Indonesian Society for Science Educators
Journal of Science Learning
journal homepage: ejournal.upi.edu/index.php/jslearning

The Influence of Environmental Insight and Virtual Reality Laboratory on Students' Argumentation: An Exploration of Solar System Concepts Integrated with Qur'anic Science

Neti Wulandari[1]*, Wirawan Fadly[1], Primus Demboh[2]

[1]Tadris IPA Department, Faculty of Education and Teacher Training, IAIN Ponorogo, Ponorogo, Indonesia
[2]Ministry of Secondary Education, Cameroon Government, Yaoundé, Cameroon

*Corresponding author: netiwulandari0904@gmail.com

ABSTRACT This study investigates the role of environmental insight—defined as students' prior knowledge—and the use of a virtual reality laboratory in exploring celestial bodies and solar system content integrated with Qur'anic science, with a focus on their effects on students' argumentation abilities. The research employs a quasi-experimental design, utilizing a virtual reality laboratory to enhance students' scientific argumentation during learning. Four junior high school science classes participated, categorized based on their previous levels of environmental insight and exposed to either virtual reality or conventional laboratory learning environments. The study found that the virtual reality laboratory significantly influenced students' argumentation related to celestial bodies and the solar system, particularly when these topics were contextualized through Qur'anic science. Students began to construct more structured arguments when engaged in interactive dialogues about celestial phenomena. Critical argument components emerged specifically during discussions involving Qur'anic integration. Moreover, environmental insight was found to significantly affect students' environmental and scientific argumentation within this integrated context. Importantly, students with low prior environmental knowledge were still able to outperform peers with higher prior knowledge when supported by virtual reality learning and interactive discussion. These findings highlight the importance of both prior environmental understanding and immersive, interactive learning environments in fostering scientific argumentation skills.

Keywords Argumentation, Celestial bodies, Qur'anic science, Solar system, Environmental insight, Virtual real laboratory

1. INTRODUCTION

Scientific argumentation skills play a crucial role in enabling students to articulate their arguments with valid evidence, rooted in a deep understanding of concepts, skills, and scientific thinking (Novanda et al., 2024). These skills are increasingly integrated into learning processes to facilitate the acquisition of new knowledge (Apriyani & Alberida, 2023). Key variables influencing argumentative learning patterns include: (1) technology-based teaching methods and media (Matovu et al., 2023; Ramli et al., 2023; Murdani et al., 2023); (2) students' early environmental insights (Rauf et al., 2021; Grogan et al., 2023); and (3) internalization of specific teaching topics (Haley & Uusimäki, 2024).

The Toulmin Argumentation Pattern (TAP) is a recognized model consisting of six components that shape the quality of students' argumentation (Rahayu et al., 2020). TAP has been shown to influence students' scientific thinking, behavior, and communication, particularly with an environmental lens (Hasnunidah et al., 2019). These components include:

- Claim: Defines the direction and focus of arguments, representing key topics imparted by educators (Dawson, 2024).
- Ground: Serves as the foundation and support for the claim, linked to students' environmental insights (Härmä et al., 2021).
- Warrant: Connects data to claims through general principles (Dawson, 2024).
- Backing: Reinforces the warrant, often through collaborative methods and teaching materials (Jumariati et al., 2021).

Received: 31 December 2024
Revised: 21 March 2025
Published: 29 March 2025

- Rebuttal: Tests the strength of evidence by identifying weaknesses (Majidi et al., 2021).
- Qualifier: Indicates the confidence level in the claim (Irvan et al., 2020).

Scientific arguments are distinguished from those in other fields by the integration of claims, evidence, and justification (Imaniar & Astutik, 2019). Effective argumentation learning is best supported by real-life and contextual learning environments (Jumariati et al., 2021). Innovations like virtual real laboratories simulate authentic lab experiences and provide interactive, computational learning opportunities (Purwaningtyas et al., 2022; Safiatuddin & Asnawi, 2023; Mulya et al., 2021). Science topics, particularly in natural sciences, benefit greatly from such immersive technologies (Asare et al., 2023).

Recent research focuses on various factors influencing students' scientific argumentation (Majidi et al., 2021), including contextual understanding and teacher innovation (Chen & Chen, 2024). Independent science learning must be communicated accurately and rationally (Hendratmoko et al., 2023). Integration of science with religious contexts, such as the Qur'an, has gained attention for its role in deepening student engagement and values (Sukamad et al., 2023; Riwanda et al., 2024; Ghofur et al., 2021). The Qur'anic approach enhances gratitude, curiosity, and research motivation (Uroidli et al., 2024).

Despite the emphasis on TAP components and their benefits, there remains limited analysis of the interaction between students' environmental insights and the influence of technology-based media on argumentation patterns (Andreani & Yonata, 2024; Nakrowi et al., 2024). Prior knowledge and environmental insight are critical in determining students' academic and argumentation success (Liu et al., 2018). This study introduces the use of real laboratory visualization and compares students' insights and content internalization to assess argumentation quality (Meiliana, 2024). The research questions are:

- How does real laboratory learning affect students' argumentation ability on celestial topics integrated with Qur'anic science?
- How does students' environmental insight affect their argumentation ability on celestial topics integrated with Qur'anic science?

1.1 Theoretical Framework

Environmental Insight and the Conditioning of Virtual Real Laboratory Learning

Previous studies have found that students' environmental insight significantly affects their ability to formulate arguments when understanding academic material. Students' perception of the learning environment is a key factor influencing scientific argumentation skills (Ginting et al., 2023). A lack of environmental insight can hinder students' ability to express themselves socially and communicate effectively with peers (Hulu et al., 2022). If not addressed, this character gap in social interaction can lead to further issues (Revalina et al., 2023). The challenge of fostering environmentally conscious character is often reflected in students' daily behavior patterns (Fiolanisa et al., 2023). Environmental insight is developed through the cultivation of positive character traits, along with a deep understanding and implementation of knowledge related to memorized content (Ismail et al., 2019; Mebert et al., 2020).

Educational researchers emphasize the importance of giving students with low environmental insight opportunities to improve (Buerkle et al., 2023). Academic growth can be achieved through a structured and rigorous learning process (Wilson et al., 2021). Students with limited insight may struggle to express their cognitive understanding effectively, often due to misaligned teaching and assessment methods (Dunlosky et al., 2013; Munna & Kalam, 2021). To address this, science educators are encouraged to design learning sequences that develop high-level thinking skills—such as problem-solving, argumentation, and skill internalization—across all grade levels (Winarto et al., 2022). Learning activities should be inclusive of students' diverse environments, backgrounds, languages, cultures, and knowledge shaped by everyday experiences (Abacioglu et al., 2023). Supporting students in expressing their arguments fosters educational development regardless of their backgrounds (Brown et al., 2023). Notably, argumentation skills are not necessarily tied to initial academic performance (Darmaji et al., 2022); some students with lower grades have outperformed their peers in argumentation-based assessments (Ho et al., 2019; Chitera et al., 2025).

While environmental insight plays an important role, it is not the sole predictor of academic success (Mebert et al., 2020). Educators must carefully assess students' environmental understanding to effectively implement argumentation learning (Villarreal Arroyo et al., 2023). The Toulmin Argument Pattern (TAP) construction process requires activation of this insight (Steensen et al., 2020). Research has shown that technology-based learning models can effectively trigger students' initial understanding. When arguments are structured around communicative, convergent, and systematic questioning, students' memory recall is enhanced—resulting in arguments that are grounded in stronger evidence (Bulent et al., 2016). Over time, this dialectical learning model fosters a naturally structured pattern of argumentation as part of students' daily habits.

Virtual real laboratory models have been used in previous studies to enhance students' argumentation abilities (Agustina & Putra, 2022). These studies found that environmental insight had a significant impact on students' research abilities, argumentation, and teaching performance. Peer interaction also influenced the development of scientific concepts and methods in argumentative contexts (Wilson et al., 2021; Chitera et al., 2025). Educational stakeholders view this as a positive approach, particularly for students with low initial environmental insight (Nakrowi et al., 2024). Environmental insight can be optimized through intentional conditioning of the virtual real laboratory learning environment—this includes peer interactions, interactive learning features, and teacher support (Steensen et al., 2020).

Social Interaction in Argumentation-Based Learning on Celestial Bodies and the Solar System

Argumentation, as a skill for revealing information, can be categorized based on how conclusions are reached in the methodological process. Prior research distinguishes between monological and dialogical argumentation (Purwaningtyas et al., 2022). Monological argumentation is typically implicit and deductive, focusing on a single conclusion. However, monological reasoning should not be narrowly interpreted as solitary thinking—it also involves constructing intuitive cases that support research (Al-Ajmi & Ambusaidi, 2019). In contrast, dialogical argumentation emphasizes social coordination, critical thinking, and cognitive creativity (Munna & Kalam, 2021).

Research has shown that the presence of teaching resources within student social interactions can influence their scientific understanding and knowledge construction (Wilson et al., 2021). Coordinated group learning activities help students shift perspectives, engage in communal knowledge-building, and develop accountability in shaping their character (Härmä et al., 2021). In science courses, conceptual reasoning often promotes collaboration as students develop strong, evidence-based arguments in response to cognitively demanding tasks (Ho et al., 2019). These collaborations also enhance reflective learning (Matovu et al., 2023).

