BIO-EDU: JURNAL PENDIDIKAN BIOLOGI
Available in https://jurnal.unimor.ac.id/JBE/index
2026, Vol 11, Issue 2, pp 104-113, e-ISSN: 2527-6999
https://doi.org/10.32938/jbe.v11i2.11050

Profile of Epistemic Assessment Experiences in Science: Scientific Models in Biology Learning

Futri Fuspita Ayu[1*], Ana Ratna Wulan[1], Sariwulan Diana[1].
[1]Department of Biology Education, Faculty of Mathematics and Natural Sciences, Universitas Pendidikan Indonesia, Bandung, Indonesia

Article Information
Received: 2026-06-12
Revised: 2026-06-26
Accepted: 2026-07-07
Published: 2026-08-30

***Corresponding Author**
Futri Fuspita Ayu
(futriayu12@upi.edu)

Abstract

This study aims to describe high school students' experiences with the scientific model of epistemic assessment in biology learning. The method used was quantitative descriptive, involving 225 11th-grade students from ten high schools with A and B accreditations in the cities of Bandung and Cimahi. Data were collected using a four-point Likert-scale questionnaire with multiple-response options and semi-structured interviews, then analyzed descriptively by calculating mean scores and conducting a Mann-Whitney U test to compare the two school groups. The results showed that all sub-elements of epistemic assessment experiences in the scientific model fell into the "sometimes" category (2.39), with the sub-element "models for prediction and explanation" being the aspect most frequently present in assessments (2.50), while "limitations of models" and "differences between models and reality" were the aspects students experienced least frequently (2.31). A comparison based on school accreditation showed that the mean for schools with A accreditation was slightly higher than that for schools with B accreditation, but this difference was not statistically significant. These findings indicate that biology assessments are still dominated by the use of models to explain and predict phenomena.

Keywords: *Epistemic assessment; Scientific modeling; Biology education; Epistemic science knowledge; Science assessment*

Abstrak

Penelitian ini bertujuan menggambarkan pengalaman asesmen epistemik model ilmiah siswa SMA dalam pembelajaran biologi. Metode yang digunakan adalah deskriptif kuantitatif dengan melibatkan 225 siswa kelas XI dari sepuluh SMA berakreditasi A dan B di Kota Bandung dan Cimahi. Data dikumpulkan melalui kuesioner skala Likert empat tingkat yang dilengkapi *multiple response* dan wawancara semi-terstruktur, kemudian dianalisis secara deskriptif dengan menghitung rerata skor dan dilakukan uji Mann-Whitney U untuk membandingkan kedua kelompok sekolah. Hasil penelitian menunjukkan bahwa seluruh sub-elemen pengalaman asesmen epistemik model ilmiah berada pada kategori kadang-kadang (2,39), dengan sub-elemen model untuk prediksi dan penjelasan menjadi aspek yang paling sering hadir dalam asesmen (2,50), sementara keterbatasan model dan perbedaan model dengan kenyataan menjadi aspek yang paling jarang dialami siswa (2,31). Perbandingan berdasarkan akreditasi sekolah menunjukkan rerata akreditasi A sedikit lebih tinggi daripada akreditasi B, tetapi perbedaan tersebut tidak signifikan secara statistik. Temuan ini menunjukkan bahwa asesmen biologi masih didominasi oleh penggunaan model untuk menjelaskan dan memprediksi fenomena.

Kata Kunci: *Asesmen epistemik; Pemodelan ilmiah; Pendidikan biologi; Pengetahuan epistemik sains; Penilaian sains*

1. INTRODUCTION

The continuous development of scientific information and its increasing accessibility in the public sphere require students not only to understand scientific concepts, but also to understand how scientific knowledge is constructed, tested, and applied (Zetterqvist & Bach, 2023). Without an adequate epistemic foundation, students are more vulnerable to accepting or rejecting scientific information without critical consideration, particularly amid the growing spread of scientific misinformation (Sidik et al., 2025). In biology learning, this need becomes even more urgent because many biological phenomena are complex, dynamic, and cannot be directly observed. Consequently, students need to understand biological knowledge as the result of reasoning and the use of evidence, rather than merely memorizing facts. The development of these epistemic abilities can only be optimally achieved when students are actively engaged in authentic scientific practices, rather than passively receiving information (Inkinen et al., 2020).

