26 (2), 2025, 1007-1024
Jurnal Pendidikan MIPA
e-ISSN: 2685-5488 | p-ISSN: 1411-2531
https://jpmipa.fkip.unila.ac.id/index.php/jpmipa

The Moderating Effect of Computational Thinking and Multirepresentation on the Relationship of Academic Resilience and Biology Literacy in Indonesian High School Students

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Abstract: Academic resilience helps students overcome learning challenges and stay motivated in understanding complex biology materials. Computational thinking skills enable students to break down complex biology problems logically and structured, while the use of multirepresentations such as diagrams and graphs facilitates the understanding of abstract concepts. Biological literacy has a very important urgency for students because it plays a role in equipping them with the ability to understand, analyze, and apply biological concepts in everyday life. In the era of globalization and rapid development of science, biological literacy is an important basis for making intelligent decisions, especially related to environmental, health, and sustainability issues. The objective of this study is to investigate the influence of academic resilience on the biological literacy of students by means of computational thinking and multirepresentations. It is hypothesized that students' capacity to surmount intricate biology learning obstacles is enhanced by their high academic resilience. This study examines the correlation between academic resilience, computational thinking, multirepresentations, and biological literacy in high school pupils in Mataram City, Indonesia, utilizing quantitative methods and Structural Equation Modeling (SEM) analysis. The findings indicated that academic resilience has a substantial impact on the biological literacy of students ($p < 0.05$), both directly and through the mediation of computational thinking abilities and the use of multirepresentations. Computational thinking assists students in the deconstruction of intricate biological problems, while multirepresentations, such as diagrams and graphs, facilitate comprehension of abstract biological concepts. This study underscores the significance of fostering academic resilience, computational thinking, and visual representations in order to enhance students' biological literacy, thereby facilitating the development of more effective and adaptive biology learning strategies.

Keywords: academic resilience, biology literacy, computational thinking, multirepresentation, students.

▪ INTRODUCTION

Biology education is a critical component in the cultivation of students' scientific knowledge and critical thinking abilities. In order to comprehend fundamental concepts in the natural sciences and implement them in daily life, it is imperative to possess strong biological literacy skills (Kusuma, 2023). However, the complexity of the subject matter necessitates a deep comprehension and the capacity to think systematically, which is why many students struggle to learn biology (Paradise & Bartkovich, 2021). Madjid et al. (2021) and Masten et al. (2021) have demonstrated that this challenge is exacerbated when students lack sufficient academic resilience in their learning efforts. Rudd et al. (2022) define academic resilience as the capacity of an individual to endure, adjust, and rebound in the presence of academic obstacles. Students with a high level of academic

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*Email: anyfatmawati@undikma.ac.id
DOI: http://dx.doi.org/10.23960/jpmipa/v26i2.pp1007-1024
Received: 18 May 2025
Accepted: 31 May 2025
Published: 07 June 2025

resilience are more likely to be able to overcome learning obstacles and maintain their motivation to continue comprehending the material in the context of complex biology learning. These findings demonstrate that academic resilience is not solely associated with affective factors; it also has a direct effect on academic performance.

The use of multirepresentations, computational reasoning skills, and academic resilience, in addition to non-cognitive factors, also significantly influence biological literacy. Numerous investigations have demonstrated that computational reasoning and multirepresentation are crucial components of the process by which students comprehend biology material more effectively. Students are capable of deconstructing intricate problems into smaller components, identifying patterns, and formulating solutions in a structured and logical manner through computational thinking (Maryanti et al., 2024). Meanwhile, the comprehension of abstract biological concepts can be facilitated by multirepresentation skills, including the utilization of visual models, diagrams, and graphs (Fathonah et al., 2024). Emphasized that students' overall learning abilities in biology subjects can be enhanced by mastering these two aspects. The research, by analyzing this mediating function, provides a more profound comprehension of the collaborative efforts of computational thinking skills and multiple representations to facilitate more comprehensive and in-depth learning.

