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The development of integrated project-based and 4C-scaffolding model with AI to overcome misconceptions

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Abstract

The present study aimed to evaluate the validity, practicality, and effectiveness of an integrated project-based learning model and 4C scaffolding techniques in addressing students' misconceptions in biology. In this research and development (R&D) study, the learning model was validated by five experts. A limited product trial was conducted with fourth-semester students from the State Islamic Institute (IAIN) of Ternate. Data were collected using validation sheets, observation sheets, response sheets, and a three-tier diagnostic test. Data collection involved observation, testing, and interviews. Data analysis focused on examining the validity, practicality, and effectiveness of the model based on the collected data. The findings indicated that (1) the prototype model was highly valid, with a mean score of 3.93; (2) the model was practical, as confirmed by consistency test results and observations during implementation; and (3) the model was effective in overcoming misconceptions in biology. Participants responded positively to the implementation of the model. The results suggest that Pj4CS is practical, valid, and effective in addressing students' misconceptions in biology. Implementing Pj4CS in classrooms can also enhance students' 21st-century skills and promote learning independence.

Keywords: Collaborative participation, Critical reading, Learning models, Misconceptions in biology, Pj4CS model, Scaffolding.

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Contents

Contribution of this paper to the literature

The Pj4CS is one of the new and innovative learning models designed to respond to the learning needs of the 21st century. Project-based learning combined with scaffolding can contribute to the empowerment of 4C skills. Pj4CS can be useful in overcoming biology misconceptions among prospective teachers. Collaborative learning is very important for strengthening the learning independence of prospective biology teachers.

1. Introduction

The digital age challenges educational institutions by requiring graduates to possess competitive competencies and 21st-century skills. Thus, learning should be able to enhance students' aptitudes and cognitive abilities, which in turn enable them to acquire knowledge and effectively address challenges within their immediate environment. The scope of intelligence extends beyond the acquisition of knowledge in practical settings. Rather, an individual's intelligence is demonstrated by their ability to solve everyday problems effectively and contextually (Amin, Karmila, et al., 2023; Desgamalia & Syamsurizal, 2019). Therefore, educators should strive to acquire global competencies to help their students compete in a globalized world (Amin, Adiansyah, & Hujjatusnaini, 2023; Keleman, Rasul, & Jalaludin, 2021; Sugiharto, Corebima, & Susilo, 2019).

To graduate successfully from a university or college, succeed in work, and engage in civic activities in the contemporary era, it is imperative for students to attain proficiency in the four essential global competences, namely critical thinking, communication, collaboration, and creativity (4C) (Ritter & Mostert, 2017). Consequently, educators need to employ instructional frameworks that facilitate student engagement and foster the development of the 4C skills (Marsiti, Santyasa, Sudatha, & Sudarma, 2023; Rahmawanti & Umam, 2019). Educators must also possess the capacity to develop instructional approaches that are enjoyable, imaginative, and groundbreaking, while concurrently fostering students' learning independence. This objective can be accomplished by incorporating the 4C global skills into classroom instruction.

Project-based learning has been suggested by experts as a means for educators to face the challenges of 21st century global education. Project-based learning (PjBL) engages students in actively utilizing cognitive skills to resolve challenges through the completion of projects (Nurhidayah, Wibowo, & Astra, 2021). Nijat asserts that incorporating PjBL into biology classes is essential due to a multitude of factors (Nijat, 2021). Learning through projects promotes the acquisition and application of biological knowledge and skills through engaging experiential activities. Furthermore, project-based learning offers an enhanced opportunity for in-depth study within the realm of scientific studies. Project-based learning can cultivate and enhance the abilities necessary to foster a scientific mindset during students' college education and their subsequent career readiness in higher education. Project-based learning facilitates student engagement in providing feedback on the outcomes of their work. The implementation of project-based learning in educational settings can increase students' comprehension on a deeper level and promote the cultivation of scientific attitudes within the classroom environment (Markula & Aksela, 2022; Syawaludin, Prasetyo, Jabar, & Retnawati, 2022). Nevertheless, the project-based learning model has several drawbacks.

Past studies have highlighted several flaws in implementing PjBL in the classroom. First, students need more time to prepare and design initiatives in project-based learning (Grant, 2002). They often encounter obstacles when generating and formulating innovative ideas collaboratively and when negotiating to resolve intragroup conflicts (Sumarni, 2015). Students can be trained more independently by employing a project-based learning model with simpler learning syntax (stages), while still accommodating 4C global skills to surmount the weaknesses of this learning model.

Biology instruction should not only include memorization techniques but also assist students in comprehending concepts, which are the fundamental capacity for thinking (Auwaliyah, 2017). By understanding concepts, students can connect one concept with related concepts (Agustina, Sipahutar, & Harahap, 2016). Individuals can only comprehend a concept accurately if they have mastered the underlying concept. Misconceptions occur when the understanding of concepts differs from empirical ones (Imran, Zulyusri, & Advinda, 2015). Misconceptions may also refer to individual knowledge derived from formal and informal experiences that have nothing to do with understanding science (Allen, 2014).

