0.01   * p=0.05

As shown in Table 3, the scale statements had correlation coefficients ranging from 0.371 to 0.734, indicating an appropriate level of internal consistency.

Scale Stability. The stability coefficient of the scale on a sample of 75 individuals was calculated using the Cronbach's alpha equation, and the results are presented in Table 4.

Table 4
Cronbach's Alpha Stability Coefficient for Scale Axes and Total Degree

Domain	Number of paragraphs per dimension	Alpha value
Planning	7	0.683
Monitoring	7	0.672
Calendar	7	0.773
The scale as a whole	21	0.709

The alpha coefficient values ranged between 0.672 and 0.773, and the general stability of all axes of the scale was 0.709, indicating adequate strength.

3.4.3. Sustainable Educational Development Scale for University Students:

Developed by for (researcher, 2024), The scale included five axes: environmental, social, ethical, technological, and economic. The validity of the test was calculated based on structural consistency using correlation coefficients between the overall score and dimensions of the scale.

Internal Consistency Validity. The Pearson correlation coefficient was used to compare the scores of each item and the overall scores of the subscales after excluding the line values. The results showed statistical significance at the 0.01 and 0.05 levels, confirming the validity of the measures (Table 5).

Table 5
Pearson's Correlation Coefficients between the Scores of the Statements of Each Axis and the Total Degree of the Axis (*)

Environmental dimension		Social Dimension		Ethical dimension		Technological dimension		Economic dimension	
Phrase	modulus	Phrase	modulus	Phrase	modulus	Phrase	modulus	Phrase	modulus
46	0.657**	51	0.642**	56	0.514**	61	0.508**	66	0.488**
47	0.372**	52	0.610**	57	0.763**	62	0.410**	67	0.658**
48	0.613**	53	0.461**	58	0.603**	63	0.704**	68	0.647**
49	0.610**	54	0.458**	59	0.667**	64	0.705**	69	0.645**
50	0.572**	55	0.533**	60	0.737**	65	0.754**	70	0.616**

** p=0.01   * p=0.05

As shown in Table 5, the scale statements had correlation coefficients ranging from 0.372 to 0.763, indicating an appropriate level of internal consistency.

Scale Stability. The stability coefficient of the scale on a sample of 75 individuals was calculated using the Cronbach's alpha equation, and the results are presented in Table 6.

Table 6
Cronbach's Alpha Stability Coefficients for Scale Axes and Total Score

Domain	Number of paragraphs per dimension	Alpha value
Environmental dimension	5	0.669
Social Dimension	5	0.638
Ethical dimension	5	0.64
Technological dimension	5	0.703
Economic dimension	5	0.779
The scale as a whole	25	0.685

The alpha coefficients ranged between 0.638 and 0.779, and the general stability of all scale axes was 0.685, indicating adequate stability.

4. Results

The first research question was "Does successful intelligence have a direct positive effect on metacognitive thinking?" To answer this question, a multiple regression analysis was performed to determine the impact of successful intelligence on metacognitive thinking.

Table 7
Results of Multiple Regression Analysis of the Effect of Successful Intelligence on Metacognitive Thinking

Dependent variable	Correlation coefficient (R)	Correlation coefficient (R)	F Calculated	Sig. lvl.	β Regression coefficient		Sig. lvl.
					Dimensions	Value	
Metacognitive thinking	0.713	0.505	180.801	0	Analytical capabilities	0.27	0
					Creative abilities	0.079	0.054
					Practical capabilities	0.347	0

*The effect is statistically significant at α≤ 0.05.

The data in Table 7 indicate that there was a statistically significant effect of all dimensions of successful intelligence on metacognitive thinking (R=0.713, R2=0.505), with a significance level of 0.000, meaning that 50.5% of the changes in metacognitive thinking were caused by the change in successful intelligence. This effect was significant (F = 180.801), with a significance level of p < 0.05. The impact of each dimension of successful intelligence on metacognitive thinking was significant. The following statements provide a detailed breakdown of these impacts:

1. The coefficient of determination (β) for the analytical capabilities dimension was 0.270, with a significance level of 0.000, indicating statistical significance.

2. The coefficient of determination (β) for the analytical capabilities dimension was 0.079, with a significance level of 0.054, which was not statistically significant.
3. The coefficient of determination (β) for the practical capabilities dimension was 0.347, with a significance level of 0.000, which was statistically significant.

These results support the direct positive effect of successful intelligence on metacognitive thinking.

The second question was "Does successful intelligence have a direct positive impact on sustainable educational development?" Multiple regression analysis was used to determine the impact of successful intelligence on sustainable educational development.