Numerous prior investigations have investigated the impact of academic resilience on academic achievement in a variety of disciplines, such as mathematics and natural sciences (Demir, 2023; Fitrah Ishak et al., 2020; Ledesma & Linaugo, 2023). In contrast, there is a scarcity of research that has explicitly investigated the relationship between academic resilience and biological literacy, particularly in the context of the application of computational thinking and multirepresentation as mediating factors (Guo et al., 2025; Mallick & Kaur, 2016). Current research emphasizes learning strategy factors to enhance students' comprehension of biology material in general, but it fails to account for the significance of academic resilience in the learning process. This lacuna implies that there is a necessity to conduct additional research on the impact of academic resilience on computational thinking and multirepresentational skills in order to enhance students' biological literacy.

Therefore, the objective of this investigation is to investigate the influence of academic resilience on biological literacy by employing computational thinking and multirepresentational methodologies as mediating factors. This research is anticipated to offer novel insights into the correlation between students' capacity to comprehend intricate biological concepts and their academic resilience. In addition, it is anticipated that this investigation will be able to make theoretical and practical contributions to the development of biology learning strategies that are more adaptive, integrative, and responsive to the learning challenges of students. Consequently, biology education is not solely focused on content mastery; it also emphasizes the development of learning resilience and critical thinking skills that facilitate long-term academic success.

Conceptual Framework and Hypothesis Development

Academic resilience is the capacity of students to remain motivated and persist in their efforts in the presence of academic obstacles and setbacks (Jumraeni et al., 2023). Adapting to changes in the educational environment, maintaining enthusiasm, and overcoming learning difficulties are all capabilities of students who possess high academic resilience (Fachmi & Kustiwa, 2022). Not only does academic resilience influence learning motivation, but it also enhances cognitive abilities, including the capacity to manage information in a multirepresentational manner and computational thinking, which are critical for the study of biology. The capacity to deconstruct intricate problems into more manageable and structured components and employ logic and algorithms to identify solutions is known as computational thinking (Korkmaz & Bai, 2019). Sirakaya (2020) emphasizes the significance of computational thinking in contemporary education, particularly in the context of science education, as it aids students in the systematic resolution of problems and the development of critical thinking skills. Resilient students will be more adept at employing computational thinking skills to surmount challenges in comprehending intricate biological concepts within the context of academic resilience.

H1: Academic resilience has a positive effect on students' computational thinking skills.

Multirepresentation abilities are the capacity of students to comprehend and correlate information through the use of a variety of representations, including text, images, graphs, and diagrams (Mohamad et al., 2023). Fatmawati et al. (2019) emphasize the importance of multirepresentation abilities in biology learning, as numerous abstract concepts necessitate visual representations to facilitate comprehension. Students who exhibit high academic resilience are more inclined to employ these diverse representations in their learning, which facilitates their comprehension of biological concepts (Bahri et al., 2021).

H2: Academic resilience has a positive effect on students' multirepresentation..

Students' comprehension of biological concepts and their capacity to implement that knowledge in pertinent circumstances are referred to as biological literacy (Dhani & Agustinah, 2023). Students who exhibit high academic resilience, computational reasoning skills, and multirepresentation abilities are more likely to possess superior biological literacy. They have the ability to incorporate information obtained through various representations and employ systematic logic to comprehend and elucidate biological phenomena.

H3: Academic resilience has a positive effect on students' biological literacy.

Computational thinking is a skill that entails the capacity to deconstruct intricate problems into smaller, more manageable components and employ logic and algorithms to identify solutions (Fenwick & Unsworth, 2022). In order to assist students in the resolution of intricate problems and to facilitate comprehension of abstract concepts, computational thinking is crucial. The capacity to think computationally is highly influential in the context of biological literacy, as it enables students to analyze biological data, design experiments, and interpret results in a structured manner (Fenwick & Unsworth, 2022). This computational thinking enables students to surmount intricate biology learning obstacles, including the ability to comprehend the interactions between diverse biological systems and to describe dynamic biological processes.

H4: Computational thinking has a positive effect on students' biological literacy.

Multirepresentation abilities refer to the ability of students to understand and articulate scientific concepts through the use of a diverse array of representations, such as text, images, diagrams, models, and graphs (Utami & Subiantoro, 2021). This capacity is crucial in the field of biology education, as numerous biological concepts are abstract and challenging to comprehend solely through verbal or written explanations. Visual representations can aid students in comprehending intricate biological processes (Listiana & Bahri, 2019). Students' comprehension of biological concepts that are challenging to visualize in real life is enhanced by the use of a variety of visual representations (Hahn & Klein, 2023). Consequently, the development of students' biological literacy is significantly enhanced by the acquisition of multirepresentation skills.