Misconceptions in the classroom can also result from the inappropriate application of learning models (Agustina et al., 2016). Students find the technique of memorizing content to be tedious (Chavan & Patankar, 2018). Memorization-based learning cannot hone students' abilities to implement material in real-world contexts. Students who do not comprehend the concepts underlying their acquired knowledge are unable to apply them in the real world (Galvin, Mooney, Simmie, & O'Grady, 2015; Sukmawati, Setyosari, Sulton, & Purnomo, 2019). Therefore, educators must overcome students' misconceptions before they can learn new concepts in context (Keleş & Kefeli, 2010; Yangin, Sidekli, & Gokbulut, 2014). Students' misconceptions can be obstacles for them in constructing knowledge about more complex concepts (Astuti, Bhakti, Prasetya, & Zulherman, 2023; Wancham, Tangdhanakanond, & Kanjanawasee, 2023). Misconceptions are typically the result of insufficient understanding of a concept or incomplete assimilation of a fact (Lin, Yang, & Li, 2016; Maison et al., 2022).

Understanding scientific concepts and phenomena is an essential part of any science curriculum (Vitharana, 2021; Yates & Marek, 2015). Unfortunately, many 21st-century teaching strategies are not implemented effectively in actual educational practice (Mtebe & Raphael, 2018). We have considered the pros and cons of the project-based learning model as well as the requirements of a learning design that incorporates 4C global skills. Therefore, we were intrigued to create a project-based learning model with simpler syntax that still allows for the development of 4C global skills. Incorporating scaffolding techniques in the stages of learning will aid students in discovering and designing biology-related projects. As scaffolding is transient assistance, it must be periodically adjusted and is not permanent. Gradual guidance is issued when a student has autonomously mastered a certain competency (Hasnunidah, Susilo, Irawati, & Suwono, 2020). Scaffolding enables prospective teachers to identify crucial conceptual knowledge and apply pertinent information in learning contexts (Wu, Weng, & She, 2016).

The development of the integrated project-based and 4C-scaffolding (Pj4CS) learning model is anticipated to overcome learners' misconceptions in biology. Thus, the current study attempted to answer three research questions as follows: (1) Is Pj4CS a *valid* learning model? (2) Is Pj4CS a *practical* learning model? (3) Is Pj4CS *effective* in overcoming learners' misconceptions in biology? The study's findings are predicted to have implications for enhancing the quality of prospective biology teachers' abilities to address global challenges effectively.

2. Methodology

2.1. Research Design

We utilized a Research and Development (R&D) design to generate a new learning model that is practical, valid, and effective in overcoming students' misconceptions in biology. The development of the product followed the stages suggested by Plomp (2007). It included four primary stages: preliminary investigation, design, realization/construction, testing, evaluation, and revision. The following sections explain the procedures for developing the integrated project-based and 4C-scaffolding (Pj4CS) learning model.

2.1.1. Preliminary Investigation

The initial stage of the Pj4CS prototype development was *preliminary investigation*. During this stage, we conducted a needs analysis of pre-service biology teachers. In the process, we identified the global competencies required in the Industry 4.0 era for a professional educator to transition into the Society 5.0 era. The rationale for model development was also supported by philosophical theories of learning model development. This stage concluded with identifying the conceptual knowledge and misconceptions among pre-service biology teachers in Ternate, North Maluku, Indonesia.

2.1.2. Design

During this stage, the Pj4CS prototype design was developed. We conducted a critical analysis of research articles that support the prototype development. The current study focused on the design of the model's syntax or learning stages, the design of the social system for implementing the model, the design of the reaction principle between educators and students, the design of the support system and the model's instructional impact, as well as the accompanying impacts that may be generated by the application of this learning model.

2.1.3. Realization/Implementation/Construction

During the implementation, the Pj4CS model prototype was validated by four experts and one practitioner in biology education. Validity tests were conducted by a lecturer who is an expert in learning model development, a lecturer specializing in learning design, an expert in research instruments for biology education, a professor of biology education, and a biology education practitioner (i.e., a high school biology teacher). Throughout the validation process, we evaluated the validation results and revised the prototype based on the validators' feedback and recommendations. The cumulative mean score for each component of the model assessment was then calculated.

2.1.4. Test, Evaluation, and Revision

Following the expert validation test, the prototype underwent a limited trial by fourth-semester students from the State Islamic Institute (IAIN) of Ternate, North Maluku, Indonesia. We conducted a tryout to determine the effectiveness of Pj4CS in overcoming students' misconceptions in biology. A questionnaire was then distributed to the students to collect their feedback regarding their learning experiences using Pj4CS. Subsequently, the Pj4CS learning model was disseminated to Tadris Biology professors at IAIN Ternate through Focus Group Discussions (FGD) and to biology teachers who teach at senior high schools in Ternate through *Musyawarah Guru Mata Pelajaran (MGMP)* or Subject Teachers Association forums. The results from this stage were evaluated and used to improve the learning model.