Epistemic knowledge in science consists of four main elements: scientific models, data and evidence in scientific claims, the nature of scientific reasoning, and the collaborative and communal nature of science (OECD, 2023). Among these four elements, scientific models play a central role in biology learning, not merely as visual aids, but as ways of thinking that enable students to explain, predict, and evaluate phenomena that cannot be directly observed, while also helping them make decisions based on scientific reasoning in real-life contexts (Chiu & Lin, 2019; Wilson et al., 2020). Understanding scientific models epistemically means not only being able to use them, but also understanding the nature and purpose of models as tentative and revisable representations (Jansen et al., 2019). However, in practice, secondary school students still tend to use models at a descriptive level and are not yet able to evaluate their limitations or revise them based on evidence (Tillah & Subekti, 2025; Chiu & Lin, 2019).

The development of epistemic understanding of scientific models is determined not only by instruction, but also by the assessments students experience. Assessment plays a role beyond evaluation because it also shapes what is considered important to learn and master (Lee et al., 2021). Assessments that target epistemic understanding of scientific models can provide meaningful feedback for students to recognize the limitations of models and revise them based on evidence (Schwarz et al., 2025; Erduran et al., 2021). Empirical evidence indicates that formative assessments integrated with modeling activities are more effective in developing students' scientific thinking skills compared to assessments based on memorization (Rahmi et al., 2025). In addition, assessment results provide diagnostic information for teachers to better adjust instruction to students' needs (Minshew et al., 2022).

Existing research has largely focused on instructional interventions to improve modeling skills (Manee & Nuangchalerm, 2023; Chan et al., 2025), while how students experience scientific model assessments in school has rarely been studied (Lieberei et al., 2024; Fairuz & Putri, 2025). The actual state of epistemic assessment practices of students' scientific models has not been adequately mapped, particularly regarding the extent to which such assessments are implemented and which aspects remain neglected. Therefore, mapping students' assessment experiences is crucial as a foundation for gaining insight into the implementation of epistemic assessment of scientific models in biology learning practices (Rifan & Latif, 2025).

Unlike previous studies that focused on learning interventions, this study specifically maps students' epistemic assessment experiences related to the scientific model in biology classrooms at the high school level in Indonesia. The novelty of this study lies in the use of the scientific model's sub-element framework which references the OECD science framework as the basis for mapping students' assessment experiences in the field; this framework has traditionally been used more in the context of instrument development than in documenting actual classroom conditions. Therefore, this study aims to profile students' epistemic science assessment experiences regarding the scientific model in biology learning as a basis for developing assessments that are more aligned with the epistemic goals of biology learning.

