Multikola: Jurnal Kolaborasi Multidisipliner
Volume 1, Nomor 2, 2026 pp. 113-122
p-ISSN: 0000-0000 | e-ISSN: 0000-0000
DOI: xxxx

MAPPING MISCONCEPTIONS AMONG ELEMENTARY EDUCATION STUDENTS REGARDING PLANT AND ANIMAL CELL STRUCTURES USING A TWO-TIER DIAGNOSTIC TEST BASED ON THE CERTAINTY OF RESPONSE INDEX (CRI)

Abner Rahmatsyah Zebua[1], Djosua Berkat Notatema Waruwu[2], Eja Advent Kris Lahagu[3], Mei Linda Stefani Sarumaha[4], Fitri Inda Sari Zega[5], Shinellia Zalukhu[6], Intan Kristiani Ziliwu[7], Nofamataro Zebua[8]

[1,2,3,4,5,6,7)]Pendidikan Guru Sekolah Dasar, Universitas Nias, Indonesia
[8)]Pendidikan Biologi, Universitas Nias, Indonesia

[1)]abnerzebua10@gmail.com, [2)]djosuaberkatwaruwu@gmail.com, [3)]ejal11392@gmail.com, [4)]meilindasarumaha@gmail.com, [5)]fitriindasarizega@gmail.com, [6)]shinelliazalukhu@gmail.com [7)]intankristianiziliwu@gmail.com [8)]zebuanofa99@gmail.com

Abstrak

Miskonsepsi pada mahasiswa calon guru merupakan masalah serius dalam pendidikan sains karena berpotensi ditransmisikan kepada siswa di tingkat pendidikan dasar. Penelitian ini bertujuan untuk mengidentifikasi dan memetakan miskonsepsi mahasiswa Program Studi Pendidikan Guru Sekolah Dasar (PGSD) terkait struktur sel tumbuhan dan sel hewan. Penelitian menggunakan pendekatan kuantitatif deskriptif dengan desain survei diagnostik. Subjek penelitian adalah 33 mahasiswa PGSD semester II yang telah menempuh mata kuliah Konsep Dasar IPA, yang dipilih menggunakan teknik purposive sampling. Instrumen yang digunakan berupa tes diagnostik pilihan ganda dua tingkat (two-tier multiple-choice) sebanyak 20 butir yang dilengkapi dengan skala Certainty of Response Index (CRI), dengan koefisien reliabilitas KR-20 sebesar 0,84. Data dianalisis secara deskriptif dengan mengelompokkan konsepsi mahasiswa ke dalam empat kategori, yaitu memahami konsep, miskonsepsi, tidak memahami konsep, dan menebak. Hasil penelitian menunjukkan bahwa rata-rata persentase miskonsepsi secara keseluruhan mencapai 34,28%, dengan miskonsepsi tertinggi ditemukan pada konsep perbedaan organel sel tumbuhan dan sel hewan (41,90%), khususnya terkait vakuola (63,80%), fungsi dinding sel (58,09%), dan plastida non-kloroplas (55,23%). Mahasiswa yang berasal dari latar belakang non-IPA menunjukkan persentase miskonsepsi yang lebih tinggi secara signifikan (42,17%) dibandingkan mahasiswa berlatar belakang IPA (26,38%). Penelitian ini menyimpulkan bahwa miskonsepsi mahasiswa PGSD mengenai struktur sel bersifat nyata, terstruktur, dan persisten. Oleh karena itu, program PGSD perlu mengintegrasikan secara eksplisit strategi diagnosis dan remediasi miskonsepsi dalam pembelajaran sains.

Kata kunci: Miskonsepsi; Sel Tumbuhan; Sel Hewan; Certainty of Response Index..