Although argumentation-based learning can be applied in both monological and dialogical formats, monological forms are more commonly used. In most cases, student-teacher interactions are limited to guided Q&A sessions, with little emphasis on developing students' own argumentative structures (Dawson, 2024).

Many junior and senior high school students face challenges in both individual and collaborative argumentation settings. These challenges include reviewing relevant literature, generalizing data to form conclusions, making claims supported by evidence, and rebutting arguments with strong counterevidence. Structured questioning helps guide students to develop arguments with clear claims and data, including refutations. When students are given credible, methodologically aligned prompts—such as those structured around the six Toulmin elements—they are more likely to develop complex arguments. To strengthen students' collaborative argumentative skills, educators can employ strategies such as guided language use, scaffolding intermediate language skills, and providing group-level instruction (Moser & Mercer, 2020). Regardless of their initial insight levels, students benefit from peer collaboration, which enhances understanding (Liu et al., 2018). The collaborative model creates variation in learning outcomes and allows for integration of teaching content across topics.

Scientific rationalization within collaborative learning facilitates methodological exploration in integrated instruction. This research investigates the effectiveness of such integrated learning—comparing how general versus topic-specific learning (such as celestial bodies and the solar system) affects students' argumentation abilities (Sunhaji, 2018).

Virtual Real Laboratory for Celestial Bodies and the Solar System Internalized through Qur'anic Science

A literature review shows that integrated or internalized learning can take many forms depending on how content is combined collaboratively (Hasnunidah et al., 2019). Ian G. Barbour, in his theory of "scientific theology," proposed integrating science and religion, where science explains how nature works, and religion offers insight into the meaning behind the universe (Waston et al., 2024). This study critically explores Barbour's theory through dialogue, appreciation, and reflection (Köppen et al., 2022). Based on his framework, the research identifies three applicable educational approaches: (1) meaningful learning, (2) structured science learning, and (3) internalized religious learning.

The first concept refers to learning that builds mental and moral structures—such as concepts of right and wrong, health and illness, or physical qualities like light and heavy (Jumariati et al., 2021). The second concept involves structured curriculum delivery, where science knowledge is taught through carefully planned instruction aligned with innovative and effective strategies (Rahmah & Novita, 2024). The third concept addresses the differentiation of learning models—both in scope and in assessment methods—and applies to all faith-based schools. However, this study focuses on Islamic education, particularly the emerging field of Qur'anic science.

Educational experts and psychologists agree that not all students receive equal opportunities to benefit from all three conceptual approaches (Moser & Mercer, 2020). Successful implementation of integrated learning requires qualified teachers, appropriate methods, and relevant instructional models (Winarto et al., 2022). Prior studies report that many students struggle to link theological concepts with general science knowledge—particularly in learning about the solar system—due to the cognitive demands exceeding their level of understanding. The transition from general scientific knowledge to Qur'anic science is a complex process requiring careful instructional design. Inexperienced teachers often face challenges teaching such integrated content (Wasehudin et al., 2022).

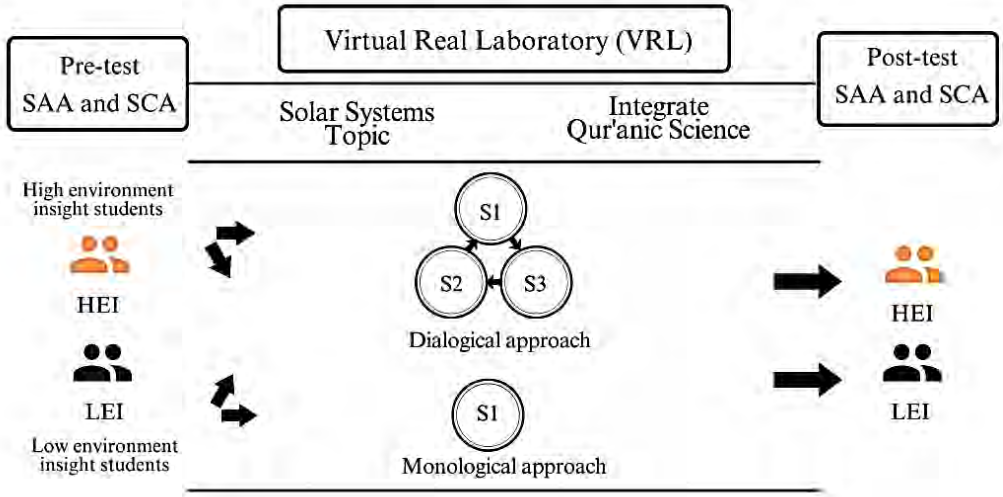

Figure 1 A quasi-experimental design by researchers

Traditional argumentation techniques are declining in favor of technology-assisted methods that provide greater flexibility and appeal (Pho et al., 2021). Virtual real laboratories (VRLs) offer simulated digital environments that mimic physical lab conditions. These simulations allow students to experiment with variables and observe outcomes in a controlled virtual space. Prior studies used Physics Education Technology (PhET) to support understanding of wave and sound concepts, demonstrating improved research accuracy and data interpretation (Maulidah & Prima, 2018). Other studies developed STEM-based virtual labs to improve science literacy on topics such as water pollution (Ismail et al., 2016; Sellberg et al., 2024). The Sophisticated Thinking Blended Laboratory (STB-LAB) was shown to improve argumentation skills through repeated practice involving structured syntax and disposition phases (Agustina & Putra, 2022).

This research continues that legacy, aiming to enhance students' argumentation skills through the use of virtual real laboratories while integrating different educational methods. The study focuses on improving students' argumentation by accounting for their environmental insight and leveraging the growing emphasis on curriculum-integrated religious content.

2. METHOD

2.1 Participants and Procedures

The research sample comprised 100 students, divided into groups based on their level of environmental insight—either high or low—determined by the average daily assessment scores across four classes. These daily assessments were conducted prior to the implementation of the virtual real laboratory (VRL) learning. This procedure aimed to evaluate students' understanding of celestial bodies and the solar system according to the level of insight they had gained while studying these topics.

Scores were normalized on a scale of 0–100. Students scoring 80 and above were categorized as having high environmental insight, while those scoring 79 and below were categorized as having low environmental insight. The participants were then assigned to either a control group, which followed monological individual learning, or an experimental group, which used a dialogical VRL to facilitate argument exchange. Each VRL group consisted of four to five members.

The results were analyzed using a t-test to compare the average scores across the four classes that contributed to the daily assessment data, determining the significance of each variable individually.

This study employed a quasi-experimental design, as illustrated in Figure 1. The three components of Kuhn's Argumentation Triangle Model were treated as independent variables. Environmental insight and argumentation skills served as between-subject variables, while the content on celestial bodies and the solar system was treated as a within-subject variable.

Before participating in VRL learning, all students were introduced to Toulmin's Argumentation Pattern, which includes six elements: claim, ground, warrant, backing, rebuttal, and qualifier, along with their interrelationships. Next, students took two pretests: a Science Concept Test (SCT) on celestial bodies and the solar system, and a Scientific Argumentation Test (SAT) focused on environmental insight.

All students then engaged in VRL sessions in the classroom using 2D and 3D augmented reality learning media and innovative educational applications. After the VRL learning experience, the SAT was administered again to assess improvements in students' argumentation skills.

2.2 Argumentation in Virtual Real Laboratory Learning

The VRL approach promotes an integrated learning method that emphasizes the development of students' argumentative skills. The topics used to explore students' argumentative abilities included:

- Celestial Bodies
- Solar Systems
- Eclipses
- Celestial Events

These four topics align with the junior high school learning objectives defined by the Independent Curriculum standard. Argumentation indicators for each component were tailored to these topics.

The VRL presentations were supported by digital teaching aids, such as introductory materials and short space-themed films, to stimulate students' interest in science. Reciprocal questioning was employed as a key strategy to encourage students to build arguments during the program. A sample display from the VRL simulation developed by the researchers is shown in Figure 2.

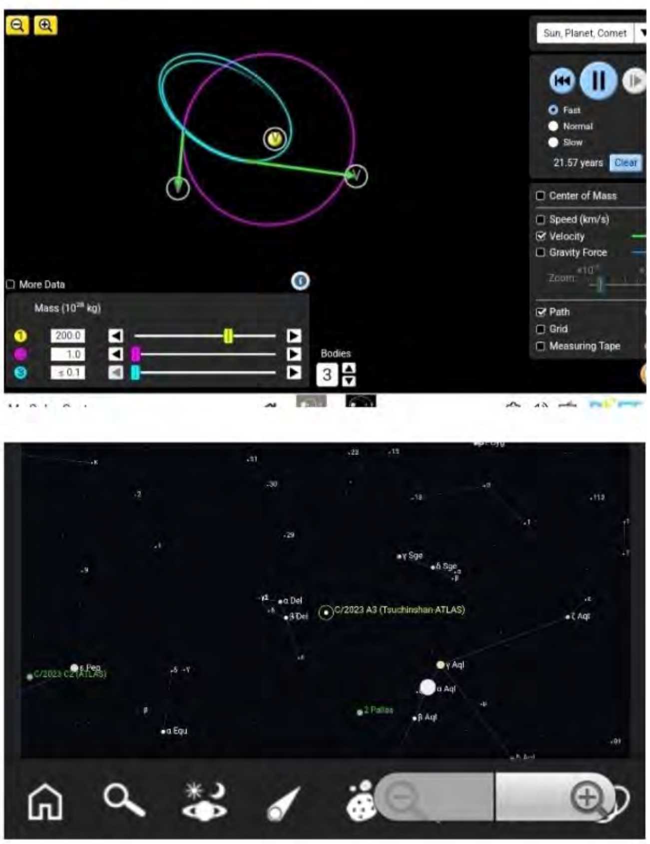

Figure 2 Virtual simulation of real laboratory by researcher

The VRL environment enabled both collaborative and individual practical activities. Group discussions formed the core of collaborative practice, while individual tasks included recording, reviewing, and reflecting on arguments. The VRL environment also encouraged students to support their arguments with evidence, and students were prompted to construct various arguments and engage their curiosity, even beyond the confines of the VRL templates.