2.2. Research Subject

The Pj4CS learning model prototype was validated by four experts and one practitioner. There were 133 students participating in the preliminary investigation stage. The participants consisted of 56 students from the State Islamic Institute (IAIN) Ternate, North Maluku, Indonesia; 35 students from the Kie Raha Teacher Training and Education College (STKIP), North Maluku, Indonesia; and 42 students from Khairun University, North Maluku, Indonesia. Meanwhile, a limited trial of the Pj4CS model prototype was conducted on fourth-semester biology education students at IAIN Ternate. Dissemination of the Pj4CS model prototype was conducted with 55 lecturers at the Faculty of Tarbiyah and Teacher Training, IAIN Ternate, through focus group discussions (FGD). The dissemination of the Pj4CS model was also conducted with 33 high school teachers in the city of Ternate, North Maluku, Indonesia, through the Subject Teachers Association forum (MGMP). The research data were collected from January to August 2023.

2.3. Instruments and Data Collection

Data collection at every research stage varied according to the objective of each phase. In the *preliminary investigation* phase, the data were gathered via questionnaire surveys, documentation, interviews, and field observation. Meanwhile, at the *design* stage, data collection was performed through a critical analysis of articles relevant to the development of the Pj4CS model. Then, in the *realization/construction* phase, we collected data using validation sheets that were distributed to four experts and one practitioner in biology education. The data collection process during the *Test, Evaluation, and Revision* stage was executed by (a) administering a pretest to examine biology education students' misconceptions; (b) observing student activities during the implementation of the Pj4CS syntax in the classroom; (c) administering a post-test (a misconception test similar to the pretest); (d) distributing a questionnaire to elicit students' responses to the Pj4CS model implementation following the limited product trial; and (e) administering a questionnaire to biology teachers to examine the model's practicality.

2.4. Data Analysis Technique

Data analysis was performed by examining the product validity, practicality, and effectiveness test results. The product validity score was obtained by averaging the scores given by five experts. The score for each assessment component was then categorized based on the following criteria: $3.5 \leq M \leq 4$ (highly valid); $2.5 \leq M < 3.5$ (valid); $1.5 \leq M < 2.5$ (fairly valid); $M < 1.5$ (not valid) (Amin, 2020; Nurdin, 2007). The practicality of the Pj4CS learning model was determined based on (1) the result of the consistency test on the model implementation; (2) the observation result. The practicality score of the product was categorized based on the following criteria: Pt>3 (practical), 2<Pt<3 (less practical); Pt<2 (not practical) (Maimunah, 2016). The effectiveness of the model in overcoming students' misconceptions was determined based on (1) a decrease in participants' misconceptions and (2) participants' positive responses to the Pj4CS learning model's implementation. The product's effectiveness was determined based on the results of the three-tier diagnostic testing regarding human anatomy and physiology.

The diagnostic test consisted of multiple-choice reasoning questions (Andariana, Zubaidah, Mahanal, & Suarsını, 2020). The test questions asked participants to fill in the Confidence Rating Index (CRI) (0 to 5) and provide reasons for their answers. The CRI analysis aimed to categorize students into those who understood the concepts well, those who understood the concepts but were not confident in their answers, those who experienced misconceptions, and those who did not understand the concepts at all. Table 1 presents a matrix for determining answer category in the three-tier test (Hakim, Kadarohman, & Syah, 2016).

After identifying the answer category, percentage calculations were performed for each category: a complete understanding of the concept, a partial understanding accompanied by a lack of confidence in the provided answer, a misconception, and a lack of understanding of the concept. Using descriptive statistics (percentages), the research data were analyzed.

Table 1. Decision making for answer category in the three-tier test.

First tier	Second tier	Third tier	Category
Answer	Reason(s) for choosing the answer	Level of confidence in the answer and reason for choosing the answer	
True	True	> 2.5	Understand the concept
True	True	< 2.5	Understand the concept but am not confident in the answer
True	False	> 2.5	Misconception
True	False	< 2.5	Fail to understand the concept.
False	True	> 2.5	Misconception
False	True	< 2.5	Fail to understand the concept.
False	False	> 2.5	Misconception
False	False	< 2.5	Fail to understand the concept.

3. Results

3.1. The Pj4CS Learning Model's Validity

The Pj4CS learning model's validity was assessed using validation sheets by four experts and one practitioner in the field of biology education. The results of the expert validation are summarized in Table 2.

Table 2. Summary of the Pj4CS expert validation results.