Table 8.
Results of Multiple Regression Analysis of the Impact of Successful Intelligence on Sustainable Educational Development

Dependent variable	Correlation coefficient (R)	Correlation coefficient (R)	F Calculated	DF Degrees of freedom		Sig. lvl.	β Regression coefficient		Sig. lvl.
Metacognitive thinking	0.592	0.347	94.527	Between totals	3	0.000	Dimensions	Value	
							Analytical capabilities.	0.157	0.000
							Creative abilities	0.087	.039
							Practical capabilities	0.271	0.000

*The effect is statistically significant at α ≤ 0.05.

As shown in Table 8, The data indicated a significant effect of the dimensions of successful intelligence on sustainable educational development, with the correlation coefficient (R) of 0.592 and a coefficient of determination (R2) of 0.347, with a significance level of 0.000. Overall, 34.7% of the changes in educational development were caused by successful intelligence. This effect was significant (F=94.527), with a level of significance of p < 0.05. The impacts of each dimension of successful intelligence on sustainable educational development were as follows:

1. The coefficient of determination (β) for the analytical capabilities dimension was 0.157, with a significance level of 0.000, indicating statistical significance.
2. The coefficient of determination (β) for the creative abilities dimension was 0.087, with a significance level of 0.039, which was not statistically significant.
3. The coefficient of determination (β) for the practical capabilities dimension was 0.271, with a significance level of 0.000, which was statistically significant.

The results confirm the direct positive effect of successful intelligence on sustainable educational development.

The third research question was "Does sustainable educational development have a direct positive impact on metacognitive thinking? To answer this question, multiple regression analysis was employed to determine the impact of sustainable educational development on metacognitive thinking.

Table 9.

Results of Multiple Regression Analysis of the Impact of Sustainable Educational Development on Metacognitive Thinking

Dependent variable	Correlation coefficient (R)	Correlation coefficient (R)	F Calculated	Sig. lvl.	β Regression coefficient		Sig. lvl.
					Dimensions	Value	
Metacognitive thinking	0.682	0.461	91.154	0	Environmental dimension	0.081	0.006
					Social Dimension	0.206	0
					Ethical dimension	0.223	0
					Technological dimension	0.23	0
					Economic dimension	0.052	0.093

*The effect is statistically significant at $\alpha \leq 0.05$.

As shown in Table 9,There was a statistically significant combined effect of all dimensions of sustainable educational development (environmental dimension, social Dimension, ethical dimension, technological dimension, and economic dimension) on metacognitive thinking, with a correlation coefficient (R) of 0.682, a coefficient of determination (R2) of 0.461, and a significance level of 0.000. Overall, 46.1% of the changes in metacognitive thinking were caused by the change in combined sustainable educational development (environmental, social, ethical, technological, and economic dimensions). This effect was significant (F=91.154, $\alpha \leq 0.05$). The impacts of each dimension of sustainable educational development on metacognitive thinking were as follows:

1. The coefficient of determination (β) for the environmental dimension was 0.081, with a significance level of 0.006, indicating statistical significance.
2. The coefficient of determination (β) for the social dimension was 0.206, with a significance level of 0.054, which was not statistically significant.
3. The most significant finding was the coefficient of determination (β) for the ethical dimension, which was 0.223, with a significance level of 0.000, indicating statistical significance.
4. The coefficient of determination (β) for the technological dimension was 0.230, with a significance level of 0.000, indicating statistical significance.
5. The coefficient of determination (β) for the economic dimension was 0.052, with a significance level of 0.093, which was not statistically significant.

These results confirm the direct positive impact of sustainable educational development on metacognitive thinking.

The fourth research question was "Is there a positive indirect and statistically significant impact of successful intelligence on metacognitive thinking in the presence of sustainable educational development as a positive mediator?" Structural equation modeling was used, specifically the Amos program, to address this question. This method was chosen for its ability to construct a model that represents the relationships between the study variables, providing a clear and comprehensive view of research.*Fig.* 1 Illustrates the structural model,