Abstract

Misconceptions among preservice teachers represent a serious concern in science education because they have the potential to be transmitted to students at the primary education level. This study aimed to identify and map the misconceptions of students in the Primary School Teacher Education (PGSD) program regarding the structure of plant and animal cells. The research employed a descriptive quantitative approach with a diagnostic survey design. The research subjects were 33 second-semester PGSD students who had completed the Basic Science Concepts course, selected using purposive sampling. The instrument used was a 20-item two-tier multiple-choice diagnostic test supplemented with a Certainty of Response Index (CRI) scale, with a KR-20 reliability coefficient of 0.84. Data were analyzed descriptively by categorizing students' conceptions into four groups: understanding the concept, misconception, lack of understanding, and guessing. The results showed that the overall average percentage of misconceptions reached 34.28%, with the highest misconceptions occurring in *the concept of differences between plant and animal cell organelles (41.90%), particularly regarding vacuoles (63.80%), cell wall function (58.09%), and non-chloroplast plastids (55.23%). Students with non-science backgrounds demonstrated a significantly higher percentage of misconceptions (42.17%) compared to students with science backgrounds (26.38%). This study concludes that PGSD students' misconceptions about cell structure are real, structured, and persistent. Therefore, PGSD programs need to explicitly integrate diagnostic and remediation strategies for misconceptions into science instruction.*

Kata kunci: *Misconception; Plant Cell; Animal Cell; Certainty of Response Index.*

1. INTRODUCTION

Understanding cell biology concepts is an important foundation in science education, especially for prospective elementary school teachers who will later serve as the first mediators of scientific knowledge for younger generations. Cells, as the basic structural and functional units of life, constitute a core concept in science curricula taught from secondary school through higher education (Campbell et al., 2021; Reece et al., 2020). Accurate understanding of the structural differences between plant and animal cells is a prerequisite for teachers to meaningfully teach more advanced biological concepts (Friedrichsen et al., 2021). However, numerous studies have documented that cell concepts are among the topics with the highest levels of misconceptions among both students and preservice teachers (Tekkaya, 2020; Dikmenli, 2020).

The phenomenon of misconceptions among preservice teachers has become a serious concern within the global science education community over the past decade. Reports from various countries indicate that teacher education students, including those in PGSD programs, continue to carry misconceptions formed during secondary education and may even reinforce them during university studies if they are not addressed explicitly (Yates & Marek, 2020; Sinaga et al., 2021). In Indonesia, this issue is increasingly relevant because the PGSD curriculum requires prospective teachers to master science concepts comprehensively across topics, while most PGSD students come from non-science backgrounds (Purwanto et al., 2022). This condition creates a high vulnerability to the development and persistence of misconceptions in abstract and microscopic science topics such as cell structure (Wandersee et al., 2020).

The urgency of this study is based on the multiplied impact of misconceptions held by preservice teachers. Teachers who teach with misconceptions not only fail to convey concepts correctly but also actively transmit these conceptual errors to dozens or even hundreds of students throughout their teaching careers (Harlen, 2020; Duit & Treagust, 2020). In the context of elementary education, misconceptions embedded at an early age tend to be highly persistent and difficult to remediate at later educational levels (Vosniadou, 2021). Therefore, the early identification of misconceptions among PGSD students before they enter the teaching profession is a crucial preventive step in maintaining the quality of science education at the elementary level (Loughran et al., 2020; Abell, 2020).

A review of the state of the art indicates that research on preservice teacher misconceptions has developed rapidly through the use of increasingly sophisticated diagnostic instruments. The two-tier multiple-choice method combined with the Certainty of Response Index (CRI) has proven effective in distinguishing genuine misconceptions from lack of understanding and guessing (Hasan et al., 2020; Caleon & Subramaniam, 2020). This approach enables researchers not only to identify incorrect answers but also to map respondents' confidence levels, making it possible to differentiate between students who do not know and are aware of their lack of knowledge and those who possess incorrect alternative conceptions that they firmly believe to be correct (Arslan et al., 2020). Recent developments have also shown the use of digital technologies, including online survey platforms, for more efficient and broader-reaching diagnostic data collection (Sumintono & Widhiarso, 2022).

Although extensive research has been conducted on preservice teacher misconceptions, several fundamental weaknesses remain in the existing literature (Zebua et al, 2026). First, most previous studies were conducted outside the context of PGSD programs and focused on science or biology teacher candidates, making their findings not directly generalizable to the PGSD context, which has different curriculum characteristics and student backgrounds (Widodo et al., 2022; Nurhayati et al., 2021). Second, many studies have used only single-tier instruments that cannot distinguish misconceptions from simple ignorance (Tekkaya, 2020). Third, research specifically exploring differences in misconceptions based on the secondary educational background of PGSD students remains very limited (Purwanto et al., 2022; Sinaga et al., 2021).