No	Aspect to evaluate	Mean score
1	Aim and objectives	3.90
2	Supporting theories	3.75
3	Development studies	3.95
4	Learning syntax	3.97
5	Social system	3.92
6	Reaction principle	3.97
7	Supporting system	4.00
8	Instructional and accompanying impacts	3.90
9	Conclusion	4.00
	Mean	3.93 (Highly valid)

According to Table 2, the integrated project-based and 4C-Scaffolding (Pj4CS) learning model was very valid with a score of 3.93.

3.2. The Pj4CS Learning Model's Practicality

The Pj4CS learning model's validity was determined through (1) a consistency test of the model's implementation and (2) observations of the model's implementation.

3.2.1. Analysis of the Pj4CS Implementation Consistency

A consistency test was conducted to evaluate the implementation of the Pj4CS learning model. The results indicated a significance level of 0.822 (greater than 0.05) for data parallelism and 0.005 (less than 0.05) for data coincidence level. These figures suggest that the Pj4CS syntax was parallel but not coincident. The consistency test results can be seen in Table 3 and Figure 1.

Table 3. The results of the consistency test on Pj4CS syntax.

Model	Aspect	Sum of squares	df	Mean square	F	Sig.
1	Regression	33336.393	3	11112.131	961.364	0.000
	b1,b2	0.593	1	0.593	0.051	0.822
	b1,b2,b3	140.546	2	70.273	6.080	0.005
	Residual	462.349	40	11.559		
	Total	161914.890	44	-		

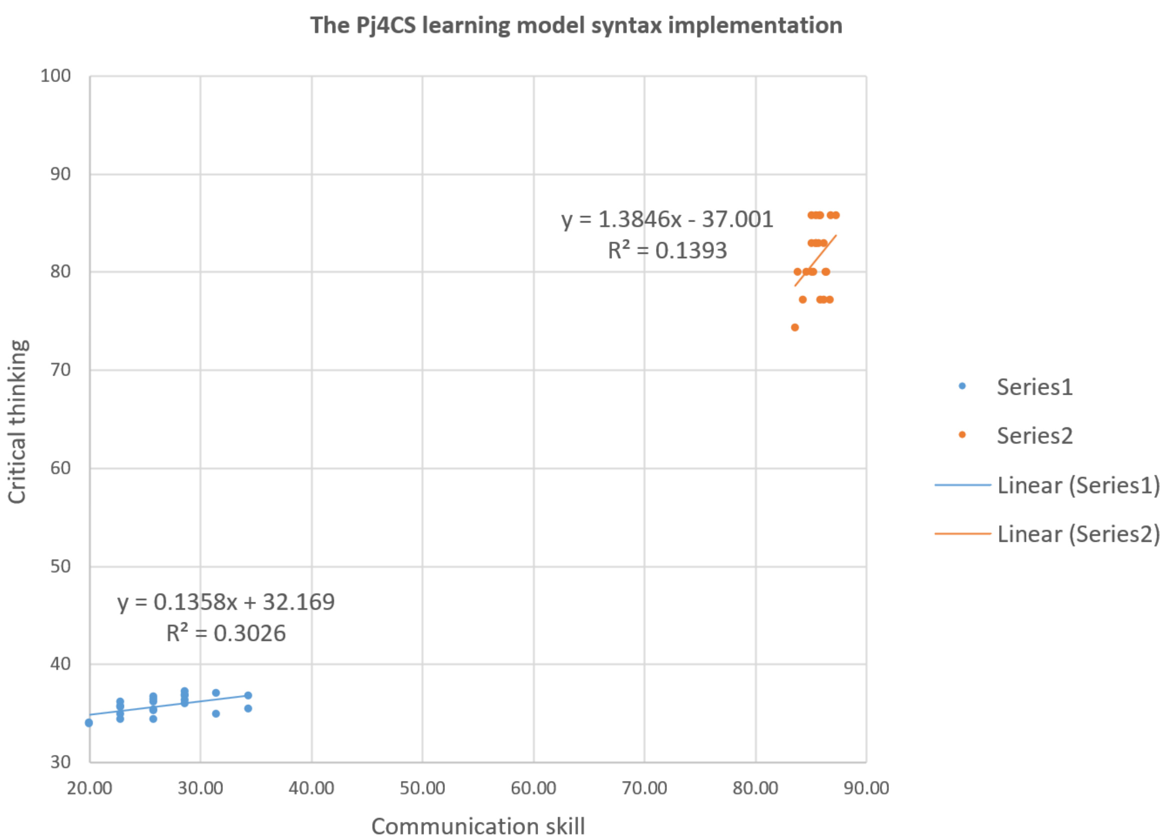

Figure 1. The Consistency of the Pj4CS learning model syntax implementation.

3.2.2. Analysis of the Pj4CS Implementation Observation Results

The observation results regarding the implementation of Pj4CS in the classroom are presented in Table 4.

Table 4. The implementation of the Pj4CS learning model.