2.3 Instruments

The researchers utilized two instruments:

- Science Concept Test (SCT)
- Scientific Argumentation Test (SAT)

Scientific reasoning-based assessment is crucial for producing statistically comparable results across different test formats (Schreiner, 2024). The SCT was developed as a baseline measure of students' argumentative skills prior to VRL instruction. It consisted of 30 items:

- 15 multiple-choice questions (1 point each, correct answer only)
- 5 descriptive questions (scored from 4 to 1 points)
- 10 socio-emotional questions contextualized through Qur'anic science (scored from 4 to 1 points)

The maximum possible score on the SCT was 75. Content validity was ensured through a panel of three experts—one professor and two science teachers. The test's internal consistency, measured by Cronbach's α, was 0.87.

The SAT was administered as an open-ended test, consisting of written scenarios designed by the researchers. It was adapted from earlier studies to evaluate students' scientific argumentation skills in the context of the study (Fakhriyah et al., 2022). SAT topics mirrored those used in VRL learning.

Students were asked to respond to each question using the six Toulmin components. They were encouraged to generate at least three argument positions per scenario. Each argumentative question allowed a maximum of six arguments, one for each Toulmin element. With six scenarios, students could produce up to 36 arguments. These were assessed using an analytical scoring framework.

2.4 Argumentation Theory Analysis

Argument data from both the SAT and the VRL sessions were analyzed using a framework based on argument component levels, as shown in Table 1.

The analysis involved two main stages:

- Categorization of arguments based on the six Toulmin components: claim, ground, warrant, backing, rebuttal, and qualifier.
- Validation and quality analysis, where each argument component was rated as either Level 1 (low) or Level 2 (high) based on content accuracy and relevance of explanation.

Arguments supported by scientific theories, data, or principles were considered Level 2. Level 1 and Level 2 components were scored 1 and 2 points, respectively. The inter-rater reliability (Cohen's ϰ) was estimated at 0.85.

To support students in constructing arguments, argument scripts were provided for use during the SAT and VRL activities. These included prompts such as:

"According to the definition/grouping/elaboration... I agree with the argument..." (for supporting an argument)

Table 1 Descriptions of coding framework by researchers

Indicators	Levels		Description of the indicators of each level
Claim	1	:	A statement based on scientific observations clearly and determining the direction of the argument
	2	:	The focus of the discussion is to have at least one supporting data and make a target for criticism
Ground	1	:	Arguments along with concrete and coherent reasons or evidence
	2	:	Argument reinforcement statements and analysis of key claim-supporting data
Warrant	1	:	Analyze data-appropriate arguments
	2	:	Connect claims with data
Backing	1	:	Additional support for justification of arguments and demonstrated rebuttal ability
	2	:	Submit suggestions
Rebuttal	1	:	Evaluate the quality of arguments and identify weaknesses in arguments
	2	:	Testing the strength of the evidence of an argument and providing rebuttals to inappropriate arguments
Qualifier	1	:	Ensuring the veracity of claims
	2	:	Providing answers that are guaranteed to be accurate

Table 2 Multivariate analysis in science concept test

Source	SS		SS-QS		Wilk's Λ (Sig)	Dependent variable	Unvariate analysis		
	M	SD	M	SD			F(sig)	Post hoc	Cohen's d
	Pre/Posttest								
Approach	9/9.5	3/3.4	7.6/10.3	3.9/2.5	.991(.648)	SS	.35		.09
V (N=72) L (N=65)	8.8/9.3	2.6/3.4	6.9/9.9	3.3/3.5		SS-QS	. 85		.135
Environmental insights	9.4/10.8	2.9/2.9	7.7/11.3	3.9/2	.784 (.001)	SS	21.3***	H>L***	.862
H (N=72) L (N=65)	8.5/8	2.7/3.2	6.8/8.9	3.2/3.4		SS-QS	23.8***	H>L***	.911
Approach × environmental insights					.987 (528)	SS	.6		
						SS-QS	1.2		

"I do not agree with/support the statements/ideas in/on... due to the imbalance in concepts/chapters/points..." (for refuting an argument)

These scripted formats were introduced by the researchers during the VRL to provide a structured approach and help students systematically construct their arguments. This also facilitated easier categorization and evaluation of argumentative skills.

2.5 Data Analysis

Multivariate analysis of covariance (MANCOVA) was used to analyze SCT and SAT results for each research question. The fixed factors included:

- Environmental insight
- Condition of VRL learning

The pretest scores were treated as covariates, and each posttest served as a dependent variable. The data analysis also involved the following assumption checks:

- Linearity test
- Homogeneity of variance-covariance matrices
- Variance equivalence test

3. RESULTS

The researcher used two commonly used assumption tests, the normality test, and the homogeneity test. The researcher used the general graphical method Kolmogorov–Smirnov and the normal probability plot on the normality assumption. The SAT post-test score was found to be normal (ϱ = .089) from the analysis results showing that the test data was normal and met the assumption of normality. Homogeneity was tested using the Levene test with the results showing that the error variance for the dependent variable (posttest SAT) had similar conditions between VRL and non-VRL study groups both in the main topic of celestial bodies and the solar system ($F(1, 136)$= .432, ϱ = .116) and internalized Qur'anic science ($F(1, 116)$= .847, ϱ = .359).

Table 2 shows that the approach variables do not affect students' learning of celestial matter and the solar system as well as the integration of Qur'anic science. On the other hand, the variables of students' environmental insight have a significant influence on learning about celestial matter and the solar system (F = 21.26, ϱ < .001) and the integration of Qur'an science (F = 23.76, ϱ < .001). The results of the post hoc provided information that the group with high environmental insight had better material absorption and productivity than the peer group who had low environmental insight. The results of multivariate analysis in science concept assessment are shown in Table 2.

3.1 Scientific argumentation test (SAT)

The VRL variable had a great influence on students' argumentation on internalized topics only (F = 21.32, ϱ

<.001). A significant influence also occurred on the variables of students' environmental insight on the learning of celestial body matter and the solar system without internalization (F = 7.332, ϱ <.05), while the internalization of Qur'an science was not significant. The VRL study group performed better than the non-VRL group and the pre-previous high level according to the post hoc results. Groups of environmentally friendly students get progressive learning outcomes above students with low-level environmental insights. Descriptive statistics showed that the learning outcomes of low-environmental students from the VRL group increased concerning the learning materials of celestial bodies and solar systems. High environmental insights in the non-VRL category had a lower improvement than other categories. The results of multivariate analysis in science argumentation assessment are shown in Table 3.

3.2 Virtual real laboratory argumentation learning

The two-way ANOVA test is used as a reference for the ability to argue in celestial matter and solar system systems that are internalized by Qur'anic science). The results in Table 4 in the form of students' environmental insights (F = 6.322, ϱ < 05) have a slightly significant influence on argumentation in internalized material. The results of the post hoc show that students with high environmental insight have much better performance than students with minimal environmental insight. The progressivity of the ability to argue significantly on the VRL topic of environmental insight and so on (F = 94.834, ϱ <.001). The two-way repeated two-way ANOVA test is shown in Table 4.

The repeated bidirectional test of ANOVA significantly showed the results in Table 5 with VRL learning conditioning (F =51.26, ϱ < .001) affecting the ability to argue in celestial matter and the solar system internalized by Qur'anic science. The VRL group had a more progressive performance than the non-VRL group. The results of data analysis inform that VRL learning conditioning has a positive effect on students' argumentative ability in celestial matter and the solar system. However, students' environmental insights affect their argumentative abilities only in integration with the science of the Qur'an. In celestial bodies and solar system

Table 3 Multivarate analysis in science argumentation test

Source	SS		SS-QS		Wilk's Λ (Sig)	Dependent variable	Unvariate analysis		
	M	SD	M	SD			F(sig)	Post hoc	Cohen's d
	Pre/Posttest								
Approach V (N=72) L (N=65)	11/18.2	7.9/7	6.5/20	5.2/8.3	.865(.001)	SS	.052		.024
	11.5/18.2	7.8/7.6	6.5/14.5	5.4/7		SS-QS	21.32***	C>I***	.658
Environmental insights H (N=72) L (N=65)	15.8/21.8	8/7	9.4/20	5.2/8.4	.951 (.037)	SS	7.332*	H>L*	.523
	6.7/14.5	4/5.7	6.8/8.9	3.3/3.4		SS-QS	1.345		.189
Approach × environmental insights					.995 (.523)	SS SS-QS	2.354 789		

Table 4 Two-way repeated ANOVA test results on celestial matter and the VRL solar system