2. METHOD

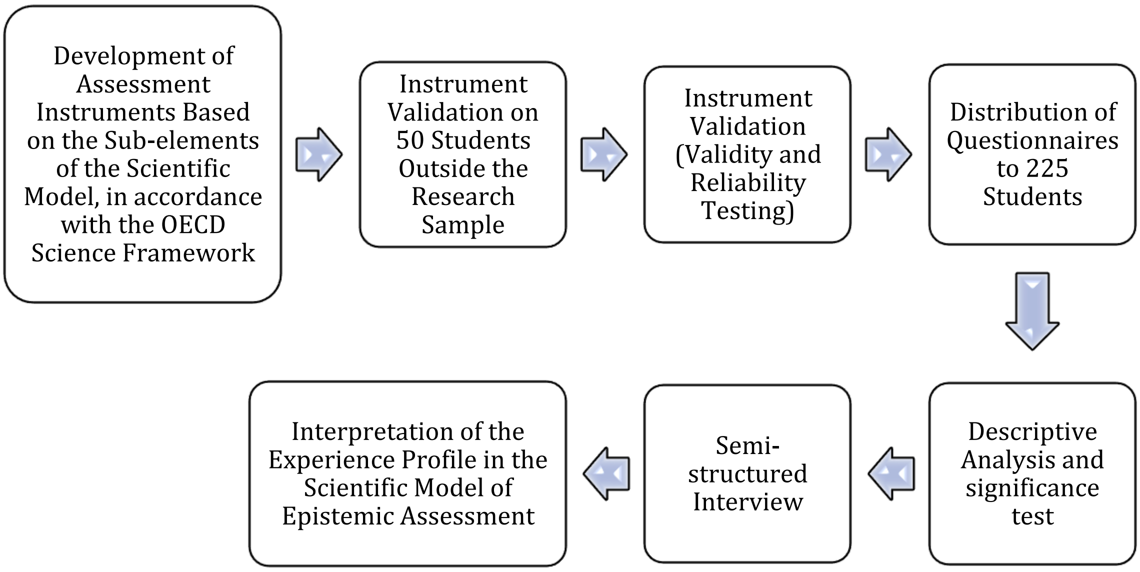
2.1. Research Design

This study employed a quantitative descriptive method. This method was chosen to describe the profile of students' experiences with epistemic assessment of scientific models in biology learning based on actual conditions in the field. Through this approach, the study focused on describing the actual conditions of students' assessment experiences without providing any treatment or intervention.

2.2. Population and Sample

The population of this study consisted of eleventh-grade students from ten senior high schools in Bandung and Cimahi. The sample was selected using a purposive sampling technique based on the criterion that the schools implemented biology learning with an emphasis on scientific thinking processes. Based on these criteria, the study involved 130 female students and 95 male students from schools accredited A and B. All participants had completed tenth-grade biology learning relevant to the understanding of scientific models.

2.3. Research Procedure



(**Figure 1.** Research Procedure)

The study was conducted through several stages. First, the questionnaire instrument was developed based on the sub-elements of scientific models referring to the science assessment framework developed by the Organisation for Economic Co-operation and Development (OECD). The questionnaire was then piloted with 50 students outside the research sample. Afterward, validity and reliability tests were conducted. The validity test was performed using Pearson correlation, with items considered valid when the calculated r-value exceeded the r-table value at a 5% significance level. The results of the validity test indicated that all questionnaire items were valid. The reliability test was conducted using Cronbach's Alpha coefficient based on the criteria proposed by Cohen *et al.* (2007), resulting in a coefficient value of 0.761, which was categorized as reliable. After the instrument was declared feasible, the questionnaire was distributed to the research sample. The questionnaire data were then analyzed descriptively to identify preliminary findings and to compare the assessment experiences of students from schools with A and B accreditations; a statistical significance test was conducted. Subsequently, semi-structured interviews were conducted with eight selected respondents to clarify and confirm the initial analysis results. All data were then interpreted to produce a profile of students' experiences with epistemic assessment of scientific models. The research procedure is presented in Figure 1.

2.4. Research Instrument

The main instrument used in this study was a questionnaire on students' experiences with the epistemic assessment of scientific models. The questionnaire was developed based on the four sub-elements of scientific models in the OECD Science Framework (2023) and employed a four-point Likert scale: 1 = Never, 2 = Sometimes, 3 = Often, and 4 = Always. The questionnaire framework is presented in Table 1.

Table 1. Questionnaire Outline on Experiences with the Scientific Model of Epistemic Assessment in Biology Education

Sub-elements of Scientific Models	Biology Assessment Experience Indicators	Number of Items
Models in Science	Assessments that require students to create, read, or interpret models as representations of biological phenomena	4
Differences Between Models and Reality	Assessments that require students to explain the differences between models and real-world phenomena	4
Models for Prediction and Explanation	Assessments that require students to use models to explain relationships among variables or to predict the outcomes of biological phenomena	4
Limitations of Models	Assessments that require students to identify the limitations of models, alternative models, or the need to revise models based on new data	4
Total		16

In addition to the closed-ended questionnaire, the instrument was also complemented with four open-ended multiple-response questions as supporting data. The interview guideline was developed based on the indicators of epistemic assessment experiences related to scientific models and aimed to explore more deeply students experiences in dealing with assessments related to scientific models in biology learning.