H5: Multirepresentation has a positive effect on students' biological literacy.

The correlation between computational thinking, multirepresentation abilities, and biological literacy demonstrates that they are both significant factors in the comprehension of biology. Students who have mastered computational thinking will be able to more accurately analyze scientific data and solve intricate biological problems (Maryanti et al., 2024). In addition, multirepresentation skills enable students to comprehend abstract concepts by employing a variety of representations that aid in their comprehension (Utami & Subiantoro, 2021). Computational thinking and multirepresentation skills work in tandem to enhance students' comprehension of biology, thereby enhancing their biological literacy.

H6: Computational thinking and multirepresentation affect the relationship between students' academic resilience and biological literacy.

▪ METHOD

Types and Research Design

This study uses a quantitative method with a cross-sectional approach (Syamsiah et al., 2024). The main objective of this study is to examine the causal relationship between academic resilience and students' biological literacy, with computational thinking and multirepresentation ability as mediating variables. The research design uses the Partial Least Squares Structural Equation Modeling (PLS-SEM) modeling approach. This approach allows researchers to simultaneously analyze direct and indirect relationships between variables, as well as evaluate the contribution of mediating variables to the relationship between independent and dependent variables (Hair et al., 2012). The relationship between variables and the proposed hypotheses are visualized in the Analysis path diagram in Figure 1.

Research Subjects

The study population consisted of active students from 5 Senior High Schools (SMA) in Mataram City, Indonesia. The sampling technique used was purposive sampling, with the criteria of students from the exact sciences class starting from grades X, XI, and XII. The number of samples was determined based on the approach of Hair et

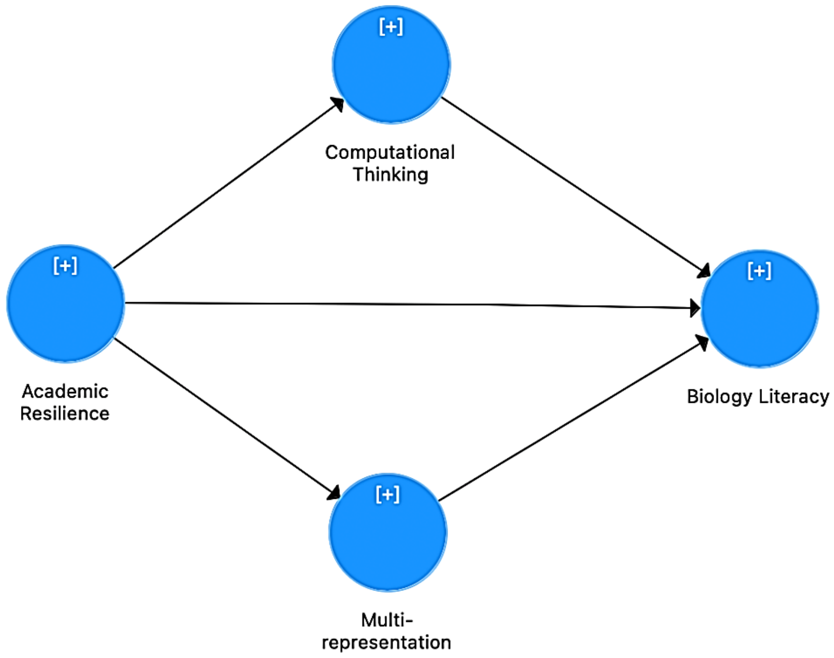

Figure 1. SEM model diagram

al. (2019), which is a minimum of 5-10 respondents per indicator. 331 students who filled out the questionnaire, 315 students met the requirements to enter the data analysis stage (Table 1).

Table 1. Demographics of the research sample

Item	Grade	N	Percentage (%)
Male Students	X	31	30.10
	XI	38	36.89
	XII	34	33.01
Total		103	100.00
Female Students	X	69	32.55
	XI	78	37.79
	XII	65	30.76
Total		212	100.00

Research Instruments

The instrument used was a closed questionnaire based on a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree), which had been compiled and modified based on the theoretical indicators of each variable: academic resilience, computational thinking, multirepresentational ability, and biological literacy (Table 2). Modifications to the original instrument are intended to ensure that it is appropriate for the research purpose, but do not change the core construct being measured. The validity of the instrument was consulted with experts in the fields of biology and psychology education. The validation results showed that the instrument was suitable for use with a score in the range of 3.15 (Valid). A range (4.00-3.51= strongly valid, 3.50-3.01= valid, 3.00-2.50= not valid, and below 2.50 = strongly not valid).