Source	Topic 1		Topic 2		Topic 3		Topic 4		df	*F*(sig)	Post hoc	Cohen's *d*
	M	SD	M	SD	M	SD	M	SD				
Approach V (N=72) L (N=65)	4.50	2.43	6.34	2.45	8.78	4.57	5.49	4.82	1	6.32*	H<L*	.298
	4.06	1.95	5.75	2.76	7.45	3.84	6.78	6.88				
Environmental insights H (N=72) L (N=65)	4.67	2.87	5.85	6.34	8.78	3.78	6.67	3.76	1	3.78		.214
	4.95	1.46	5.78	5.78	7.90	3.87	6.98	3.68				
Approach × environmental insights									1	5.20		
Topic									2	94.83***	3>2*** 2>1**	

Table 5 Results of the two-way repeated ANOVA test on the internalized material of the Qur'an science VRL

Source	Topic 1		Topic 2		Topic 3		Topic 4		df	*F*(sig)	Post hoc	Cohen's *d*
	M	SD	M	SD	M	SD	M	SD				
Approach V (N=72) L (N=65)	5.87	2.65	2.78	5.64	8.83	3.75	7.56	5.25	1	3.586		.298
	4.96	2.56	2.54	6.11	7.56	3.78	6.67	6.67				
Environmental insights H (N=72) L (N=65)	6.87	2.52	7.02	7.15	9.54	4.86	8.02	4.65	1	51.26***	C>I***	.214
	3.89	1.78	4.65	4.72	7.45	2.26	6.45	3.45				
Approach × environmental insights									1	4.00		
Topic									2	50.68***	3>2*** 2>1**	

materials, VRL learning can encourage students with lower environmental insight to argue more like a group of students with higher environmental insight. Results of the two-way repeated ANOVA test on the internalized material of the Qur'an science VRL are shown in Table 5.

3.3 Comparison of argumentation skills between VRL groups that internalized Qur'anic science and non-VRL groups that internalized Qur'anic science

The analysis of the VRL class internalized Qur'anic science showed that the average student received 67.08 points (SD = 14.35). The average score of the internalized material was 20.24 (SD = 8.76) and each topic of the celestial body and solar system material was 24.67 (SD = 9.44). Most students were able to meet the indicators of claims, justifications, and support for VRL arguments. Some students were able to refute to provide criticism of other students' opinions or their arguments. Figure 4 provides information on the average scores and results of independent sample t-tests to compare argumentation skills through trials between VRL and non-VRL classes in internalized Qur'anic science material. The group of students who were used as the trial obtained a better average argument score in internalized Qur'anic science material. However, no significant differences were found between the VRL and non-VRL groups.

The argumentation ability of the VRL and non-VRL groups reached a significant difference in the material of celestial bodies and the solar system: celestial bodies (t = 8.46, Sig <.001), the solar system (t = 7.23, Sig <.001), eclipses (5.54, Sig<.001) and celestial events (t = 3.55, Sig <.001). These results imply that VRL learning conditioning has a positive effect on students' argumentation, especially those related to the material of celestial bodies and the solar system. A comparison of the percentage of argumentation ability of the VRL and non-VRL learning groups on the four topics of celestial bodies and the solar system and four topics that integrate Qur'anic science is shown in Figure 3.

3.4 Comparison of students' argumentation skills with high and low environmental insight

Information on the distribution and comparison of average scores between the arguments of students with high and low environmental insight in the material of celestial bodies and the solar system. A significant difference was found (t = 2.29, Sig <.05) between the high and low environmental insight groups on the topic of celestial events. A comparison of the percentage of argumentation ability of the VRL and non-VRL learning groups between high with low prior knowledge students in four topics not integrated and integrated Qur'anic science is shown in Figure 4.

The comparison shows no significant difference between groups with high and low environmental insight on the material of celestial bodies and the solar system internalized by the science of the Qur'an. Students with low environmental insight can have good learning outcomes equal to students with high environmental insight on the material of celestial bodies and the solar system internalized by the science of the Qur'an. The analysis shows that students with high environmental insight can perform better in almost all VRL argumentation activities compared to students with low environmental insight. However, most of the comparisons did not reach a significant level of difference. These results imply that students with low environmental insight have the potential to perform as well as students with high environmental insight in VRL. Students in the group with low environmental insight had a better gradual increase in VRL learning arguments regarding the material on celestial bodies and the solar system internalized by Qur'anic science than other students in the group with high environmental insight.

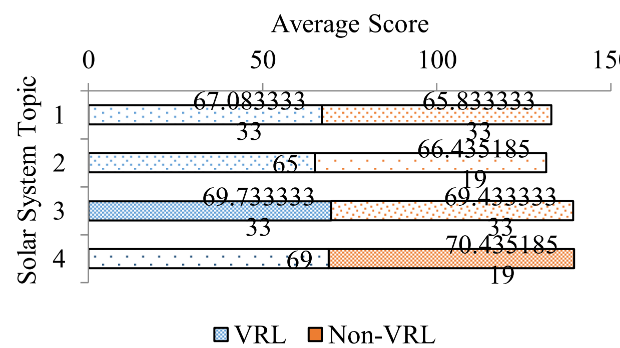

Figure 3 The comparison of argumentation between the two approaches (VRL and non-VRL) in four topics not integrated and integrate Qur'anic science

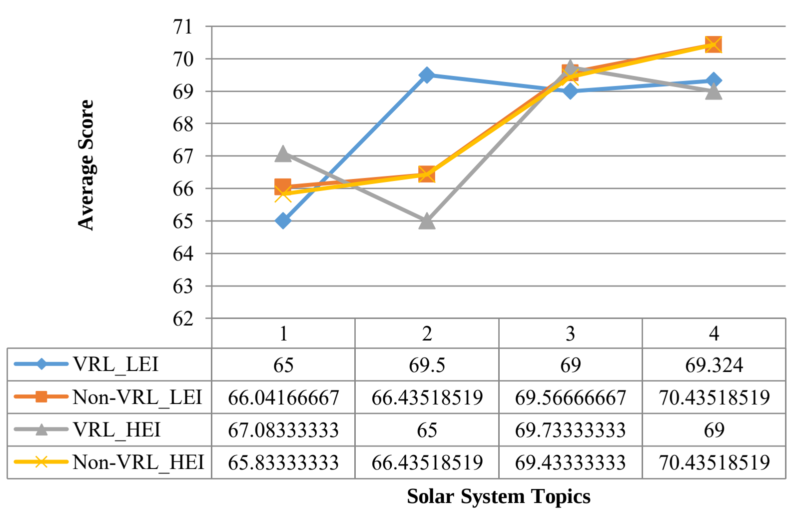

Figure 4 The comparison of argumentation between high and low prior knowledge students in four topics

3.5 Dialogue on argumentation skills in the material of celestial bodies and the solar system and internalization of Qur'anic science

Students tend to have high-quality argumentative skills through critical debate interactions or conversations in the material of celestial bodies and the solar system. Critical reasoning develops through debate topics or conversations that suit students' interests. Here is an example of a presentation of conversation interactions in the material of celestial bodies and the solar system about 'celestial bodies'. The process of argumentative dialogue on questions such as: *'What is the difference between the activities of planets, the sun, meteors, and other celestial bodies that affect the life of space circulation from virtual real laboratory activities?'*

Neti: *VRL reminds me of watching space movies in the cinema before... the condition I saw at that time was probably the planet rotating or revolving around the sun but the meteors were also similar to the conditions of the planets. It seems that planets and meteors are similar.*

Wulan: *As far as I understand, the activity of the planets is to rotate and evolve along their respective orbits, the sun is the center of the solar system because the planets always orbit or revolve around the sun along its lines, and it is impossible for it not to be by the lines because that is how Allah has determined it.*

Ari: *I don't think so; the activity of the universe with all celestial bodies also adjusts its time. Indeed, planets rotate according to their orbits, but the activity of each celestial body can change along with factors that affect the condition of its characteristics. VRL does provide simulations, but there are times when it will also adjust to the latest conditions of space.*

Ria: *It could be that the condition of space is related to the reciprocity between the constituent particles and human carrying capacity in preserving rather than destroying life.*

The interactive dialogue implies that a student named Neti has a misunderstanding when conveying the idea that celestial bodies have the same activity conditions so that their characteristics are the same. Neti's misunderstanding of Wulan provides an opportunity to show a counterargument as a criticism of Neti's opinion. Ari and Ria in the discussion activity channeled their understanding of the arguments expressed by Wulan. The interaction between students in the dialogue process describes the condition of the VRL group building weighted argumentation skills. The dialogue above is concluded from three discovery processes, namely, scientific concepts about celestial bodies and the solar system cause confusion and inaccuracy for students in explaining celestial bodies. Second, rebuttal statements are then produced by other students to provide an assessment of the inadequacy of the information. Third, students indirectly practice the collaboration of VRL learning conditions to build an accurate scientific understanding. These three stages are the characteristics of dialogue argumentation in the material of celestial bodies and the solar system.