2.5. Data Analysis

The questionnaire data were analyzed using descriptive statistics by calculating the mean score for each sub-element to profile students epistemic assessment experiences of the scientific model. The mean score was calculated using the formula by Nurgiyantoro, et.al. (2012) as follows: $\bar{X} = \Sigma X/N$, where $\bar{X}$ is the mean value, ΣX is the sum of all respondents' scores, and N is the number of respondents. The mean results were then categorized based on the score ranges of the four-point Likert scale used in this study, as presented in Table 2. The determination of category ranges was performed using the interval formula according to Sugiyono (2020), namely interval = (highest score − lowest score) / number of categories, resulting in an interval value of $(4 - 1) / 4 = 0.75$. In addition to descriptive analysis, a t-test was also conducted to compare students' experiences with the scientific model of epistemic assessment between those from schools with A and B accreditation. Prior to the t-test, a normality test was performed using the Shapiro-Wilk test. The test results showed that the data distribution in the A-accredited group did not meet the assumption of normality ($p = 0.022$), so the Mann-Whitney U test was used as a nonparametric alternative. Data processing was conducted using Microsoft Excel and SPSS. Data from open-ended questions were analyzed descriptively, while interview data were analyzed using simple thematic analysis to support the clarification and reinforcement of the interpretation of quantitative findings.

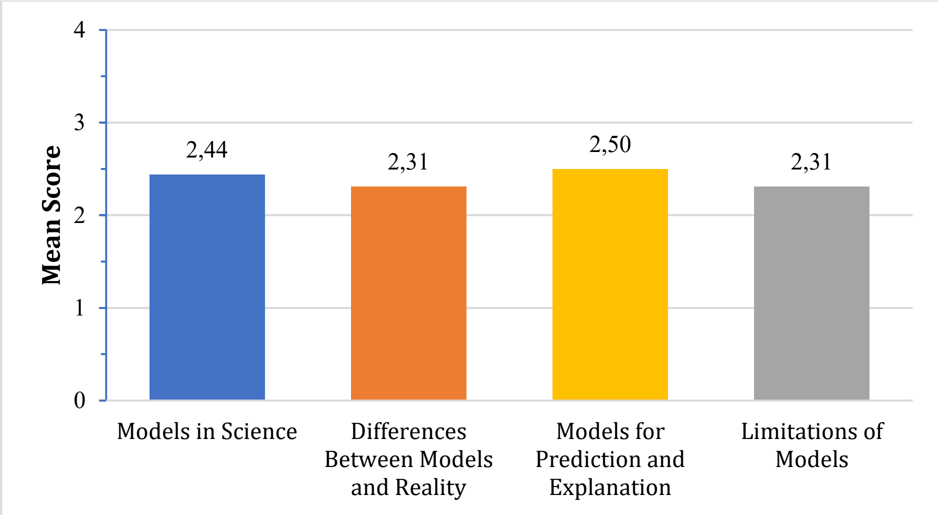
Table 2. Categorization of Questionnaire Mean Scores

Mean Score	Category
1,00 – 1,75	Never
1,76 – 2,50	Sometimes
2,51 – 3,25	Often
3,26 – 4,00	Always

3. RESULT AND DISCUSSION

3.1. Profile of Epistemic Assessment Experiences Related to Scientific Models in Biology Learning

Students' experiences with epistemic assessment of the scientific model in biology learning provide insight into their engagement with the assessment they received. The analysis focused on four sub-elements of the scientific model as defined in the OECD Science Framework. The assessment experience profiles for each sub-element are presented in Figure 2.



(**Figure 2.** Profile of Epistemic Assessment Experience in the Scientific Model for Each Sub-element)

Based on Figure 2, students' experiences with epistemic assessment of the scientific model in biology learning as a whole fall into the "sometimes" or "still rarely" categories in the classroom. The sub-elements of the model related to prediction and explanation received the highest average score (2.50), followed by the model in science (2.40), while the differences between the model and reality, as well as the limitations of the model, both received the lowest average score (2.31).