Syntax	Learning activities	Score	Criteria
Step 1. Critical reading	1. Students are assigned to read and analyze an essential concept or material.	4.38	Practical
	2. Teacher checks and identifies the results of students' critical reading.	4.38	Practical
	3. Teacher instructs students to reflect on the concept or material.	4.19	Practical
Step 2. Communication for project determination.	1. Teacher organizes students into small groups to work on a project.	4.31	Practical
	2. Teacher directs students to communicate with their team members to determine the design of the project.	4.19	Practical
Step 3. Collaborative participation	1. Teacher assigns students to collaborate within their groups to realize the design of the project.	4.00	Practical
	2. Teacher asks each group to search for any material that can support their project on the Internet.	4.00	Practical
Step 4. Scaffolding	1. Teacher provides scaffolding for each group according to their needs.	4.06	Practical
	2. Teacher provides guidance on the use of media or information technology that can be used to complete the project. The teacher can guide students on how to use Canva, Mendeley, e-library, or other useful media.	4.13	Practical
Step 5. Creativity Exploration	1. Teacher gives each group the freedom to use their creativity on the project.	4.00	Practical
	2. Teacher invites each group to present their final project in front of the classroom.	4.13	Practical
	3. Teacher gives each group rewards for the completion of the project.	4.25	Practical
Mean		4.17	Practical

According to Table 4, Pj4CS was practical with a mean score of 4.17.

3.2.3. The Pj4CS Learning Model's Effectiveness in Overcoming Misconceptions in Biology

The effectiveness of the Pj4CS model in overcoming students' misconceptions in biology was determined based on (1) a decrease in students' misconceptions and (2) students' positive responses to the implementation of the Pj4CS learning model. The results of the effectiveness test are presented in Table 5.

Table 5. The difference in participants' concept understanding before and after Pj4CS implementation.

Test	Category (%)			
	Understand the concept completely	Understand the concept but am not confident in the answer	Experience misconception	Does not understand the concept
Pre-test	8.59%	3.28%	55.93%	32.20%
Post-test	65.37%	14.76%	12.21%	7.66%

According to Table 5, the Pj4CS learning model was effective in overcoming students' misconceptions, indicated by a decline in students' misconception score from 55.93% on the pretest to 12.21% on the post-test. The effectiveness of the Pj4CS learning model in overcoming misconceptions was also determined based on students' responses to its implementation in the classroom (Table 6).

Table 6. Participants' responses to Pj4CS implementation.

No	Statement	Percentage of students' responses (%)	Category
1	In my opinion, the Pj4CS learning model is intriguing.	86.96	Positive
2	In my opinion, Pj4CS is enjoyable.	82.61	Positive
3	Pj4CS makes it simple for me to follow the lessons.	82.61	Positive
4	Pj4CS increases my motivation to learn.	86.96	Positive
5	Pj4CS enhances my independent learning skills.	86.96	Positive
6	Pj4CS increases my interest in reading.	91.30	Positive
7	Pj4CS helps me improve my critical thinking skills.	91.30	Positive
8	Pj4CS helps me improve my communication skills.	91.30	Positive
9	Pj4CS helps me improve my collaboration skills.	91.30	Positive
10	Pj4CS helps me improve my creativity and innovation skills.	91.30	Positive
11	Pj4CS helps me overcome misconceptions.	95.65	Positive
12	Pj4CS helps me fulfill my project-based learning needs.	86.96	Positive
13	Pj4CS increases my ability and confidence in asking questions.	82.61	Positive
14	Pj4CS increases my ability to answer questions on biology.	86.96	Positive
15	Pj4CS extends my learning experience.	86.96	Positive
16	Pj4CS makes me aware that I must improve my quality of learning.	82.61	Positive
17	Pj4CS increases my curiosity.	86.96	Positive
18	Pj4CS helps me regulate my learning strategies.	82.61	Positive
19	Pj4CS allows me to evaluate my learning process.	82.61	Positive
20	Pj4CS allows me to share information and knowledge with other students.	82.61	Positive
	Mean	86.96	Positive

According to Table 6, it is evident that participants responded positively to the implementation of the Pj4CS learning model, with a mean score of 86.96.

4. Discussion

The study results showed that the integrated project-based and 4C-Scaffolding Pj4CS) model was effective in overcoming students' misconceptions in biology. The learning model's syntax was proven successful in increasing pre-service biology teachers' conceptual knowledge. The first component of Pj4CS, namely *Critical Reading*, strengthens students' understanding of concepts before designing and determining the project that will be produced in learning. Project-based activities engage students in solving problems by generating a creative product (Movahedzadeh, Patwell, Rieker, & Gonzalez, 2012). Students can be taught to become active learners through collaborative problem-solving activities in project-based learning (Amin & Adiansyah, 2018). Besides problem-solving skills, students also need analytical abilities to resolve issues in their lives (Ichsan et al., 2019). Designing project activities in which students work independently or in groups enables them to implement the acquired conceptual knowledge (Baser, Ozden, & Karaarslan, 2017). Students' creativity and motivation can be influenced by project work activities, which facilitate students in identifying problems, reviewing literature, solving problems, creating and designing a product, and evaluating the product (Kai et al., 2017). Students' learning outcomes can be improved through direct involvement in developing their knowledge, planning, and generating projects that are practical in real-world scenarios.