In contrast to the process of dialogue, the ability to argue in the material of celestial bodies and the internalized solar system of the Qur'anic science is very different from without internalizing the material. Students in the VRL study group usually mostly support claims with the knowledge they gain through studying textbooks, experiences from simple experiments, and knowledge from life experiences. Students can provide arguments with rebuttals afterward. The following conversation excerpt shows the condition of students who can argue qualitatively in the material internalized by the Qur'anic science about the 'solar system'. The question of argumentation is: *'What is the condition of the solar system in the current era?'*

Lydia: *As the planet's rotation on its axis and the planet's rotation around the sun, I think it's still the same. It was also said in learning VRL that the condition of the planet from time to time also has changes that are like the daily life of humans changing according to their treatment. And now Pluto is no longer considered a planet.*

Alex: *Based on my knowledge of the solar system, Allah gives knowledge through His evidence that He created day and night. So the event does continue according to rotation and revolution, there are times when it is still in accordance with that evidence. But there are times when at the end of time it is said that the sun is above the head. Hopefully, you don't feel that.*

Ely: *Allah does explain the wonders and conditions of space, but Allah created life to run according to His plan, perhaps later there will be a new earth like the NASA news that I read recently.*

Dara: *The condition of the solar system depends on the decree of Allah SWT. If later all the planets, for example, change places or are destroyed, that is also Allah's power in controlling the entire universe. However, celestial events provide a warning to humans like us to do good deeds and assume good things about miracles and tests from Him. I heard the news that the new earth is habitable. However, from the various characteristics of outer space planets according to book information, its characteristics also need to be doubted.*

Niko: *Scientific knowledge is needed to interpret conditions that are truly similar to this with an understanding of how the components of the solar system can circulate in orbit with conditions that contain life in them. Knowledge from the spiritual aspect also supports scientific knowledge in every argument of Allah that discusses space whose truth is undoubted.*

All students participated in space creation activities before receiving learning via VRL. They are encouraged to observe how the characteristics and processes of the formation of celestial bodies so that they have the stimulus to run VRL conducive. They are also asked to make posters or pictures of the solar system according to the interests and creativity of students after the VRL activity. According to the conversation above in this session, students were found to be able to share ideas about how to make unique creations from the discovery of information on celestial bodies and the solar system (Lydia and Alex), discuss discoveries (Ely), and reflect on what could be the application of the material in everyday life (Dara and Niko). Analysis of student arguments in this case revealed that students produced more prominent supporting arguments than opposing arguments. Rarely are counterarguments given in general material arguments. Students give the impression of applying knowledge and experience learned inside and outside the school curriculum to support arguments in an interactive dialogue.

3.6 Dialogue on argumentation skills in low and high environmental insight groups

Among the material topics in VRL, only two topics achieved significant differences regarding the comparison between low and high environmental insight groups. Researchers curious about how students with low environmental insight produce high-quality arguments. Researcher chose an example of students with low environmental insight in the internalized Qur'an science learning group to explore their argumentation process. The scenario for argumentation was 'astronauts'. Students were asked to explain *'why astronauts wear specially designed suits'*.

Andy: *Astronauts wear special suits to keep them from burning or getting abraded.*

Flank: *The use of special clothing is to protect it from getting too hot or too cold. There may also be a certain temperature set on the clothing.*

Caroline: *As far as I know, humans would die if left in the condition they dress in on Earth.*

Harrison: *Yes, that's true, and, in the movies, some astronauts take off their hoods and die.*

Billy: *Maybe that's true, but that's because on Earth we breathe oxygen, whereas in space, floating, there's no way there could be oxygen.*

Students in the low environmental insight group understand that there are many reasons for the conditions of outer space and the modification of the astronaut suit design. The materials include several low environmental insights and spend most of the time building on the knowledge of the material they have learned before. Through discussions and sharing ideas, students with low environmental insight can explain constructively why humans use certain materials to design astronaut suits. Therefore, there are almost no critical arguments in the analysis of student quality. The following excerpt shows the argumentation of the dialogue in the high environmental insight group.

May: *Why do astronauts have special suit designs?*

Daisy: *I think wearing a special suit would be more protective in any condition. The sea and land worlds are different, and so is outer space.*

Linda: *I don't think so, astronaut suits certainly have the qualities to make them survive in space with all the risky conditions of the gases and the length of time spent exploring space.*

Daisy: *In most situations, astronaut suits are already qualified to adapt to the floating environment of outer space.*

Don: *I think the answer is that the spacesuit is designed with special anti-collision material to protect astronauts from various possibilities. The suit is not heavy and can still allow astronauts to conduct flexible investigations. Space dust can hurt ordinary human skin, maybe it can also protect humans from the dangers of space.*

Daisy and Linda have different opinions about which type of fire extinguisher, powder or foam, is effective for extinguishing oil fires. Daisy claims that powder extinguishers are more useful than foam extinguishers, however, Linda disagrees. Then, Daisy raises a rebuttal; she explains that powder can coat anything that is burning. Ben further points out that there is at least one powder extinguisher placed in the corner of each classroom, implying that powder extinguishers are the best choice for extinguishing different types of fires. This idea is refuted by Don, and he suggests that they consult their teacher for answers or search for answers on the internet. The content of students' arguments in the high initial scientific knowledge group is very broad. They have a greater ability to generate questions and rebuttals.

3.6 The monologic argumentation process of students with low environmental insight

Based on Figure 4, the comparison between the two argumentation approaches in the 'celestial objects' and 'solar system' topics did not reach a significant level of difference. Similar results are reported in Figure 6, which shows that the comparison between the low and high environmental insight groups in the two material topics above also did not have a significant difference. This finding implies that several students with a monologic approach in the low environmental insight group can perform as well as their peers with a dialogic approach in the high environmental insight learning group in the two material topics. An example of argumentation on the topic of 'celestial objects' is selected for further explanation. The question for the argumentation is as follows: *"An unknown celestial object has the following properties: (a) emits bright light when entering the earth's atmosphere, (b) moves quickly in the sky, (c) is usually white or yellowish, but can also be red, orange, green, and purple (d) has varying sizes, ranging from the size of a grain of rice to the size of a large round stone (e) has no orbit (f) contains metals such as iron and inorganic minerals such as quartz. Please make an argument to guess what type this unknown object is."*

Ari: *I think it's some kind of star.*

Ari: *If the sizes vary, it may be an asteroid.*

Ari: *But what is impossible is the sun.*

Ari: *I had an experience watching a galaxy movie, and if I looked closely it looked like a meteoroid.*

Ari: *I'm not sure, because I know that celestial objects vary.*

Ari: *However, I still believe my opinion is correct. It is a type of meteoroid.*

In the example above, Ari claims that the unknown object is not a meteor. He recalls various related experiences while conducting experiments to support his claim. James begins to rise to rebuttal by thinking of extraordinary conditions that make his claim wrong, even though this rebuttal is a low-quality argument. Simply put, students in the individual argumentation group can only produce high-quality arguments through remembering and reflecting on knowledge. In the rebuttal dialogue, this quote shows that it seems to be a kind of self-contradiction for students to provide counterarguments that contradict their statements.

4. DISCUSSION

4.1 The Ability to Argue in the Material of Celestial Bodies and the Solar System with Internalization of Qur'anic Science

The condition of argumentation-based dialogue provides comprehensive and progressive information, especially in internalizing Qur'anic science compared to non-internalized material. The internalized scientific concept reflects the differentiation found in the independent curriculum, which is based on students' learning interests and thought processes (Idawati et al., 2025). Students more easily understand the concept of differentiation, which accommodates diverse learning styles, expressions, and interests, as opposed to traditional integrated concepts (Baybayon & Lapinid, 2024; Muhab et al., 2024). Most students indirectly enjoy sharing environmental insights, discussing applications from multiple perspectives, and constructing arguments in an enjoyable manner—even when their perspectives differ (Frenzel et al., 2021). Another factor is the habit of exchanging ideas through interactive dialogue. The initial topic used for dialogue was celestial bodies and the solar system, internalized with Qur'anic science. In the ethics of debating, it is important to show respect, appreciate different opinions, and value every idea shared by others (Mulya et al., 2021). Criticizing others' opinions is common in dialectics, but certain behaviors may become less relevant when arguing (Liu, 2023). Many students tend to feel fear, doubt, or discomfort when criticizing others' ideas. Previous research shows that criticism is often underestimated in science classes, even though it plays a vital role in developing analytical skills (Aljarelah, 2024). To support curriculum development, appropriate learning models and designs are needed that equip students with the skills to structure arguments through critique (Soleimani & Aghazadeh, 2024).

The virtual real laboratory (VRL) version of this argumentation research shows that students can construct scientifically sound and critical arguments regarding celestial bodies and the solar system. The researcher assumes that the use of argumentation indicators—claims, data, refutations, justifications, and criticisms—is a key feature in student argumentation on this topic. Initially, students made claims expressing disagreement without supporting data. Over time, they began to use everyday experiences or scientific information as rebuttals or critiques of others' opinions. This development in students' critical abilities can be linked to misunderstandings between students. Celestial bodies and the solar system are abstract topics and more prone to misconceptions than those presented with Qur'anic internalization.

For example, Neti misunderstood the characteristics of each planet in the solar system, which allowed another student, Ari, to offer a rebuttal or correction. This kind of exchange allows students to practice modifying, reconstructing, and reflecting on their understanding by internalizing Qur'anic science. Cognitively, students often understand concepts in isolation without connecting them to other fields of science. Without the ability to explore and integrate knowledge, students struggle to make meaningful statements, especially without real laboratory stimuli. Thus, the significant impact of internalized material on students' argument structures—particularly regarding the solar system—is explained.