Table 2. Statement of each variable item in the research instrument

Variable Items	Survey Item Statement	Modification from source
AR1	I acknowledge that scientific knowledge advances through systematic observation and experimentation.	(Cassidy, 2016; Lim & Chue, 2023)
AR2	I am aware of the importance of maintaining objectivity and impartiality in scientific endeavors.	
AR3	I prioritize empirical evidence over personal opinions when making informed decisions.	
AR4	I habitually engage in critical inquiry regarding the information I encounter.	
AR5	I hold the view that scientific knowledge is subject to change as new evidence becomes available.	
AR6	I consistently collaborate and engage in scholarly discussions to address problems through scientific reasoning.	
AR7	I regard scientific practice as a reflection of honesty, precision, and a sense of responsibility.	
CT1	I am able to break down complex problems into smaller parts that are easier to analyze and solve.	(Junpho et al., 2022; Sulsilah et al., 2023)
CT2	I am used to organizing systematic steps in completing tasks or problems that I face.	
CT3	I can recognize patterns or regularities in a problem to help find a solution.	
CT4	I am able to create a representation of the solution in the form of an algorithm or logical and structured instructions.	
CT5	I am comfortable using technology or digital tools to solve problems efficiently.	
CT6	I can evaluate the effectiveness of the solutions I have created and make improvements when necessary.	
CT7	I am used to using logic and reasoning in making decisions based on available data or information.	
MP1	I can understand a concept using various forms of representation such as pictures, graphs, tables, and text.	(Omoyajowo et al., 2023; Rukmana et al., 2022)
MP2	I am able to change information from one form of representation (e.g., text) to another (e.g., pictures or graphs).	
MP3	I find it helpful to understand material when it is presented in more than one form of representation.	
MP4	I can re-explain a concept using a combination of verbal and visual language.	
MP5	I am able to compare the effectiveness of different representations in explaining a scientific phenomenon.	
MP6	I can integrate information from different representations to build a complete understanding of a concept.	
MP7	I am accustomed to using visual representations (e.g., diagrams or models) to help solve problems or explain ideas.	

BL1	I am able to explain basic concepts of biology, such as cells, ecosystems, body systems, and genetics, scientifically.	(Najmah et al., 2024; Wright et al., 2014)
BL2	I can relate biological knowledge to everyday life issues, such as health, environment, and technology.	
BL3	I am used to using scientific data or information to support my opinions in biology discussions.	
BL4	I am able to read, interpret, and conclude information from graphs, tables, or diagrams related to biological material.	
BL5	I can differentiate between scientific facts and personal opinions in studying biology.	
BL6	I feel confident in communicating my understanding of biology, both orally and in writing.	
BL7	I recognize the importance of biological literacy in making responsible decisions regarding the environment and health.	

Data Collection, Analysis Techniques, and Research Ethics

The researcher's official email and social media were utilized to disseminate an online questionnaire that was administered through the Google Forms digital platform. Data were gathered through this mode. The data collection procedure adhered to the ethical principles of research, which include voluntary participation, data confidentiality, and informed consent. SmartPLS software version 3 was employed to conduct data analysis using Partial Least Squares-Structural Equation Modeling (PLS-SEM). Outer loading (>0.70) was employed to evaluate validity. When it comes to the consistency of reliability, it is determined by Cronbach's Alpha (>0.70), Rho A (>0.70), Composite Reliability (>0.70), convergent validity AVE (>0.50), and discriminant validity through the Fornell-Larcker criteria and cross-loading. The discriminant validity of the Fornell-Larcker criteria with the AVE root value (in the diagonal) of each variable score must be greater than that of the other variables (Hair et al., 2012; Henseler, 2012). Furthermore, the cross-loading variable must be the most significant among all other cross-loadings (Hair et al., 2021).