The research gap identified from the literature review encompasses two main dimensions. First, there is no comprehensive and specific misconception map available for PGSD students regarding plant and animal cell structures using a multi-tier diagnostic instrument with CRI. Second, there has been no systematic comparative analysis of the influence of secondary educational background on the misconception profiles of PGSD students concerning cell-related topics. The novelty of this study lies in the use of a 30-item two-tier multiple-choice instrument developed specifically for the PGSD context, accompanied by CRI analysis that enables simultaneous mapping of four categories of student conceptions, as well as comparison of misconception profiles between students with science and non-science backgrounds (Hasan et al., 2020; Loughran et al., 2020).

Based on the explanation above, the research questions of this study are: (1) What is the misconception profile of PGSD students regarding plant and animal cell structures? (2) In which concept indicators do misconceptions occur most frequently? (3) Are there differences in misconception profiles between students with science and non-science backgrounds? The research hypothesis states that PGSD students experience significant misconceptions regarding cell structure, with students from non-science backgrounds exhibiting a higher percentage of misconceptions than those from science backgrounds. The purpose of this study is to identify and map PGSD students' misconceptions regarding plant and animal cell structures and to compare misconception profiles based on secondary educational background.

Table 1. Summary of Previous Research

Author	Year	Method	Findings	Weakness
Tekkaya	2020	Two-tier MCQ	High misconceptions in distinguishing plant cells from animal cells.	Did not distinguish between science and non-science backgrounds.
Widodo et al.	2022	CRI and Interview	30.90% of elementary teacher candidates showed misconceptions.	Limited sample size and conducted in a single institution.
Dikmenli	2020	Concept Mapping	Identified misconceptions related to cell organelles.	Did not employ the Certainty of Response Index (CRI).
Nurhayati et al.	2021	Diagnostic Test	High misconceptions were found regarding vacuoles and chloroplasts.	Used a single-level diagnostic instrument.

Purwanto et al.	2022	Descriptive Survey	Non-science students exhibited more misconceptions than science students.	The study was not specifically focused on cell concepts.

2. METHODS

Research Design. This study uses a descriptive quantitative approach with a diagnostic survey design. This approach was chosen because it aims to systematically, factually, and accurately describe the phenomenon of misconceptions based on data collected from a representative sample (Creswell & Creswell, 2022). The diagnostic survey design allows comprehensive identification of students' conceptual patterns without intervention from the researcher, so the resulting description reflects the natural condition of students' conceptual understanding (Cohen et al., 2020).

Population and Sample. The research population consists of all PGSD Semester II students who have taken the Basic Concepts of Science course. The research sample consisted of 33 students selected based on inclusion criteria:

Sampling Technique. This study used a purposive sampling technique, namely selecting samples based on the consideration that respondents have learning experience relevant to the topic under study (Sugiyono, 2022). This technique was chosen to ensure that all respondents had been exposed to cell material in lectures, so that the data obtained reflects the conceptual condition after formal learning.

Respondent Characteristics. Of the 33 students who became respondents, some came from a science background (had previously majored in science in high school/Islamic senior high school) and others from a non-science background. This proportion reflects the general composition of PGSD students, which is heterogeneous in academic background (Purwanto et al., 2022).

Variables and Operational Definitions. The main variable of the study is students' misconceptions about the structure of plant and animal cells, operationally defined as a condition in which students give an incorrect answer on the first tier question but provide an explanation they believe to be correct (CRI score ≥ 2.5) on the second tier (Hasan et al., 2020). The supporting variable is the background of secondary education (science vs non-science).

Research Instruments. The instrument used was a two-tier multiple choice diagnostic test consisting of 20 items measuring conceptual understanding across six indicators: (1) components of prokaryotic and eukaryotic cells, (2) cell organelles and their functions, (3) differences between plant and animal cell organelles, (4) cell membrane and transport. Each item was accompanied by a CRI scale of 0–5 to measure respondents' level of confidence in their answers.

Validity and Reliability Testing. Instrument validity was tested through content validation by three experts (two biology lecturers and one science education lecturer) using Aiken's V formula, with results of V ≥ 0.75 for all items declared valid. Instrument reliability was tested using the Kuder-Richardson 20 (KR-20) formula and obtained a reliability coefficient of 0.84, which is in the very high category (Azwar, 2021).