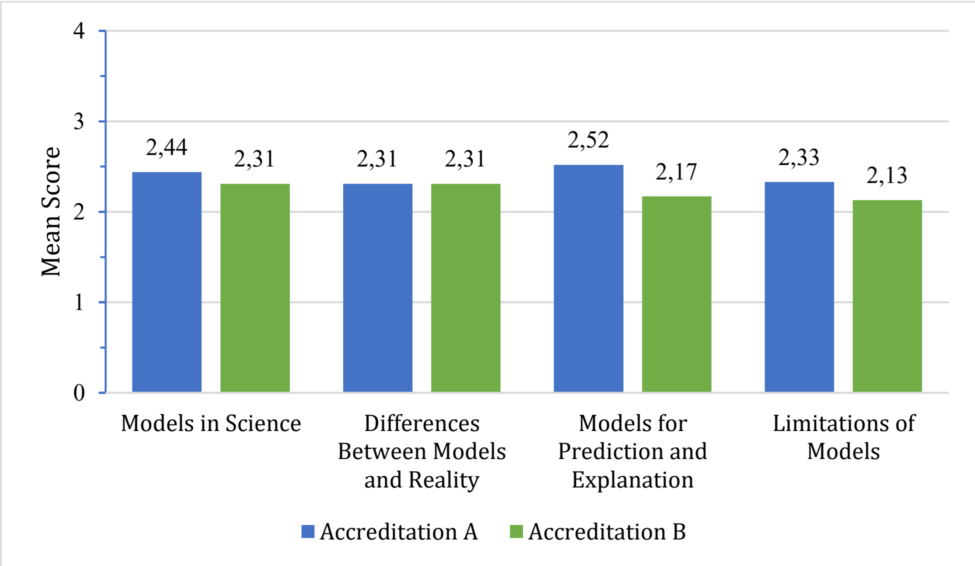
These average patterns indicate that the biology assessments students encounter generally still treat models as tools for explaining and predicting phenomena, while evaluative aspects such as assessing the limitations of models and comparing them to real-world conditions are still rarely practiced. In biology learning, the scientific models in question can include cell diagrams, ecosystem diagrams, food chain diagrams, or representations of viral and bacterial structures. The assessments administered generally remain limited to asking students to read, complete, or use these models to explain biological processes such as the relationships among ecosystem components based on food chain diagrams or identifying cell parts based on provided images without encouraging students to question the extent to which the models represent real-world conditions or which aspects of the actual phenomena have been simplified.

This situation aligns with Chang (2022) findings, which show that models in the classroom are more often used to help visualize phenomena than to foster critical reasoning. Conceptually, scientific models should not only help represent phenomena but also enable students to connect evidence, explanations, and theories in a more reflective manner (Louca & Zacharia, 2012). When students are rarely asked to assess the limitations of models or compare models with real-world conditions, opportunities to enhance epistemic understanding are also limited (Chiu & Lin, 2019; Schwarz et al., 2025). These findings align with those of Habsari et al. (2025), who noted that students' understanding of biology remains largely descriptive and has not yet evolved toward deeper reasoning.

These findings are supported by multiple-response data and interviews. Students are generally more familiar with assessments that ask them to use or explain existing models rather than construct, compare, or critique them. This is reflected in a statement from one student when asked whether they had ever been asked to evaluate the weaknesses of a model in a biology question; the student replied, "*never, usually, we're just told to explain using pictures, like the predator-prey relationships* between *organisms in a food chain.*" Thus, the assessment of scientific models in biology education remains representational in orientation and does not yet fully support the development of students' epistemic reasoning.

3.2. Students' Experiences with the Epistemic Assessment of Scientific Models Based on School Accreditation

To gain a deeper understanding, the analysis of students' epistemic assessment experiences with the scientific model was also examined in relation to school accreditation. The results showing the differences in mean scores for each sub-element are presented in Figure 3.



(**Figure 3.** Mean Scores on the Scientific Model Epistemic Assessment for Each Sub-element by School Accreditation)

Based on Figure 3, students from accreditation A schools showed slightly higher mean scores of assessment experiences compared to students from accreditation B schools across almost all sub-elements. The most noticeable difference was found in the sub-element models for prediction and explanation. To present a more detailed comparison of the scores, including the highest and lowest scores in each accreditation group, the analysis results are presented in Table 2.