The subsequent stage of Pj4CS facilitates pupils in effectively conveying the fundamental principles that will be incorporated into the project. Understanding intricate topics poses a significant difficulty for students (Jammeh, Karegeya, & Ladage, 2023). According to Haryono and Aini (2021), the dissemination of educational content by the instructor has an impact on students' understanding of concepts. When an educator demonstrates genuine concern for the subject matter being taught to their pupils, it is likely to result in a more comprehensive and enduring understanding of the underlying concepts by the students (Andriani, Mulyani, & WIji, 2020; Latif, Mursalin, Buhungo, & Odja, 2021; Mubarokah, Mulyanı, & Indrıyantı, 2018). Pj4CS can train students to increase their high-level thinking capacity and sharpen their identity (Ahmat et al., 2022; Irham, Tolla, & Jabu, 2022).

The Pj4CS third syntax has been shown to be successful in enhancing students' engagement in lessons. During this stage, students exhibited a high level of interest and were actively involved in the collaborative process of project design. According to Dillon and Avraamidou, the level of complexity and depth of learning information can potentially lead to a decline in students' interest. Acquiring a thorough understanding of concepts is important to help students overcome misconceptions (Dillon & Avraamidou, 2021). Misconceptions have the potential to impede the facilitation of teaching and learning activities, thereby obstructing students' comprehension of a given topic (Ilhan & Akin, 2022; Kshetree, Acharya, Khanal, Panthi, & Belbase, 2021). Furthermore, these misconceptions can undermine the efficacy of the learning process and influence subsequent stages of learning (Thompson & Logue, 2006). Misconceptions show a notable degree of resistance to modification, as their remains frequently impede the comprehension of even rudimentary notions. Misconceptions that arise during a certain temporal context have the potential to resurface as misconceptions once more (Berg, 2004; Vermeulen & Meyer, 2017). Students' conceptual knowledge can be negatively impacted by incorrect or insufficient knowledge resulting from inadequate learning experiences, misinformation delivered by teachers, and misunderstandings arising from the study of information in textbooks (Hakim et al., 2016; Kirbulut & Geban, 2014; Zlatkin-Troitschanskaia, Shavelson, & Kuhn, 2015).

The incorporation of scaffolding within the project design process is a notable advantage within the Pj4CS learning approach. Students are provided with progressive coaching until they attain a certain level of learning autonomy and can generate their own project outcomes. Educators can enhance their instructional strategies by prioritizing scientific principles and procedures. This can be achieved by providing targeted guidance or scaffolding, which aids students in effectively accomplishing assignments in alignment with established best practices (Sabel, 2020). Developing a robust understanding of concepts is crucial in the learning process, as it serves as a foundation for applying knowledge (Hyder & Bhamani, 2016; Susilowati, Degeng, Setyosari, & Ulfa, 2019). The implementation of a robust conceptual understanding is achieved by engaging in a process of reconstructing meaning, drawing upon prior knowledge. The complexity of a new concept is likely to influence the educational achievements of students (Chatila & Al Husseiny, 2017). In order to effectively teach crucial concepts in the modern classroom, educators are required to employ appropriate pedagogical strategies and information and communication technology (ICT) techniques (Mtebe & Raphael, 2018). In addition to possessing the necessary qualifications, educators must also have effective classroom management skills and the ability to support active learning among their students. This approach ensures that students develop the capacity to effectively utilize information rather than passively consume it (Aun & Kaewurai, 2017). Understanding communication patterns with students is crucial for promoting student learning accomplishment (Putra, Akrim, & Dalle, 2020). Students must experience observing scientific events and completing experiments to develop useful knowledge of scientific concepts. Educators must take a role in designing active learning to achieve learning success and progress in students' cognitive development.

The Pj4CS learning model offers students an opportunity to recognize and value the creative aspects of their project designs. The students enrolled in the research class demonstrated high enthusiasm when presenting their projects. The implementation of project-based learning has the potential to enhance the utilization of advanced concepts, foster problem-solving skills, stimulate creative thinking, and promote collaborative efforts (Love, Hodge, Corritore, & Ernst, 2015). The meaningfulness of learning can be enhanced when it is supplemented by the surrounding environment as a valuable resource for learning. This way, knowledge, skills, and attitudes will be adequately developed and have longer retention (Sholahuddin, Anjuni, & Faikhamta, 2023). The implementation of learning activities that encourage student involvement in acquiring knowledge is substantially important for students' future career development (Nga, Huy, & Tam, 2024). The Pj4CS model was also found to have an impact on improving students' communication skills in interactive discussions. The high scores of students' communication and collaboration skills are positively correlated with their learning independence.