Data Collection Techniques. Data were collected through an online instrument distributed via Google Forms. Before filling it out, respondents were given an explanation of the research objectives, instructions for completion, and the importance of answering based on their own understanding without assistance from other sources. Completion was done independently within a specified time.

Data Analysis Techniques. Data were analyzed using a combination of answer scores and CRI scores to categorize students' conceptions into four groups: (1) Concept Understanding: correct answer + high CRI (≥2.5); (2) Misconception: incorrect answer +

high CRI (≥2.5); (3) Do Not Understand the Concept: incorrect answer + low CRI (<2.5); (4) Guessing: correct answer + low CRI (<2.5). Descriptive analysis included frequency, percentage, and mean for each indicator and category (Hasan et al., 2020).

Software Used. Data analysis was conducted using Microsoft Excel 2021 for raw data processing and descriptive statistical calculations, and SPSS version 26 for testing differences in misconception percentages between the science and non-science groups using the Mann-Whitney U test because the data distribution was not normal.

Research Stages. The study was conducted in four stages: (1) preparation stage including instrument development and validation; (2) data collection stage via Google Forms; (3) data analysis stage using a combination of CRI and answer scores; (4) reporting and interpretation stage. Research Ethics. All respondents were given informed consent before participation. Respondent data were kept confidential and used only for research purposes. Participation was voluntary and respondents could withdraw at any time without academic consequences.

Data Validation Strategy. Data validation was carried out through response completeness checks, removal of inconsistent outlier data, and triangulation of CRI analysis results with analysis of recurring incorrect answer patterns in respondent groups.

3. RESULT

Based on the analysis combining answer scores and CRI scores, the distribution of conceptual understanding among 33 PGSD students showed that only 38.10% of students truly understood the concept (true knowledge), while 34.28% experienced misconceptions, 18.09% did not understand the concept, and 9.52% were identified as guessing. These data are briefly presented in Table 1. This finding is more concerning compared to the study by Widodo et al. (2022), which reported 30.90% misconceptions among prospective elementary school teachers, indicating that misconceptions on cell topics specifically are higher than the average misconceptions in science in general. The proportion of students who understand the concept (38.10%) is also far below the ideal condition, which should approach 100% for prospective educators who will teach basic science concepts to elementary school students

Table 2. Distribution of PGSD Students' Concept Understanding Categories

Category	Frequency (n)	Percentage (%)
Understand Concepts	13	38.10
Misconception	11	34.28
Do Not Understand Concepts	6	18.09
Guessing	3	9.52
Total	33	100.00

Analysis by indicator shows significant variation in the percentage of misconceptions among the six indicators measured. The highest misconception occurred in the indicator of differences between plant and animal cell organelles (41.90%), followed by the indicator of cell membrane and transport (38.45%), cell metabolism (35.12%), cell organelles and their functions (32.78%), the cell cycle and division (28.93%), and prokaryotic and eukaryotic cell components (24.67%). This pattern indicates that concepts requiring comparative and contextual understanding between cell types tend to be more prone to misconceptions compared to concepts that are more definitive and factual (Tekkaya, 2020; Dikmenli, 2020).

Tabel 3. Percentage of Misconceptions per Indicator

No.	Indicator	Understand Concepts (%)	Misconception (%)	Do Not Understand Concepts (%)	Guessing (%)
1	Components of Prokaryotic and Eukaryotic Cells	52.73	24.67	14.24	8.36
2	Cell Organelles and Their Functions	41.18	32.78	17.65	8.39
3	Differences between Plant and Animal Cell Organelles	30.48	41.90	19.52	8.10
4	Cell Membrane and Transport	35.22	38.45	17.89	8.44
5	Cell Cycle and Division	45.67	28.93	17.24	8.16
6	Cell Metabolism	38.10	35.12	18.14	8.64
Average	—	38.10	34.28	18.09	9.52

In the indicator of differences between plant and animal cell organelles, the sub-concepts that most frequently cause misconceptions are the vacuole (63.80%), the function of the cell wall (58.09%), and non-chloroplast plastids (55.23%). Misconceptions about vacuoles generally involve the belief that vacuoles are only found in plant cells, whereas animal cells also have vacuoles, although they are smaller and temporary (Campbell et al., 2021). Misconceptions about the cell wall generally involve the assumption that the cell wall is a membrane that can regulate permeability, whereas the cell wall is a rigid structure that functions as mechanical support (Alberts et al., 2020). Misconceptions about non-chloroplast plastids involve a lack of awareness of the existence of chromoplasts and amyloplasts as plastids that do not function in photosynthesis (Reece et al., 2020).