showing the relationships among variables, including the mediating role of sustainable educational development between successful intelligence and metacognitive thinking
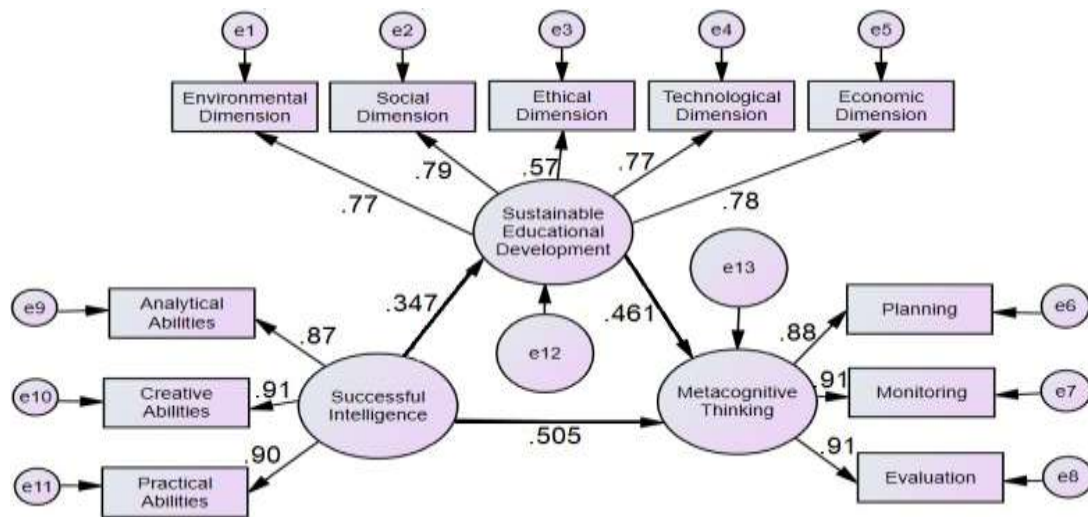

Fig.1 Structural model of study variables and the relationships between them using the Amos program.

The product of the direct effect of the independent variable (successful intelligence) on the intermediate variable (sustainable educational development) was calculated based on the direct impact of the intermediate variable (sustainable educational development) on the dependent variable as follows: $0.505 \times 0.347 = 0.159$ (VanderWeele, 2011). *Fig.* 2 illustrates the trajectory of the indirect effect, summarizing the research findings.
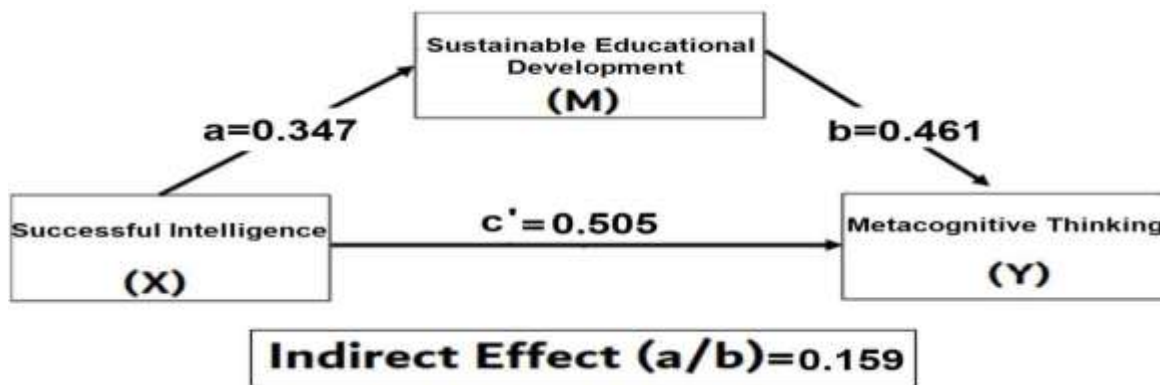
Fig .2
The indirect effects of successful intelligence on sustainable educational development and metacognitive thinking

The size of the effect (small = 0.01, medium = 0.09, large = 0.25) was estimated to assess the indirect effect of successful intelligence on metacognitive thinking in the presence of sustainable educational development as a positive medium (Verma & Verma, 2023). The results confirmed the positive indirect and statistically significant effect of successful intelligence on metacognitive thinking in the presence of sustainable educational development.

5. Discussion

The results indicate that successful intelligence has a direct positive effect on metacognitive thinking among university students. This effect can be attributed to the fact that successful intelligence enhances students' ability to analyze and evaluate information, improving their learning strategies and critical and creative thinking. This finding is in line with the studies of (Shouman, 2019), (Al-Otebi and Al-Iqamah, 2016), and (Khalaf, 2019), which showed a positive correlation between successful intelligence and metacognitive skills. Successful intelligence positively affects sustainable educational development due to the ability of individuals with successful intelligence to analyze data accurately and think creatively, which contributes to introduce innovative educational methods. Similarly, (Azid and Md-Ali,2020) reported a positive relationship between successful intelligence and its dimensions and sustainable educational development.