Table 3. Mean Scores on the Scientific Model Epistemic Assessment Based on School Accreditation

Sub-element	Mean Score		Highest Score		Lowest Score	
	Accreditation A	Accreditation B	Accreditation A	Accreditation B	Accreditation A	Accreditation B
Models in Science	2,44 (Sometimes)	2,31 (Sometimes)	4,00	3,00	1,25	1,50
Differences Between Models and Reality	2,31 (Sometimes)	2,31 (Sometimes)	4,00	3,25	1,00	1,50
Models for Prediction and Explanation	2,52 (Often)	2,17 (Sometimes)	4,00	3,00	1,00	1,50
Limitations of Models	2,33 (Sometimes)	2,13 (Sometimes)	4,00	3,00	1,00	1,25

Based on Table 3, students from schools with A accreditation showed slightly higher averages than those from schools with B accreditation across all sub-elements, with the most striking difference observed in the "models for prediction and explanation" sub-element (A accreditation = 2.52; B accreditation = 2.17). The only sub-element showing identical means across both groups was the difference between the model and reality (Accreditation A and B = 2.31). To determine whether these mean differences were statistically significant, a Mann-

Whitney U test was conducted, and the results indicated no significant difference between the two groups ($U = 1026.500$; $Z = -1.148$; $p = 0.251$).

Although the mean for Accreditation A was consistently higher, the statistical test results indicate that this difference is not statistically significant, meaning that school accreditation is not statistically associated with students' experiences of epistemic assessment of the scientific model. More interestingly, both school groups exhibited similar patterns of epistemic orientation; the evaluative sub-elements—namely, the limitations of the model and the differences between the model and reality—remained the aspects least frequently present in classroom assessments, regardless of the school's accreditation.

This similarity in patterns indicates that the limitations of epistemic assessments of the scientific model are systemic and do not occur in just one type of school. Nurfitriani et al. (2018) found that biology assessments in schools are still more oriented toward cognitive mastery than toward epistemological thinking skills, while An Nisaa and Maesaroh (2022) also demonstrated that biology instruction is still more frequently oriented toward content mastery rather than the development of students' scientific reflection; consequently, the evaluative dimension of modeling has not received much attention in classroom assessment practices. This situation is also related to teachers' readiness to design assessments that encourage epistemic reflection, consistent with the findings of Astriningrum and Widodo (2025), who found that even prospective biology teachers still face difficulties in guiding students to critically interpret data and scientific representations. Sidik et al. (2025) also emphasize that the limitations of epistemic assessment instruments in the context of biology in Indonesia remain a systemic barrier, which explains why similar patterns emerged in both school groups.

These statistical findings are reinforced by multiple-response data from both school groups. Students in both groups indicated that experiments and simulations were the most frequently used forms of assessment. The most dominant activity was using models to predict and explain phenomena, while comparing two models was the activity students engaged in least frequently. This pattern is consistent with the quantitative results and indicates that the quality of students' epistemic assessment experiences regarding scientific models is more closely related to how teachers design assessments than to the school's institutional context itself, in line with the findings of Nurdini et al. (2020) and Nurhijah et al. (2020), who state that an explicit formative assessment design that encourages reflection has a greater impact on the development of students' scientific thinking than institutional factors.

4. CONCLUSION

Students' epistemic assessment experiences of scientific models in biology learning as a whole fall into the "sometimes" category, with the sub-elements of models for prediction and explanation being the aspects most frequently present in assessments, while the limitations of models and the differences between models and reality are the aspects students experience least often. This pattern indicates that biology assessments remain representational in orientation and do not yet adequately encourage students to critically evaluate, compare, or revise scientific models. A comparison based on school accreditation shows that students from A-accredited schools have a slightly higher average than those from B-accredited schools; however, this difference is not statistically significant. Both groups exhibit similar patterns of epistemic orientation, with the evaluative dimension of modeling being equally absent in the assessments. This indicates that the limitations of epistemic assessment of scientific models are systemic and are not determined by school accreditation, but rather by how teachers design assessments in the classroom and how students are accustomed to responding to them. Therefore, the development of biology assessments needs to be more focused on providing opportunities for students to critically evaluate, compare, and revise scientific models. In this way, assessments will not only measure conceptual understanding but also support the more comprehensive development of students' scientific thinking.