The analysis is advanced to the structural model (inner model) to assess the intensity of the relationship between latent constructs after the measurement model has successfully passed validation. In this analysis, the R^2 value is computed to determine the extent to which the independent variable explains the dependent variable. The significance of the path is also tested using the bootstrapping technique of 5000 resamplings. For a significance level of 5% ($\alpha = 0.05$), the path value is deemed significant if the t value is greater than 1.96 (Acosta-Gonzaga & Ruiz-Ledesma, 2022). To ensure that the research findings can be interpreted and statistically accounted for, all procedures are executed in a systematic manner.

This study adheres to all ethical principles of research from the commencement of the research process to publication, which include the explicit declaration that all data use is for academic purposes only, the preservation of data confidentiality, and the voluntary consent of research participants.

▪ RESULT AND DISSCUSSION

Table 3 shows a strong relationship between the observed variables and their related constructs, thus meeting the recommended convergent validity threshold. For example, indicators CT4 (0.873), CT7 (0.815), and MP4 (0.800) show high loadings, indicating that these indicators can be relied upon to represent the latent constructs. The Composite Reliability (CR) values for all constructs exceed 0.8, supporting the internal consistency and reliability of the measurement model, with the highest value reaching 0.920 in the CT construct. In addition, the Average Variance Extracted (AVE) value is also above the threshold of 0.5, with the highest value of 0.657 in CT, indicating adequate convergent validity. However, several indicators such as BL1, BL2, and BL5 are listed as "Out," indicating that they were removed due to low loading values. These findings indicate that the overall measurement model is quite strong, with well-defined and reliable constructs.

Table 3. Reflective measurement model analysis result

Indicators	Outer Loadings	Alpha	Rho_A	CR	AVE
AR1	0.761	0.869	0.871	0.899	0.559
AR2	0.711				
AR3	0.760				
AR4	0.754				
AR5	0.722				
AR6	0.794				
AR7	0.731				
CT1	0.793	0.895	0.901	0.920	0.657
CT2	0.728				
CT3	0.844				
CT4	0.873				
CT5	0.624 (Out)				
CT6	0.802				
CT7	0.815				
MP1	0.748	0.875	0.876	0.905	0.615
MP2	0.790				
MP3	0.807				
MP4	0.800				
MP5	0.779				
MP6	0.671 (Out)				
MP7	0.778				
BL1	0.698 (Out)	0.796	0.801	0.867	0.619
BL2	0.689 (Out)				
BL3	0.786				
BL4	0.754				
BL5	0.675 (Out)				
BL6	0.805				
BL7	0.802				

Table 4 shows that all correlations between variables are lower than the root value of AVE of each variable, indicating that there is no problem of discriminant validity. This indicates that the instrument used in this study has the ability to clearly distinguish the variables being measured.

Table 4. Descriptive fornell-larcker criterion

	AR	**CT**	**MP**	**BL**
AR	0.748			
CT	0.449	0.810		
MP	0.642	0.442	0.784	
BL	0.523	0.480	0.577	0.787

Based on the analysis results in Table 5, the AVE square root value for academic aesilience (AR) is 0.748, computational thinking (CT) is 0.810, multirepresentation (MP) is 0.784, and biology literacy (BL) is 0.787. The results show that each construct has a higher AVE square root value compared to the correlation between other constructs, which means that these constructs have good discriminant validity. In addition, computational thinking (CT) shows the highest correlation with biology literacy (BL) of 0.723, which indicates a fairly strong positive relationship between the two constructs. Overall, these results support the convergent and discriminant validity of the constructs tested, indicating that each construct measured in this study is able to clearly distinguish the attributes to be measured without significant overlap.

Table 5. Descriptive HTMT

Variable	**AR**	**CT**	**MP**	**BL**
AR	0.748			
CT	0.449	0.810		
MP	0.642	0.442	0.784	
BL	0723	0.480	0.577	0.787

Table 6 shows the cross loading values between indicators on the relevant constructs showing a fairly good relationship. For example, the CT1 indicator has the highest loading on the CT construct (0.793) and lower on other constructs such as AR (0.305) and BL (0.269), indicating that the indicator is more appropriate to represent the CT construct. Similar things are also seen in the BL3 indicator, which has the highest loading value on the BL construct (0.786). Overall, most indicators have shown a clear relationship with their respective latent constructs.