Meaningful learning occurs when students can establish connections between their existing experiential knowledge and the new material they acquire during classroom instruction. Hence, things or circumstances that are close to students can aid in facilitating this process. The utilization of this significant strategy leads to the acquisition of profound knowledge (Sholahuddin et al., 2023). Critical thinking, creative thinking, and metacognitive skills are considered determining factors for students' achievement and resilience in navigating the complexities of contemporary life in the 21st century (Chalkiadaki, 2018). Students' positive self-concept is associated with their increased levels of independence in learning and heightened self-efficacy (Amin, 2023). In a broad sense, conventional instructional methods, such as lectures, routine practicums, basic discovery-based learning, or mere text-based reading, tend to exhibit limited efficacy in rectifying students' misconceptions (Yangin et al., 2014). Educators must identify aspects used to stimulate students so that classroom learning is more active (Lillo, 2023). Designing appropriate models and teaching methods will enable students to have a better understanding of science concepts (Lagoudakis, Vlachos, Christidou, Vavougios, & Batsila, 2023). University teaching staff must provide guidance and assistance so that prospective teachers understand more deeply the steps needed to accommodate strong thinking skills and mastery of concepts (Johar, Ramli, Sasalia, & Walker, 2023). Motivation acts as a psychological foundation for students to continue to develop their potential according to their respective characteristics. Active learning can only be realized with the right psychological touch and scientific approach (Aydede, 2022; Hidayat, Lengkana, Rohyana, Purwanto, & Rosalina, 2023). The following are the main advantages of learning through projects: it assists students in their efforts to connect theory to application, increases their enthusiasm for learning, promotes independence and accountability, fosters creativity, trains them to solve complex problems, practices patience and persistence, trains them to work collaboratively, and develops their capacity for assessment (Duc, Thi, Hoang, & Thanh, 2022). Interaction among students in the classroom environment can improve procedural knowledge (Adijaya, Widiana, Agung Parwata, & Suwela Antara, 2023).

5. Conclusion

The data analysis results demonstrated that the integrated project-based and 4C-Scaffolding (Pj4CS) model was highly valid, with a mean score of 3.93. The Pj4CS learning model consists of several phases: critical reading, communication for project determination, collaborative participation, scaffolding, and creativity exploration. This study also proved that the Pj4CS learning model was practical, as confirmed by the results of the consistency test and observations on the model's implementation. Furthermore, the Pj4CS model was effective in overcoming students' misconceptions. Participants in this study also reacted positively toward the implementation of the model. This research introduces a novel project-based learning model that effectively incorporates critical thinking skills, communication skills, collaboration skills, and creative thinking skills (4C). The model also contains scaffolding techniques that can promote independent learning.

6. Suggestions

It is envisaged that the Pj4CS model developed in this study will help students become more adept at handling difficulties related to global development. It is imperative to train students to develop critical-creative, collaborative, communication, and literacy skills to facilitate knowledge production and address misconceptions. There is an optimistic anticipation that future researchers will have the opportunity to examine the implementation of Pj4CS on a broader scope and under more favorable circumstances.

The fourth stage in the Plomp model procedure, namely testing, evaluation, and revision, in this research was carried out through limited trials with a small sample. Therefore, in the future, it is hoped that further research can be conducted using different research method designs to examine the effectiveness of the Pj4CS learning model, as well as with larger samples and over a longer research period.

References

Adijaya, M. A., Widiana, I. W., Agung Parwata, I., & Suwela Antara, I. (2023). Bloom's taxonomy revision-oriented learning activities to improve procedural capabilities and learning outcomes. *International Journal of Educational Methodology, 9*(1), 261-270. https://doi.org/10.12973/ijem.9.1.261

Agustina, R., Sipahutar, H., & Harahap, F. (2016). Analysis of misconceptions in biology textbooks for grade XII high school students. *Jurnal Pendidikan Biologi, 5*(2), 113-118. https://doi.org/10.24114/jpb.v5i2.4307

Ahmat, N., Azmee, N. A., Mohamed, N. H., Zamzamir, Z., Zahari, N. S., Shafie, S., . . . Raja Ma'amor Shah, R. N. F. A. (2022). Knowledge, skills and attitude of pre-service mathematics teachers towards higher-order thinking skills. *International Journal of Educational Methodology, 8*(4), 795-804.

Allen, M. (2014). *Misconceptions in primary science*. Maidenhead, UK: McGraw-hill Education.

Amin, A. M. (2020). *The effect of reading, questioning, and answering (RQA) model combined with argument-driven inquiry (ADI) on different academic abilities on motivation, critical thinking skills, metacognitive skills, argumentation skills, concept mastery*. Unpublished Dissertation. Malang: State University of Malang.

Amin, A. M. (2023). The Effect of the RQANI Learning Model on Self-Efficacy of Pre-Service Biology Teachers in Ternate City, Indonesia. *Jurnal Pendidikan Progresif, 13*(2), 296-309. https://doi.org/10.23960/jpp.v13.i2.202312

Amin, A. M., & Adiansyah, R. (2018). Identification of learning styles and student responses to determine learning strategies in animal physiology lectures. *Jurnal Biologi & Pembelajarannya, 5*(April), 1–9.