5. ACKNOWLEDGMENT

The author would like to thank all the schools and students who participated in this study, as well as everyone who supported the conduct of this research.

6. REFERENCES

An Nisaa, R., & Maesaroh. (2022). Analisis Buku Ajar Biologi SMA Kelas XI Materi Sistem Peredaran Darah dan Sistem Endokrin. *BIO-EDU: Jurnal Pendidikan Biologi*, *7*(1), 61–67. https://doi.org/10.32938/jbe.v7i1.1949

Astriningrum, D., & Widodo, A. (2025). Preservice biology t eachers ' readiness to teach inquiry lessons : A reflective analysis from microteaching class. *Assimilation Indonesian Journal of Biology Educational*, *8*(2), 137–146. https://doi.org/10.17509/aijbe.v8i2.85723

Chan, K. K. H., Lau, D. S. P., & van Driel, J. (2025). Different Designs, Different Outcomes? A Critical Systematic Review of Interventions for Preparing Preservice Science Teachers to Teach Scientific Models and Modeling. *Science Education*, *109*(2), 386–428. https://doi.org/10.1002/sce.21911

Chang, H. Y. (2022). Science teachers' and students' metavisualization in scientific modeling. *Science Education*, *106*(2), 448–475. https://doi.org/10.1002/sce.21693

Chiu, M. H., & Lin, J. W. (2019). Modeling competence in science education. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), 1–11. https://doi.org/10.1186/s43031-019-0012-y

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education* (6th ed.). Routledge. DOI: https://doi.org/10.4324/9780203029053.

Erduran, S., Ioannidou, O., & Baird, J. A. (2021). The impact of epistemic framing of teaching videos and summative assessments on students' learning of scientific methods. *International Journal of Science Education*, *43*(18), 2885–2910. https://doi.org/10.1080/09500693.2021.1998717

Fairuz, T., & Putri, M. D. (2025). Epistemic Knowledge Assessment Instrument on Energy Crisis Material for Junior High School Students. *INKUIRI: Jurnal Pendidikan IPA*, *14*(2), 109. https://doi.org/10.20961/inkuiri.v14i2.101249

Habsari, K. Y., Sumarno, & Rahayu, P. (2025). Identifikasi Faktor Penyebab Miskonsepsi Siswa dengan Menggunakan Five-Tier pada Materi Menjelajah Sel Kelas XI. *BIO-EDU: Jurnal Pendidikan Biologi*, *10*(2), 121–128. https://doi.org/10.32938/jbe.v10i2.7787

Inkinen, J., Klager, C., Juuti, K., Schneider, B., Salmela-Aro, K., Krajcik, J., & Lavonen, J. (2020). High school students' situational engagement associated with scientific practices in designed science learning situations. *Science Education*, *104*(4), 667–692. https://doi.org/10.1002/sce.21570

Jansen, S., Knippels, M. C. P. J., & van Joolingen, W. R. (2019). Assessing students ' understanding of models of biological processes : a revised framework processes : a revised framework. *International Journal of Science Education ISSN:*, *41*(8), 981–994. https://doi.org/10.1080/09500693.2019.1582821

Lee, D., Wright, M., Faber, C., Kennedy, C., & Dittrich-Reed, D. (2021). Participation in biology education research influences students' epistemic development. *CBE Life Sciences Education*, *20*(4). https://doi.org/10.1187/CBE.20-11-0255

Lieberei, T., Großmann, L., Welter, V. D. E., Krüger, D., & Krell, M. (2024). Considering Multiple Sources of Validity Evidence Can Help to Address Challenges in the Development of Pedagogical Content Knowledge (PCK) Multiple-Choice Items. *Research in Science Education*, 1349–1369. https://doi.org/10.1007/s11165-024-10227-9

Louca, L. T., & Zacharia, Z. C. (2012). Modeling-based learning in science education: Cognitive, metacognitive, social, material and epistemological contributions. *Educational Review*, *64*(4), 471–492. https://doi.org/10.1080/00131911.2011.628748