4.2 The Role of Environmental Insight in Building Quality Arguments

The SAT analysis shows that environmental insight affects students' argumentative abilities only in non-internalized material. The SAT is a test completed independently via Google Forms during class. Students were assessed on their monological argumentation skills in response to the SAT. Researchers found that environmental insight had a greater influence on monological arguments regarding the topic of celestial bodies and the solar system. The statistical results from the VRL support this: students with high environmental insight significantly outperformed their peers in topics involving Qur'anic internalization. However, no significant differences were found between students with low and high environmental insight across the three non-internalized topics.

The results from VRL-assisted learning show notable improvement in students' argumentative abilities regarding celestial bodies and the solar system. In other words, students with low environmental insight can still develop strong scientific argumentation skills if taught within a VRL-supported environment. This aligns with previous findings suggesting that digital laboratories contribute meaningfully to material comprehension and scientific development (Aljarelah, 2024). As Patel (2024) and others have highlighted, virtual laboratories have a strong positive influence on students' learning outcomes and attitudes. These environments encourage exploration of real-world concepts and increase motivation through innovative models (Ardhayantia et al., 2022).

VRL allows students to experiment, gather data, and analyze findings to form reasoned conclusions. This process supports their ability to submit claims backed by evidence (Mihret et al., 2022). For instance, Neti (a student with low environmental insight) and Ely (with high insight) learned together in a VRL environment to build strong arguments. The researcher highlights the perspective that environmental insight can support cognitive quality in arguments. VRL conditions increase the likelihood of students mastering knowledge that aligns with argument structures. The analysis confirms that Toulmin's six components are interconnected and contribute to the strength of the arguments presented.

Interestingly, students with lower environmental insight sometimes show more significant gains in argumentative ability—within Qur'anic science-integrated topics—than their high-insight peers. While environmental insight may introduce uncertainty into argumentation, it is not the sole determinant of argumentative ability (Garrecht et al., 2021). A limitation of VRL is that students are only allowed to select arguments within pre-uploaded topics, which restricts material exploration. As a result, students may not fully explore or develop comprehensive arguments. Supplementary media may be necessary to enrich VRL-based learning.

4.3 Limitations and Implications for Science Teaching on Celestial Bodies and the Solar System Integrated with Qur'anic Science

Students' arguments on the topic of celestial bodies and the solar system integrated with Qur'anic science differ significantly from those in non-integrated contexts. In Qur'anic science-integrated topics, students generate claims and data more readily, but rebuttals and critiques tend to remain theoretical and abstract, with little cross-disciplinary integration. High-quality arguments emerge after students evaluate and reflect on their knowledge in VRL-supported environments. VRL significantly enhances students' argumentation abilities more than non-integrated approaches, as seen in both SAT and VRL outcomes.

This research suggests that science teachers should use argumentation activities grounded in internalized material to help students develop skills in refutation and critique. While refuting arguments is typically linked to cognitively demanding statements, debate activities often focus more on winning than exploration (Mobit et al., 2022). Therefore, explicit guidelines and scripts should be provided to help students learn to argue scientifically and logically rather than emotionally (Khalifa & Albadawy, 2024). Based on the research design, the VRL approach for celestial bodies and the solar system should differ from that used for Qur'anic science-integrated topics. Developing and refining complex prototypes will be a challenge for future research.

Factors that influence argumentation in these topics—such as motivation, IQ, and theories supporting VRL use—need to be examined further. The design of VRL platforms must effectively support argumentation, addressing areas such as service quality, topic coverage, and implementation scope. Even without VRL, foundational elements like environmental insight, prior knowledge, and self-reflection remain critical to developing strong arguments.

Reflection plays an essential role in crafting rebuttals, as it often involves confronting contradictions between one's knowledge and counterarguments (Gani & Khan, 2024). Science educators should develop VRL-supported learning environments that encourage students to reflect on and rationalize their arguments through real-life visualization (Kotsis, 2024). This research sheds light on the interplay between internalized science learning—with and without VRL—and offers valuable directions for future research in science education.

4. CONCLUSION

Students demonstrate comprehensive mastery of argumentation through structured, scripted discussions on the topic of celestial bodies and the solar system. However, more critical and reflective arguments tend to emerge when the material is internalized with the science of the Qur'an. The use of a virtual real laboratory (VRL) for teaching topics integrated with Qur'anic science effectively supports the construction of all six components of Toulmin's argumentation model, more so than non-integrated topics.

The integration of Qur'anic science offers not only thematic relevance but also functions as a source of validation and justification, enhancing the weight and quality of students' arguments. Furthermore, environmental insight, VRL-assisted learning, and continuous internalization of interdisciplinary content collectively contribute to the improvement of students' argumentative abilities.

This research successfully positions the argumentation-based approach as a key strategy to reinforce collaborative aspects of analysis and provides a foundation for future exploration of additional factors influencing students' argumentative competence.

REFERENCES

Abacioglu, C. S., Epskamp, S., Fischer, A. H., & Volman, M. (2023). Effects of Multicultural Education on Student Engagement in Low - and High - Concentration Classrooms : The Mediating Role of Student Relationships. *Learning Environments Research*, *26*(3), 951–975. https://doi.org/10.1007/s10984-023-09462-0

Agustina, R. D., & Putra, R. P. (2022). Sophisticated Thinking Blended Laboratory (STB-Lab) Learning Model: Implications on Virtual and Real Laboratories for Increasing Undergraduate Student'S Argumentation Skills. *Jurnal Pendidikan IPA Indonesia*, *11*(4), 657–671. https://doi.org/10.15294/jpii.v11i4.38772

Al-Ajmi, B., & Ambusaidi, A. (2019). The level of scientific argumentation skills in chemistry. *Science Education International*, *33*(1), 66–74.

Aljarelah, A. K. (2024). A Linguistic Analysis of Literary Criticism a Study of How Language Influences the Evaluation of Literary Works. *The American Journal of Interdisciplinary Innovations and Research*, *6*(6), 35–50. https://doi.org/10.37547/tajiir/volume06issue06-09

Andreani, L. A., & Yonata, B. (2024). Validity Test of E-LKPD to Improve Students' Argumentation Skills on Chemical Equilibrium Material. *HYDROGEN: Jurnal Kependidikan*

Kimia, *12*(3), 429–439.

Apriyani, N. D., & Alberida, H. (2023). Pengaruh Model Problem Base Learning (PBL) terhadap Keterampilan Argumentasi Peserta Didik pada Pembelajaran Biologi: Literature Review [The Influence of Problem Based Learning (PBL) Model on Students' Argumentation Skills in Biology Learning: Literature Review]. *BIOCHEPHY: Journal Of Science Education*, *03*(1), 40–48.

Ardhayantia, L. I., Asmaraa, A. A., Wantoputria, N. I., Sulistyoa, E. N., & Marlina, N. (2022). The Impact of Virtual Learning Process on The Assessment Results at Environmental Chemistry. *IJCER*, *6*(4), 39–44. https://doi.org/10.20885/ijcer.vol

Asare, S., Amoako, S. K., Biilah, D. K., & Apraku, T. B. (2023). the Use of Virtual Labs in Science Education: A Comparative Study of Traditional Labs and Virtual Environments. *International Journal of Science Academic Research*, *4*(November), 6563–6569. http://www.scienceijsar.com

Baybayon, G. G., & Lapinid, M. R. C. (2024). Effects of Differentiated Instruction in Flipped Classrooms on Students' Mastery Level and Performance in Quadratic Equations. *Mathematics Teaching-Research Journal*, *16*(1), 213–237.

Brown, C., Ventista, O. M., & Brown, C. (2023). Teachers' Professional Learning and Its Impact on Students' Learning Outcomes : Findings from A Systematic Review. *Social Sciences & Humanities Open*, *8*(1), 100565. https://doi.org/10.1016/j.ssaho.2023.100565

Buerkle, A., O'Dell, A., Matharu, H., Buerkle, L., & Ferreira, P. (2023). Recommendations to Align Higher Education Teaching with the UN Sustainability Goals – A Scoping Survey. *International Journal of Educational Research Open*, *5*(August), 100280. https://doi.org/10.1016/j.ijedro.2023.100280

Bulent, D., Erdal, B., Ceyda, A., Betul, T., Nurgul, C., & Cevahir, D. (2016). An Analysis of Teachers Questioning Strategies. *Educational Research and Reviews*, *11*(22), 2065–2078. https://doi.org/10.5897/err2016.3014

Chen, F., & Chen, G. (2024). Technology-Enhanced Collaborative Inquiry in K–12 Classrooms: A Systematic Review of Empirical Studies. In *Science and Education* (Issue 0123456789). Springer Netherlands. https://doi.org/10.1007/s11191-024-00538-8

Chitera, J., Dziva, R., & Daimond, G. (2025). Investigating the Impact of Argumentation on High School Students' Achievement in Probability Investigating the Impact of Argumentation on High School Students' achievement in probability. *Advanced Researvh Journal*, *1*(1), 45–49. https://doi.org/10.71350/3062192515

Darmaji, D., Astalini, A., Kurniawan, D. A., & Triani, E. (2022). The Effect of Science Process Skills of Students Argumentation Skills. *Jurnal Inovasi Pendidikan IPA*, *8*(1), 78–88. https://doi.org/10.21831/jipi.v8i1.49224

Dawson, V. (2024). Teachers' Support in Developing Year 7 Students' Argumentation Skills About Water-Based Socioscientific Issues. *International Journal of Science Education*, *46*(3), 222–239. https://doi.org/10.1080/09500693.2023.2226334

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving Students ' Learning With Effective Learning Techniques : Promising Directions From Cognitive and Educational Psychology. *Association for Phychological Science*, *14*(1), 4–58. https://doi.org/10.1177/1529100612453266

Fakhriyah, F., Rusilowati, A., Nugroho, S. E., Saptono, S., Ridlo, S., Mindyarto, B., & Susilaningsih, E. (2022). The Scientific Argumentative Skill Analysis Reviewed From The Science Literacy Aspect Of Pre-Service Teacher. *International Journal of Evaluation and Research in Education*, *11*(4), 2129–2139. https://doi.org/10.11591/ijere.v11i4.22847

Fiolanisa, S., Lestari, D., Prasasti, D. A., & Santoso, G. (2023). Hubungan Pendidikan Karakter dengan Pola Perilaku Siswa di Lingkungan Sekitar [The Relationship between Character Education and Student Behavior Patterns in the Surrounding Environment]. *Jurnal Pendidikan Transformatif (Jupetra)*, *02*(02), 380–390.