Table 6. Item variable cross-loading

Variable Items	**AR**	**CT**	**MP**	**BL**
AR1	*0.761*	0.346	0.436	0.592
AR2	*0.711*	0.214	0.352	0.455
AR3	*0.760*	0.315	0.469	0.564
AR4	*0.754*	0.360	0.507	0.614
AR5	*0.722*	0.345	0.523	0.478
AR6	*0.794*	0.330	0.478	0.523
AR7	*0.731*	0.406	0.561	0.534
CT1	0.305	*0.793*	0.288	0.269
CT2	0.345	*0.728*	0.396	0.337
CT3	0.361	*0.844*	0.324	0.430
CT4	0.409	*0.873*	0.337	0.479
CT6	0.394	*0.802*	0.455	0.393

CT7	0.348	*0.815*	0.325	0.386
MP1	0.502	0.292	*0.748*	0.392
MP2	0.552	0.280	*0.790*	0.373
MP3	0.439	0.331	*0.807*	0.463
MP4	0.497	0.362	*0.800*	0.467
MP5	0.532	0.409	*0.779*	0.533
MP7	0.494	0.387	*0.778*	0.468
BL3	0.502	0.404	0.374	*0.786*
BL4	0.503	0.373	0.460	*0.754*
BL6	0.633	0.381	0.411	*0.805*
BL7	0.621	0.357	0.560	*0.802*

Table 7 shows that all paths between constructs show very high t-statistic values, with significant p-values (all below 0.05), indicating that all tested relationships have a significant effect. For example, the path between H1 academic resilience (AR) and computational thinking (CT) shows a positive coefficient of 0.449 with a t-statistic of 8.588 and a p-value of 0.000, indicating a strong and significant positive relationship between the two constructs. Other significant paths include the relationship between H2 academic resilience and multirepresentation (MP) (coefficient 0.556, t-statistic 12.091, p-value 0.000), and between H4 computational thinking and biology literacy (BL) (coefficient 0.165, t-statistic 4.079, p-value 0.000). However, the path between H5 multirepresentation and biology literacy has a lower coefficient (0.149), although it remains significant with a t-statistic of 2.171 and a p-value of 0.030. Overall, these results indicate that academic resilience has a significant effect on computational thinking, multirepresentation, and biology literacy, while the effect between computational thinking and multirepresentation on biology literacy, although significant, tends to be weaker.

Table 7. Direct path analysis

H	**Path**	**Original Sample (O)**	**Sample Mean (M)**	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**P Values**
H1	Academic Resilience -> Computational Thinking	0.449	0.453	0.052	8.588	0.000
H2	Academic Resilience -> Multi-representation	0.556	0.559	0.046	12.091	0.000
H3	Academic Resilience -> Biology Literacy	0.553	0.556	0.052	10.717	0.000
H4	Computational Thinking -> Biology Literacy	0.165	0.164	0.040	4.079	0.000

H5	Multi-representation -> Biology Literacy	0.149	0.148	0.069	2.171	0.030

Both paths tested in Table 8 show significant t-statistics and p-values (all below 0.05), indicating a strong and significant influence. The path between academic resilience and computational thinking shows a coefficient of 0.076 with a t-statistic of 3.723 and a p-value of 0.000, indicating that academic resilience indirectly affects biological literacy through the development of computational thinking skills. Similarly, the path between academic resilience and multirepresentation shows a coefficient of 0.095 with a t-statistic of 2.061 and a p-value of 0.039, meaning that academic resilience also plays a role in strengthening students' ability to use multirepresentations, which in turn supports the improvement of biological literacy. These results strengthen the argument that academic resilience not only has a direct impact on biological understanding, but also plays a role through higher cognitive skills such as computational thinking and the use of visual representations.

Table 8. Indirect path analysis

H	Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
H6	Academic Resilience -> Computational Thinking -> Biology Literacy	0.076	0.076	0.020	3.723	0.000
	Academic Resilience -> Multi-representation -> Biology Literacy	0.095	0.096	0.046	2.061	0.039

In Figure 2 of this SEM diagram, the significant R^2 value can provide an overview of the strength of the model in explaining the variance of the dependent variable. For the biology literacy (BL) construct, the R^2 value is 0.566, indicating that approximately 56.6% of the variation in biology literacy can be explained by academic resilience (AR), computational thinking (CT), and multirepresentation (MP). This indicates a fairly large influence of these factors on biology literacy, with academic resilience and computational thinking as the main influences, each of which shows a significant path coefficient on biology literacy. The higher R^2 value on multirepresentation (MP) (0.413) also shows a significant contribution in the model, although lower than biology literacy. Overall, this model shows that the variables tested provide a fairly strong explanation of the dependent variable, with the largest contribution from academic resilience and computational thinking in forming biology literacy.