Manee, K., & Nuangchalerm, P. (2023). Development of grade 10 students' modelling skills on circulatory system through model-based learning. *Journal of Advanced Sciences and Mathematics Education*, *3*(2), 113–120. https://doi.org/10.58524/jasme.v3i2.321

Minshew, L. M., Anderson, J. L., & Bartlett, K. A. (2022). Outside the standard test: The development of a model-based assessment and corresponding rubric. *Instructional Science*, *50*(4), 599–624. https://doi.org/10.1007/s11251-022-09582-9

Nurdini, Y., Wulan, A. R., & Diana, S. (2020). Assessment for learning through written feedback to develop 21st-century critical thinking skills on plantae learning. *Journal of Physics: Conference Series*, *1521*(4). https://doi.org/10.1088/1742-6596/1521/4/042019

Nurfitriani, Wulan, A. R., & Anggraeni, S. (2018). Pengembangan Asesmen Kinerja untuk Menilai Keterampilan Proses Sains Terintegrasi Siswa pada Konsep Ekosistem. *Assimilation: Indonesian Journal of Biology Education*, *1*(1), 33–38. https://doi.org/10.17509/aijbe.v1i1.11454

Nurgiyantoro, B., Gunawan, & Marzuki. (2012). *Statistik Terapan untuk Penelitian Ilmu-Ilmu Sosial*. Gadjah Mada University Press.

Nurhijah, S. S., Wulan, A. R., & Diana, S. (2020). Implementation of formative assessment through oral feedback to develop 21st century critical thinking skills of student on plantae learning. *Journal of Physics: Conference Series*, *1521*(4). https://doi.org/10.1088/1742-6596/1521/4/042021

OECD. (2023). Pisa 2025 Science Framework (Draft). 1–93. https://pisa-framework.oecd.org/science-2025/assets/docs/PISA_2025_Science_Framework.pdf

Rahmi, S. N., Megawati, Alberida, H., & Fadilah, M. (2025). Assessment of biology learning outcomes in education: A systematic literature review. *Biosfer: Jurnal Pendidikan Biologi*, *18*(1), 10–25. https://doi.org/10.21009/biosferjpb.47179

Rifan, N. M., & Latif, A. A. (2025). Constructive Alignment as a Framework for Enhancing Motivation and Higher - Order Thinking in Science Classrooms : A Systematic Synthesis. *International Journal of Research and Innovation in Social Science*, *9*(26), 8078–8086. https://doi.org/10.47772/IJRISS

Schwarz, C. E., DeGlopper, K. S., Greco, N. C., Russ, R. S., & Stowe, R. L. (2025). Modeling Student Negotiation of Assessment-Related Epistemological Messages in a College Science Course. *Science Education*, *109*(2), 429–447. https://doi.org/10.1002/sce.21914

Sidik, R. M., Wulan, A. R., & Kusnadi, K. (2025). Development and validation an instrument for evaluating epistemic knowledge: Educational biology context. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *11*(3), 848–858. https://doi.org/10.22219/jpbi.v11i3.41420

Sugiyono. (2020). *Metode Penelitian Kuantitatif, Kualitatif, dan Kombinasi R&D.* Bandung: PT Alfabet

Tillah, N. F., & Subekti, H. (2025). Analisis Kemampuan Literasi Sains Siswa SMP Berdasarkan Indikator dan Level Literasi Sains. *Edusaintek: Jurnal Pendidikan, Sains Dan Teknologi*, *12*(1), 137–154. https://doi.org/10.47668/edusaintek.v12i1.1271

Wilson, K. J., Long, T. M., Momsen, J. L., & Speth, E. B. (2020). Modeling in the classroom: Making relationships and systems visible. *CBE Life Sciences Education*, *19*(1), 1–5. https://doi.org/10.1187/cbe.19-11-0255

Zetterqvist, A., & Bach, F. (2023). Epistemic knowledge–a vital part of scientific literacy? *International Journal of Science Education*, *45*(6), 484–501. https://doi.org/10.1080/09500693.2023.2166372