Frenzel, A. C., Daniels, L., & Burić, I. (2021). Teacher emotions in the classroom and their implications for students. *Educational Psychologist*, *56*(4), 250–264. https://doi.org/10.1080/00461520.2021.1985501

Gani, J. K., & Khan, R. M. (2024). Positionality Statements as a Function of Coloniality : Interrogating. *International Studies Quarterly*, *68*(2), 1–13.

Garrecht, C., Reiss, M. J., & Harms, U. (2021). 'I wouldn't want to be the animal in use nor the patient in need'–the role of issue familiarity in students' socioscientific argumentation. *International Journal of Science Education*, *43*(12), 2065–2086. https://doi.org/10.1080/09500693.2021.1950944

Ghofur, A., Joel C. Kuipers, & Askuri. (2021). Instructional Design: Multi-Site Study of the Integration of Islam in Science Teaching in Java, Indonesia. *Indonesian Journal of Islamic Education Studies (IJIES)*, *4*(1), 70–84. https://doi.org/10.33367/ijies.v4i1.1652

Ginting, S. S. W., Syukri, A., & Salminawati. (2023). Science and Technology in the Qur'an (Study of Islamic Educational Philosophy). *Reflektika*, *18*(1), 49–66. https://doi.org/10.1016/0160-9327(88)90155-x

Grogan, J., Innes, P., Carter, J., & Raciti, M. (2023). Troubling Knowledge in Australian Indigenous Studies: How Prior Knowledge Affects Undergraduate Student Learning. *Higher Education Research & Development*, *42*(8), 1920–1935. https://doi.org/10.1080/07294360.2023.2209512

Haley, A., & Uusimäki, L. (2024). The Purposes of Internationalisation–Future Teachers' Perspectives. *Journal of Education for Teaching*, *51*(1), 158–172. https://doi.org/10.1080/02607476.2024.2421866

Härmä, K., Kärkkäinen, S., & Jeronen, E. (2021). The Dramatic Arc in the Development of Argumentation Skills of Upper Secondary School Students in Geography Education. *Education Sciences*, *11*(734), 1–21. https://doi.org/10.3390/educsci11110734

Hasnunidah, N., Susilo, H., Irawati, M., & Suwono, H. (2019). The Contribution of Argumentation and Critical Thinking Skills on Students' Concept Understanding in Different Learning Models. *Journal of University Teaching and Learning Practice*, *17*(1), 1–11. https://doi.org/10.53761/1.17.1.6

Hendratmoko, A. F., Madlazim, M., Widodo, W., Suyono, S., & Supardi, Z. A. I. (2023). Inquiry and Debate in Science Learning: Potential Strategy for Improving Students' Scientific Argumentation Skills. *International Journal of Education in Mathematics, Science and Technology*, *12*(1), 114–

138. https://doi.org/10.46328/ijemst.3152

Ho, H., Chang, T., Lee, T., & Chou, C. (2019). Above- and Below-Average Students Think Differently: Their Scientific Argumentation Patterns. *Journal Pre-Proof: Thinking Skills and Creativity*. https://doi.org/10.1016/j.tsc.2019.100607

Hulu, F., Dewi, T. M., & Surahman, F. (2022). Peningkatkan Motivasi dan Wawasan Siswa Melalui Fieldtrip Observation [Improving Student Motivation and Insight Through Field Trip Observation]. *DINAMISIA*, *6*(3), 769–776.

Idawati, Fariza, A. A., & Witasari. (2025). Analysis of The Independent Curriculum Concept Through The Constructivist Philosophy of Education and The Philosophy of Ki Hadjar Dewantara. *Jurnal Ilmiah Profesi Pendidikan*, *10*, 734–739.

Imaniar, B. O., & Astutik, S. (2019). Analisis Kemampuan Argumentasi Siswa SMP pada Pembelajaran IPA [Analysis of Junior High School Students' Argumentation Ability in Science Learning]. *Prosiding Seminar Nasional Pendidikan Fisika*, *4*(1), 92–96.

Irvan, A., Admoko, S., Fisika, J., Surabaya, U. N., Ilmiah, K. A., Pembelajaran, M., & Diskusi, M. (2020). Analisis Kemampuan Argumentasi Ilmiah Siswa Berbasis Pola Toulmin's Argument Pattern (TAP) Menggunakan Model Argument [Analysis of Students' Scientific Argumentation Ability Based on Toulmin's Argument Pattern (TAP) Using Argument Model]. *IPF: Inovasi Pendidikan Fisika*, *9*(3), 318–324.

Ismail, I., Permanasari, A., & Setiawan, W. (2016). STEM Virtual Lab: An Alternative Practical Media to Enhance Student's Scientific Literacy. *Jurnal Pendidikan IPA Indonesia*, *5*(2), 239–246. https://doi.org/10.15294/jpii.v5i2.5492

Ismail, R. N., Mudjiran, & Neviyarni. (2019). Membangun Karakter Melalui Implementasi Teori Belajar Behavioristik Pembelajaran Matematika Berbasis Kecakapan Abad 21 [Building Character Through the Implementation of Behavioristic Learning Theory of 21st Century Skills-Based Mathematics Learning]. *Menara Ilmu*, *XIII*(11), 76–88.

Jumariati, Febriyanti, E. R., & Rizki, M. (2021). Argumentation Skills: An Analysis on EFL Students' Essays Based on Toulmin's Model of Argument. *Proceedings of the 2nd International Conference on Education, Language, Literature, and Arts (ICELLA 2021)*, *587*(Icella), 86–95. https://doi.org/10.2991/assehr.k.211021.013

Khalifa, M., & Albadawy, M. (2024). Using artificial intelligence in academic writing and research: An essential productivity tool. *Computer Methods and Programs in Biomedicine Update*, *5*(March), 100145. https://doi.org/10.1016/j.cmpbup.2024.100145

Kotsis, K. T. (2024). The Significance of Experiments in Inquiry-based Science Teaching. *European Journal OfEducation and Pedagogy*, *5*(2), 86–92.

Liu, D. (2023). Pragma-Dialectical Perspective to Intercultural Discussion as Communicative Activity. *Humanities and Social Sciences Communications*, *10*(1), 1–9. https://doi.org/10.1057/s41599-023-02319-0

Liu, Q., Liu, B., & Lin, Y. (2018). The Influence of Prior Knowledge and Collaborative Online Learning Environment on Students ' Argumentation in Descriptive and Theoretical Scientific Concept. *International Journal of Science Education*, *0*(0), 1–23. https://doi.org/10.1080/09500693.2018.1545100

Majidi, A. el, Janssen, D., & de Graaff, R. (2021). The Effects of In-Class Debates on Argumentation Skills in Second Language Education. *System*, *101*, 1–15. https://doi.org/10.1016/j.system.2021.102576

Matovu, H., Ungu, D. A. K., Won, M., Tsai, C. C., Treagust, D. F., Mocerino, M., & Tasker, R. (2023). Immersive Virtual Reality for Science Learning: Design, Implementation, and Evaluation. *Studies in Science Education*, *59*(2), 205–244. https://doi.org/10.1080/03057267.2022.2082680

Maulidah, S. S., & Prima, E. C. (2018). Using Physics Education Technology as Virtual Laboratory in Learning Waves and Sounds. *Journal of Science Learning*, *1*(3), 116. https://doi.org/10.17509/jsl.v1i3.11797

Mebert, L., Barnes, R., Dalley, J., Gawarecki, L., Ghazi-Nezami, F., Shafer, G., ... & Yezbick, E. (2020). Fostering student engagement through a real-world, collaborative project across disciplines and institutions. *Higher Education Pedagogies*, *5*(1), 30-51.

Meiliana, R. (2024). *Perbedaan Kemampuan Argumentasi Siswa Dalam Isu Sosiosaintifik Materi Ekologi di SMA yang Menerapkan Kurikulum 2013 dan Kurikulum Merdeka* [Differences in Students' Argumentation Abilities in Socioscientific Issues of Ecology Material in High Schools Implementing the 2013 Curriculum and the Independent Curriculum].