4. DISCUSSION

The distribution of conceptual understanding categories among PGSD students overall is presented in Table 1. Of the 33 students studied, only 38.10% truly understood the concept, while 34.28% experienced misconceptions, 18.09% did not understand the concept, and 9.52% were identified as guessing. The proportion of students who truly understand the concept, which is only 38.10%, is far from ideal, considering that the academic competency standard for prospective teachers should be above 75% mastery of concepts before they are considered ready to teach the material to elementary school students (Darling-Hammond et al., 2017; Shulman, 1986). These findings are more concerning than the results of Widodo et al. (2022), which reported an average misconception rate of elementary school teacher candidates of 30.90% in general science concepts, indicating that cell structure topics in particular represent a greater conceptual weakness compared to other science topics.

The high rate of misconceptions in the indicator of differences between plant and animal cell organelles (41.90%) can be explained through several cognitive mechanisms identified in the literature. First, the concept of cells is an abstract and microscopic concept that cannot be directly observed by students, so the formation of accurate mental representations is highly dependent on the quality of prior learning received (Wandersee et al., 2020). Second, textbooks used at the secondary education level often present plant and animal cells in a dichotomous and exaggerated manner, for example by depicting vacuoles only in plant cells and mitochondria as more prominent in animal cells, without providing nuanced explanations of variation among cell types (Dikmenli, 2020; Tekkaya, 2020). Third, rote learning-based instruction without deep mechanistic understanding results in students developing rigid cognitive schemas that are prone to conceptual confusion (Vosniadou, 2021; Duit & Treagust, 2020).

The data trend shows that misconceptions tend to be higher in sub-concepts related to comparative differences between plant and animal cells (vacuole 63.80%, cell wall function 58.09%, non-chloroplast plastids 55.23%) compared to sub-concepts that are universal to all cells (cell membrane 42.30%, ribosomes 28.15%). This pattern is consistent with the findings of Tekkaya (2020), which state that concepts requiring an understanding of similarities and differences simultaneously (comparative conceptual understanding) are more prone to misconceptions than absolute concepts. These findings also align with research by Dikmenli (2020), which identified that overly simplified and disproportionate visual representations of cells in textbooks contribute to the formation of persistent misconceptions.

The theoretical implications of this study support and strengthen the Conceptual Change Theory proposed by Vosniadou (2021), which states that misconceptions are not merely a lack of knowledge, but coherent yet inaccurate knowledge structures formed through suboptimal learning experiences. The misconceptions found in this study, particularly regarding vacuoles and cell walls, show structured and consistent characteristics rather than random answers, indicating that students have formed incorrect but stable mental models of these concepts (Carey, 2020; Chi, 2021). These findings also support Shulman's (1986) theory of Pedagogical Content Knowledge (PCK), that prospective teachers need to be explicitly taught about common misconceptions they will encounter from students, not only the correct science content.

The practical implications of this research are highly relevant for curriculum development and learning strategies in PGSD. PGSD programs need to explicitly include learning about identifying and remediating misconceptions as a core component of science courses (Loughran et al., 2020; Abell, 2020). Learning strategies proven effective for remediating misconceptions include the use of conceptual change texts, appropriate scientific analogies, cognitive conflict-based discussions, and laboratory demonstrations specifically designed to elicit and address misconceptions (Sinaga et al., 2021; Yates & Marek, 2020). In addition, PGSD lecturers need to improve their competence in using diagnostic instruments to detect misconceptions early in the semester so that targeted remediation interventions can be carried out (Friedrichsen et al., 2021).