The results of research indicate that computational thinking (CT) and multirepresentation (MP) are significantly influenced by academic resilience. Students who exhibit high academic resilience are more likely to be able to surmount challenges

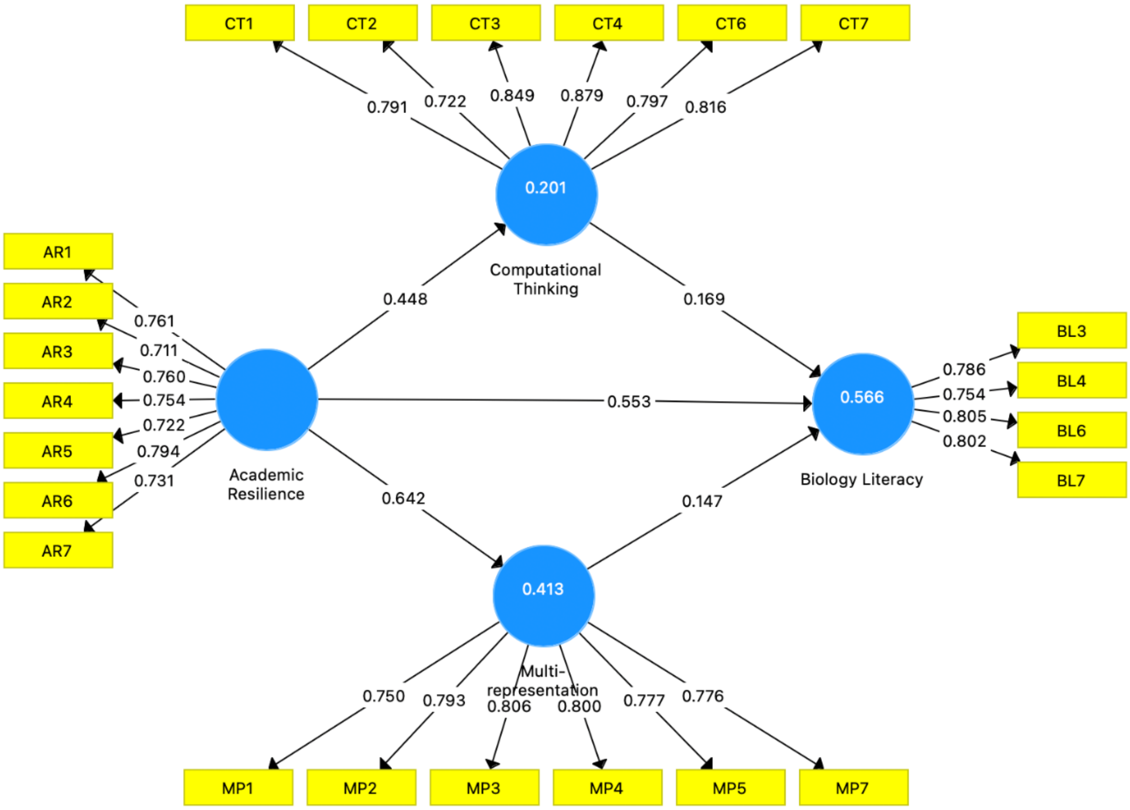

Figure 2. Structural model

in comprehending biology material and to employ more effective problem-solving strategies (Fauzi et al., 2021). The fundamental nature of academic resilience is the capacity to persevere, adapt, and rebound in the presence of academic challenges, which can influence students' computational thinking (CT) and multirepresentation (MP) (Anierobi et al., 2024; Liu et al., 2025; Salman et al., 2024). The capacity to deconstruct intricate biological issues into more manageable components can be influenced by the process of adapting to adversity (Husna et al., 2023). This enables students to approach problems in a more structured manner, utilizing methods such as algorithms in computational reasoning (Snow et al., 2019; Wang & Wang, 2024). As per the cognitive load theory, academic resilience enables students to mitigate cognitive burdens that may impede the learning process, thereby enhancing their capacity to manage the intricate information required for computational thinking (Shao & Kang, 2022). According to Tangkui (2023), students who are resilient are likely to be more inclined to employ a more structured approach to problem-solving, such as algorithms in computational thinking. Furthermore, these findings are also consistent with self-regulated learning theory, which posits that academic resilience fosters students' autonomy in managing their learning process, which includes the use of visual aids such as graphs or diagrams to comprehend abstract concepts (Yusupov et al., 2020). By fostering this resilience, students are able to employ more adaptive and effective strategies to overcome learning challenges, thereby enhancing their comprehension of the subject matter by fostering the development of computational thinking and multirepresentational skills.