Mihret, Z., Alemu, M., & Assefa, S. (2022). Effects of Blending Virtual and Real Laboratory Experimentation on Pre-Service Physics Teachers' Attitudes Toward Physics Electricity and Magnetism Laboratories. *Science Education International*, *33*(3), 313–322. https://doi.org/10.33828/sei.v33.i3.7

Mobit, Fadlillah, M. H., & Ahmad, Y. B. (2022). An Indonesian Teacher's Strategies for Preparing Students' Debate Teams for Competition. *ELT in Focus*, *5*(1), 1–9. https://doi.org/10.35706/eltinfc.v5i1.6765

Moser, E., & Mercer, R. E. (2020). Use of Claim Graphing and Argumentation Schemes in Biomedical Literature: A Manual Approach to Analysis. *Proceedings of the 7th Workshop on Argument Mining*, 88–99. https://www.aclweb.org/anthology/2020.argmining-1.10

Muhab, S., Rini, T. D. S., Erdawati, E., & Irwanto, I. (2024). Evaluation of Differentiated Learning in Chemistry by Using the CIPP Evaluation Model. *Jurnal Penelitian Pendidikan IPA*, *10*(2), 923–939. https://doi.org/10.29303/jppipa.v10i2.5985

Mulya, R., Krismadinata, Jalinus, N., & Effendi, H. (2021). Practical Work of Digital System Course Based on Virtual Laboratory. *International Journal of Online and Biomedical Engineering*, *17*(8), 22–37. https://doi.org/10.3991/ijoe.v17i08.23359

Munna, A. S., & Kalam, A. (2021). Teaching and learning process to enhance teaching effectiveness : a literature review. *International Journal of Humanities and Innovation (IJHI)*, *4*(1), 1–4.

Murdani, E., Suhandi, A., Muslim, M., Setiawan, A., Samsudin, A., & Costu, B. (2023). Physics Argumentation-Based Computer-Supported Collaborative Hybrid Learning To Increase Concept Mastery and Argumentation Skills. *Jurnal Pendidikan IPA Indonesia*, *12*(2), 232–240. https://doi.org/10.15294/jpii.v12i2.42457

Nakrowi, Z. S., Ansori, D. S., Mulyati, Y., & Setyaningsih, Y. (2024). Kemampuan Menulis Argumentasi Siswa : Analisis Profil dan Problematika Pembelajaran [Students' Argumentative Writing Ability: Analysis of Profile and Learning Problems]. *Onoma: Pendidikan, Bahasa Dan Sastra*, *10*(1), 508–518.

Novanda, N. A. L., Supeno, & Budiarso, A. S. (2024). Pengembangan LKPD Berbasis Etnosains untuk Meningkatkan Kemampuan Argumentasi Ilmiah Siswa SMP pada Pembelajaran IPA [Development of Ethnoscience-Based LKPD to Improve Junior High School Students' Scientific Argumentation Skills in Science Learning]. *Jurnal Pendidikan MIPA*, *14*(1), 8–18. https://doi.org/10.37630/jpm.v14i1.1435

Patel, S. S. (2024). Virtual Labs in Science Education: A Comprehensive Review of Their Impact on Learning Outcomes. *International Journal For Multidisciplinary Research*, *6*(2), 1–9. https://doi.org/10.36948/ijfmr.2024.v06i02.16243

Pho, D. H., Nguyen, H. T., Nguyen, H. M., & Nguyen, T. T. N. (2021). The Use of Learning Station Method According to Competency Development for Elementary Students in Vietnam. *Cogent Education*, *8*(1), 1–27. https://doi.org/10.1080/2331186X.2020.1870799

Purwaningtyas, D. A., Prabowo, H., Napitupulu, T. A., & Purwandari, B. (2022). The Integration of Augmented Reality and Virtual Laboratory Based on the 5E Model and Vark Assessment: a Conceptual Framework. *Jurnal Pendidikan IPA Indonesia*, *11*(3), 449–460. https://doi.org/10.15294/jpii.v11i3.36367

Rahayu, Y., Suhendar, S., & Ratnasari, J. (2020). Keterampilan Argumentasi Siswa Pada Materi Sistem Gerak SMA Negeri Kabupaten Sukabumi-Indonesia [Students' Argumentation Skills on Motion System Material at Sukabumi Regency State High School-Indonesia]. *Biodik*, *6*(3), 312–318. https://doi.org/10.22437/bio.v6i3.9802

Rahmah, N. A., & Novita, P. (2024). The Effects of Analytical Skills and Prior Knowledge on Student's Argumentative Writing. *Jurnal Pendidikan Generasi Nusantara (JPGenus)*, *2*(1), 64–71.

Ramli, I. U., Kurniasih, S., & Herawati, D. (2023). Pengembangan E-Magazine untuk Meningkatkan Keterampilan Argumentasi Siswa pada Materi Pembelajaran Virus [E-Magazine Development to Improve Students' Argumentation Skills on Virus Learning Material]. *Jurnal Edukasi Dan Sains Biologi*, *5*(1), 8–12. https://doi.org/10.37301/esabi.v5i1.38

Rauf, R., Wijaya, H., & Tari, E. (2021). Entrepreneurship Education Based on Environmental Insight: Opportunities and Challenges in the New Normal Era. *Cogent Arts and Humanities*, *8*(1). https://doi.org/10.1080/23311983.2021.1945756

Revalina, A., Moeis, I., & Indrawadi, J. (2023). Degradasi Moral Siswa-Siswi dalam Penerapan Nilai Pancasila Ditinjau dari Pendidikan Kewarganegaraan sebagai Pendidikan Karakter [Moral Degradation of Students in the Implementation of Pancasila Values Reviewed from Civic Education as Character Education]. *Jurnal Moral Kemasyarakatan*, *8*(1), 24–36.

Riwanda, A., Huda, H., Nadlir, N., & Yani, A. (2024). Integrating Science and Religion through Academic Writing: A Case Study at MAN Insan Cendekia. *EDUKASI: Jurnal Penelitian Pendidikan Agama Dan Keagamaan*, *22*(2), 167–183. https://doi.org/10.32729/edukasi.v22i2.1869

Safiatuddin, S., & Asnawi, R. (2023). Effectiveness of Using Virtual Reality-Based Virtual Laboratories in the Internet of Things Course. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 5062–5070. https://doi.org/10.29303/jppipa.v9i7.4040

Schreiner, G. O. (2024). Perceptions of Scientific Assessment Effectiveness. *Environmental Development*, *52*, 1–15. https://doi.org/10.1016/j.envdev.2024.101073

Sellberg, C., Nazari, Z., & Solberg, M. (2024). Virtual Laboratories in STEM Higher Education: A Scoping Review. *Nordic Journal of Systematic Reviews in Education*, *2*, 58–75. https://doi.org/10.23865/njsre.v2.5766

Soleimani, M., & Aghazadeh, Z. (2024). *Iranian EFL Academics ' and PhD Candidates ' Perceptions toward the Infusion of Critical Thinking into EFL Curriculum*. *16*(33), 298–315. https://doi.org/10.22034/elt.2024.60236.2608

Steensen, S., Ferrer-Conill, R., & Peters, C. (2020). (Against a) Theory of Audience Engagement with News. *Journalism Studies*, *0*(0), 1662–1680. https://doi.org/10.1080/1461670X.2020.1788414

Sukamad, S., Sulistiyo, U., & Yanto, Y. (2023). Implementation of Al-Qur'an Integration in the Teaching and Learning Process. *Edunesia : Jurnal Ilmiah Pendidikan*, *5*(1), 278–295. https://doi.org/10.51276/edu.v5i1.672

Sunhaji, S. (2018). The Integration of Science-Technology and Living Environment through Islam Religion Education Learning at Adiwiyata-Based Junior High School in Banyumas Regency. *Dinamika Ilmu*, *18*(2), 179–193. https://doi.org/10.21093/di.v18i2.1179

Uroidli, A., Aziz, Y., & Yudi, U. (2024). Internalization of Islamic Education Values in the Pancasila Student Profile Strengthening Project through a Multidisciplinary Approach. *Jurnal Pendidikan Islam*, *15*(1), 23–54.

Villarreal Arroyo, Y. P., Peñabaena-Niebles, R., & Berdugo Correa, C. (2023). Influence of environmental conditions on students' learning processes: A systematic review. *Building and Environment*, *231*(January). https://doi.org/10.1016/j.buildenv.2023.110051

von Köppen, M., Kümpers, S., & Hahn, D. (2022). Co-Production of Knowledge and Dialogue: A Reflective Analysis of the Space Between Academic and Lay Co-Researchers in the Early Stages of the Research Process. *Forum Qualitative Sozialforschung*, *23*(1). https://doi.org/10.17169/fqs-23.1.3726

Wasehudin, W., Syah, D., Rahman, M. T., & Hasanah, U. (2022). Developing Class Instruction for Linking The Qur'an to Biological Science. *AL-ISHLAH: Jurnal Pendidikan*, *14*(3), 3641–3658. https://doi.org/10.35445/alishlah.v14i3.1662

Waston, Yusuf Olawale Owa-Onire Uthman, Mahmudulhassan, M. (2024). Ian G. Barbour's Thoughts on Science and Religion. *Journal of World Thinkers*, *1*(1), 1–16.

Wilson, R., Joiner, K., & Abbasi, A. (2021). Improving Students' Performance with Time Management Skills. *Journal of University Teaching & Learning Practice*, *18*(4), 1–20.

Winarto, Cahyono, E., Sumarni, W., Sulhadi, S., Wahyuni, S., & Sarwi. (2022). Science Teaching Approach Ethno-Setsar to Improve Pre-Service Teachers' Creative Thinking and Problem Solving Skills. *Journal of Technology and Science Education*, *12*(2), 327–344.