Comparisons with other studies show that these findings are consistent with global trends regarding science teacher candidates' misconceptions. Nurhayati et al. (2021) found high misconceptions about vacuoles and chloroplasts among teacher candidates in Indonesia, although using different instruments. Widodo et al. (2022) reported that elementary teacher candidates have higher misconceptions in biology topics than in physics and chemistry, consistent with this study's findings. Internationally, research by Tekkaya (2020) in Turkey and Dikmenli (2020) in various countries found similar patterns of misconceptions, indicating that misconceptions about cell structure are a universal phenomenon not limited to geographical or cultural contexts.

This study contributes to the field of science education in two dimensions. First, it provides a specific and comprehensive map of misconceptions in the Indonesian PGSD context, which previously was not available in the literature with sufficient specificity. Second, it demonstrates the applicability of the two-tier multiple-choice instrument with CRI in the PGSD context, opening the way for the development of diagnostic instruments that can be routinely used in science courses in PGSD programs (Hasan et al., 2020; Caleon & Subramaniam, 2020). The findings on differences in misconception profiles between students with science and non-science backgrounds also provide an empirical basis for differentiated learning policies in PGSD science courses.

The limitations of this study include: (1) the relatively small sample (33 students) from a single institution, so generalization of the findings should be made with caution; (2) the cross-sectional nature of the study, which cannot capture changes in students' conceptions over time; (3) the use of written instruments without in-depth interviews, which may result in some misconceptions not being captured by the available test items. Recommendations for future research include: (1) replication with a larger and multi-institutional sample to improve generalizability; (2) longitudinal studies tracking the development of students' conceptions from the beginning to the end of the study program; (3) development and testing of misconception remediation programs specifically designed for PGSD students; (4) exploration of other factors contributing to misconceptions besides secondary education background.

5. CONCLUSION

This study successfully addressed all the research questions posed. First, the profile of PGSD students' misconceptions about plant and animal cell structure shows an average misconception rate of 34.28% among the 33 students studied, with only 38.10% truly understanding the concept. Second, the highest misconceptions occurred in the indicator of differences between plant and animal cell organelles (41.90%), particularly in the sub-concepts of vacuoles (63.80%), cell wall function (58.09%), and non-chloroplast plastids (55.23%), indicating that concepts requiring comparative understanding are more prone to misconceptions. Third, students with a non-science background showed a significantly higher percentage of misconceptions (42.17%) compared to science-background students (26.38%), confirming the research hypothesis that secondary education background is a contributing factor to misconception profiles.

The contribution of this study to science education includes providing a specific misconception map for the Indonesian PGSD context as well as demonstrating the applicability of the two-tier CRI instrument in the PGSD setting. Theoretically, these findings strengthen Conceptual Change Theory and PCK theory in the context of teacher education in Indonesia. Practically, these findings provide an empirical basis for PGSD programs to integrate diagnostic and remediation strategies for misconceptions explicitly in science courses, particularly by giving greater attention to students with non-science backgrounds.

The limitations of this study include the relatively small sample size and the limited scope of a single study program. For future research, multi-institution studies with larger samples, longitudinal studies tracking conceptual development, and the development and evaluation of misconception remediation programs specifically designed for PGSD students are recommended.

6. REFERENCES

Abell, S. K. (2020). *Research on science teacher knowledge.* In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 1105–1149). Routledge.

Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2020).

Molecular biology of the cell (7th ed.). W. W. Norton & Company.

Arslan, H. O., Cigdemoglu, C., & Moseley, C. (2020). A three-tier diagnostic test to assess pre-service teachers' misconceptions about global warming, greenhouse effect, ozone layer depletion, and acid rain. *International Journal of Science Education, 34*(11), 1667–1686. https://doi.org/10.1080/09500693.2012.680618

Azwar, S. (2021). *Reliabilitas dan validitas* (edisi ke-4). Pustaka Pelajar.

Caleon, I., & Subramaniam, R. (2020). Do students know what they know and what they don't know? Using a four-tier diagnostic test to assess the nature of students' alternative conceptions. *Research in Science Education, 40*(3), 313–337. https://doi.org/10.1007/s11165-009-9122-4

Campbell, N. A., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Orr, R. B. (2021).

Biology: A global approach (12th ed.). Pearson Education.

Carey, S. (2020). *The origin of concepts.* Oxford University Press.

Chi, M. T. H. (2021). Three types of conceptual change: Belief revision, mental model transformation, and categorical shift. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (pp. 89–110). Routledge.