The development of students' biological literacy is significantly influenced by computational reasoning. This is due to the fact that computational thinking skills enable students to deconstruct intricate biological problems into more manageable and structured ones (Wu et al., 2024). In biology education, numerous abstract concepts necessitate a logical approach to comprehend. Computational thinking enables students to identify patterns and relationships between biological concepts, thereby enhancing their ability to employ this knowledge more effectively in the context of problem-solving or experimentation (Hindun et al., 2020; Ningsih, 2020). The impact of computational thinking demonstrates that superior cognitive abilities directly contribute to a more profound comprehension of biological concepts. Furthermore, it has been demonstrated that multirepresentational, which encompasses the utilization of visual models, graphs, and diagrams, is a critical factor in the enhancement of students' biological literacy. Students comprehend abstract biological concepts in a more concrete and comprehensible manner through the use of visual representations (Fenwick & Unsworth, 2022). Students can visualize dynamic biological information, such as the life cycle of organisms or interactions between biological systems, through multirepresentational. Consequently, the capacity to employ these diverse representations is a substantial factor in the acquisition of biological literacy, as it facilitates the connection between theoretical concepts and their practical applications in the real world.

Academic resilience has the potential to significantly influence biological literacy. Students who possess a high level of academic resilience are capable of managing tension and overcoming obstacles that may arise during the learning process, as well as developing effective learning strategies to achieve a profound understanding. Academic resilience enables students to maintain their concentration and dedication to the acquisition of intricate biological concepts, thereby facilitating the development of a more comprehensive comprehension of abstract and dynamic material (Madjid et al., 2021). In addition, cognitive theory is consistent with these findings, which indicate that students who possess strong academic resilience are capable of managing cognitive load and coping with a significant amount of information, which facilitates the integration of biological concepts and their application in real-world scenarios (Montas et al., 2020). Consequently, academic resilience facilitates the development of biological literacy by enabling students to persist in their studies and surmount existing academic obstacles.

Academic resilience can indirectly influence biological literacy by facilitating computational thinking and multirepresentation, which enables students to confront challenges in the study of biology in a more effective and adaptive manner. The reduction of cognitive burden is facilitated by academic resilience, which enables students to effectively manage complex biological information. The development of computational thinking is facilitated by this resilience, which enables students to deconstruct intricate biological problems into more straightforward and systematic steps, thereby expediting the comprehension of biological concepts (Abdillah & Marleni, 2023). Furthermore, students are able to optimize the use of a variety of visual representations to clarify biological concepts by facilitating the implementation of more effective learning strategies, such as multirepresentation. Empirical research indicates that students who exhibit strong academic resilience are more adept at incorporating computational thinking skills and the use of multirepresentation in biology learning, thereby enhancing their biological literacy (Disastra et al., 2024; Setiawan et al., 2024). In general, this research is consistent with and enhances prior research on academic resilience, computational reasoning, multirepresentation, and biological literacy.

▪ CONCLUSION

Based on the results of data analysis and discussion that have been done, it can be concluded that academic resilience has a significant influence on students' biological literacy through the mediation of computational thinking skills and the ability to use multirepresentation. Students who have good academic resilience tend to be better able to face difficulties in learning biology and utilize more effective problem-solving strategies. Academic resilience also has an impact on the development of computational thinking skills that help students solve complex biological problems. In addition, students' ability to use multirepresentation, such as diagrams, graphs, and visual models, has also been shown to improve their understanding of abstract biological concepts. The use of these visual representations allows students to connect theory with practical applications in biology, which contributes to increasing biological literacy. This study shows that the combination of academic resilience, computational thinking, and multirepresentation has a major contribution to improving students' biological literacy. Therefore, biology learning should not only focus on mastering the material, but also on developing academic resilience and thinking skills that support long-term academic success.

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