Overall, the results highlight the role of sustainable educational development in promoting metacognitive thinking among university students. This finding, consistent with the study by (McKim and McKendree, 2020), suggests that an education that supports inclusive learning, critical analysis, and awareness of social and environmental issues can stimulate students' search for sustainable solutions and enhance their metacognitive thinking. Moreover, the results reveal an interesting indirect effect of successful intelligence on metacognitive thinking.

There was no significant effect of analytical abilities on metacognitive thinking. This is attributed to its overlap with broader dimensions, such as critical thinking, creativity, and self-learning, as well as the difficulty of determining its impact due to personal and environmental factors and the variation in analytical abilities among students. Creative abilities also had no significant effect on the sustainable educational development of university students, likely because sustainable development focuses on environmental, social, and economic aspects. Although the financial dimension is essential for the sustainability of education, its impact on metacognitive thinking may be less than the environmental or social dimensions due to students' varying interpretations of economic factors and educational policies.

6. Recommendations

Given the finding that successful intelligence has a direct positive effect on metacognitive thinking in university students, the following recommendations are presented:
1. Support the development of successful intelligence skills in the university curriculum, including analytical thinking, creative thinking, and practical intelligence.
2. Provide training programs to enhance metacognitive thinking, including workshops and courses focused on planning strategies and self-assessment.
3. Use AI to support metacognitive thinking through applications and programs that provide immediate and personalized feedback to students about their educational strategies and academic performance.

Given the finding that successful intelligence has a direct positive impact on sustainable educational development, the following recommendations are presented:
1. Integrate the concepts of successful intelligence into sustainable education strategies by incorporating successful intelligence skills (e.g., analytical, creative, and practical thinking) into sustainable education curricula and strategies.
2. Develop students' and teachers' critical and creative thinking skills through training programs and workshops.
3. Encourage cooperation between universities and industrial institutions to develop sustainable and innovative solutions using successful intelligence skills.

Given the finding that sustainable educational development has a direct positive impact on metacognitive thinking in university students, the researchers suggest:

1. Promote active and sustainable learning in the curriculum by integrating active learning practices, such as collaborative projects, problem-based learning and inquiry.
2. Develop educational programs that focus on sustainability and critical thinking.
3. Provide educational environments that support sustainable and integrated thinking through innovation, collaboration, and self-learning using sustainable and modern educational resources and technologies.

Given the finding that there is a positive indirect and statistically significant effect of successful intelligence on metacognitive thinking with sustainable educational development among university students, the following recommendations are presented:

1. Foster successful intelligence and sustainable educational development in academic programs by integrating successful intelligence skills with the principles of sustainable educational development.
2. Support research and practical projects by encouraging students to participate in projects that link the use of successful intelligence to sustainable development issues.
3. Develop specialized workshops and training programs for students and faculty members that focus on the applications of successful intelligence in sustainable educational development.

In addition, the results of this study lead to activate the impact of analytical capabilities on metacognitive thinking among university students, analytical teaching methodologies should be implemented, focusing on inquiry, self-assessment, problem analysis, and critical assessment in university curricula.

There is also a need to enhance the impact of creative abilities on sustainable educational development, learning environments should encourage students' creativity and sustainable thinking through innovative projects. This includes developing programs and curricula focused on sustainability issues.

It is also recommended to activate the impact of the economic dimension on sustainable educational development and metacognitive thinking, applied economic education curricula should integrate metacognitive thinking strategies, including modules focusing on economic issues and sustainability.

Declarations
Competing Interests

I would like to confirm that there are no known conflicts of interest associated with this publication and that the study declares no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Ethical Declaration

This study used ethical principles and guidelines for research involving human participants. Informed consent was obtained. Participants were informed about the purpose of the study, the procedures involved, and their right to withdraw at any time without penalty. Confidentiality and anonymity of participants' responses were ensured throughout the research process.

Ethical Approval

This research project received ethical clearance from institutional review board in King Faisal University. The University Research Ethics Committee at the University approved and

provided clearance with the reference number KFU-2025-ETHICS3313. The researchers adhered to established guidelines for studies involving human participants. All protocols were designed to protect participants' rights and welfare. The aforementioned ethics committee carefully reviewed and approved the study methodology, ensuring compliance with ethical standards in educational research. Thisapproval process demonstrates the researchers' commitment to conducting ethically sound and scientifically valid research.

Consent for publication

Not applicable.

Consent to Participate declaration in the manuscript .

prior consent was obtained from all participants after explaining the objectives oزf the study, ensuring the confidentiality of the data, and stating that their participation is voluntary and that they can withdraw at any time without any consequences.

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