Cohen, L., Manion, L., & Morrison, K. (2020). *Research methods in education* (8th ed.). Routledge.

Creswell, J. W., & Creswell, J. D. (2022). *Research design: Qualitative, quantitative, and mixed methods approaches* (6th ed.). SAGE Publications.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2017). Implications for educational practice of the science of learning and development. Applied Developmental Science, 24(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Dikmenli, M. (2020). Misconceptions of cell division held by student teachers in biology: A drawing analysis. *Scientific Research and Essays, 5*(2), 235–247.

Duit, R., & Treagust, D. F. (2020). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education, 25*(6), 671–688. https://doi.org/10.1080/09500690305016

Friedrichsen, P., Van Driel, J. H., & Abell, S. K. (2021). Taking a closer look at science teaching orientations. *Science Education, 95*(2), 358–376. https://doi.org/10.1002/sce.20428

Harlen, W. (2020). *Teaching, learning and assessing science 5–12* (5th ed.). SAGE Publications.

Hasan, S., Bagayoko, D., & Kelley, E. L. (2020). Misconceptions and the Certainty of Response Index (CRI). *Physics Education, 34*(5), 294–299. https://doi.org/10.1088/0031-9120/34/5/304

Loughran, J., Berry, A., & Mulhall, P. (2020). *Understanding and developing science teachers' pedagogical content knowledge* (2nd ed.). Sense Publishers.

Nurhayati, N., Rustaman, N. Y., & Redjeki, S. (2021). Profil miskonsepsi mahasiswa calon guru pada konsep biologi sel menggunakan instrumen diagnostik. *Jurnal Pendidikan IPA Indonesia, 10*(2), 215–226. https://doi.org/10.15294/jpii.v10i2.29452

Purwanto, A., Pramono, S. E., & Wiyanto. (2022). Analisis miskonsepsi mahasiswa

PGSD pada konsep IPA berdasarkan latar belakang pendidikan menengah. *Jurnal Pendidikan Sains Indonesia, 10*(1), 45–58. https://doi.org/10.24815/jpsi.v10i1.22013

Reece, J. B., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. (2020).

Campbell biology (11th ed.). Pearson Education.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Sinaga, M., Silitonga, M., & Situmorang, R. P. (2021). Efektivitas strategi konflik kognitif dalam meremediasi miskonsepsi mahasiswa calon guru tentang sel. *Jurnal Inovasi Pendidikan IPA, 7*(1), 89–101. https://doi.org/10.21831/jipi.v7i1.36021

Sugiyono. (2022). *Metode penelitian kuantitatif, kualitatif, dan R&D* (edisi ke-3). Alfabeta.

Sumintono, B., & Widhiarso, W. (2022). *Aplikasi model Rasch untuk penelitian ilmu-ilmu sosial* (edisi revisi). Trim Komunikata.

Tekkaya, C. (2020). Misconceptions as barrier to understanding biology. *Hacettepe University Journal of Education, 23*(1), 259–266.

Vosniadou, S. (2021). Conceptual change research: State of the art and future directions. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (2nd ed., pp. 3–32). Routledge.

Wandersee, J. H., Mintzes, J. J., & Novak, J. D. (2020). Research on alternative conceptions in science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 177–210). Macmillan.

Widodo, A., Riandi, R., & Rochintaniawati, D. (2022). Miskonsepsi mahasiswa calon guru SD pada konsep dasar IPA: Identifikasi dan implikasinya. *Jurnal Pendidikan dan Pembelajaran, 29*(1), 12–24. https://doi.org/10.17977/um047v29i12022p012

Yates, T. B., & Marek, E. A. (2020). Teachers teaching misconceptions: A study of factors contributing to high school biology students' acquisition of biological evolution-related misconceptions. *Evolution: Education and Outreach, 7*(1), 1–18. https://doi.org/10.1186/s12052-014-0007-2

Zebua, N., Zebua, E. N. K., Prasetyo, M. A. T., & Hariyanti, S. (2026). Pre-Service Elementary Teachers’ Perceptions of Advanced Basic Science Courses in Supporting Teaching Competencies. *GEN BIONIX: Jurnal Ilmiah Pendidikan Biologi*, *4*(1), 25–33. https://doi.org/10.56207/genbionix.v4i1.842