Amin, A. M., Adiansyah, R., & Hujjatusnaini, N. (2023). The contribution of communication and digital literacy skills to critical thinking. *Jurnal Pendidikan Sains Indonesia, 11*(3), 697-712. https://doi.org/10.24815/jpsi.v11i3.30838

Amin, A. M., Karmila, F., Laode, Z. A., Ermin, E., Akbar, A. Y., & Ahmed, M. A. (2023). The WE-ARe Model's Potential to Enhance Digital Literacy of Preservice Biology Teachers. *Journal of Biological Education Indonesia (Jurnal Pendidikan Biologi Indonesia), 9*(1), 36-45. https://doi.org/10.22219/jpbi.v9i1.23061

Andariana, A., Zubaidah, S., Mahanal, S., & Suarsını, E. (2020). Identification of biology students' misconceptions in human anatomy and physiology course through three-tier diagnostic test. *Journal for the Education of Gifted Young Scientists, 8*(3), 1071-1085.

Andriani, Y., Mulyani, S., & WIji, W. (2020). Misconceptions and troublesome knowledge on chemical equilibrium. *Journal of Physics: Conference Series, 1806*(0121), 1–6. https://doi.org/10.1088/1742-6596/1806/1/012184

Astuti, I. A. D., Bhakti, Y. B., Prasetya, R., & Zulherman. (2023). Android-based 4-tier physics test app to identify student misconception profile. *International Journal of Evaluation and Research in Education, 12*(3), 1356–1363. https://doi.org/10.11591/ijere.v12i3.25536

Aun, V. S., & Kaewurai, W. (2017). Instructional model development to enhance critical thinking and critical thinking teaching ability of trainee students at regional teaching training center in Takeo province, Cambodia. *Kasetsart Journal of Social Sciences, 38*(1), 88-95. https://doi.org/10.1016/j.kjss.2016.05.002

Auwaliyah, R. (2017). Profile of student's misconception on disgestive system for senior high school at grade XI Raharjo. *BioEdu, 6*(3), 304–310.

Aydede, M. N. (2022). Examining the primary school teacher candidates' science learning skills in terms of their attitudes towards science and their science teaching self-efficacy beliefs. *International Journal of Educational Methodology, 8*(4), 853-864. https://doi.org/10.12973/ijem.8.4.853

Baser, D., Ozden, M. Y., & Karaarslan, H. (2017). Collaborative project-based learning: An integrative science and technological education project. *Research in Science & Technological Education, 35*(2), 131-148. https://doi.org/https://doi.org/10.1080/02635143.2016.1274723

Berg, E. V. D. (2004). *Physics misconceptions and remediation*. Salatiga: Universitas Kristen Satya Wacana.

Chalkiadaki, A. (2018). A systematic literature review of 21st century skills and competencies in primary education. *International Journal of Instruction, 11*(3), 1-16. https://doi.org/https://doi.org/10.12973/iji.2018.1131a

Chatila, H., & Al Husseiny, F. (2017). Effect of cooperative learning strategy on students' acquisition and practice of scientific skills in Biology. *Journal of Education in Science Environment and Health, 3*(1), 88-99.

Chavan, R., & Patankar, P. (2018). Perception of biological concepts among higher secondary teachers: A study. *Online Submission, 7*(23), 144-153.

Desgamalia, P., & Syamsurizal. (2019). Effect of project based learning (PjBL) model on biology psychomotor competence of X grade natural science class students in SMAN 1 Kapur IX. *International Journal of Progressive Sciences and Technologies, 15*(2), 68-71.

Dillon, J., & Avraamidou, L. (2021). It's time to rethink science education. *Education in Chemistry*.

Duc, C.-N., Thi, P.-N., Hoang, T.-N., & Thanh, T.-N. T. (2022). A literature review of the project-based teaching method in the education of Vietnam. *International Journal of Educational Methodology, 8*(3), 567-584. https://doi.org/10.12973/ijem.8.3.567

Galvin, E., Mooney Simmie, G., & O'Grady, A. (2015). Identification of misconceptions in the teaching of biology: A pedagogical cycle of recognition, reduction and removal. *Higher Education of Social Science, 8*(2), 1–8. https://doi.org/10.3968/6519

Grant, M. M. (2002). Getting a grip on project-based learning: Theory, cases and recommendations. *Meridian: A middle school computer technologies journal, 5*(1), 83.

Hakim, A., Kadarohman, A., & Syah, Y. M. (2016). Effects of the natural product mini project laboratory on the students conceptual understanding. *Journal of Turkish Science Education, 13*(2), 27-36.

Haryono, H. E., & Aini, K. N. (2021). Diagnosis misconceptions of junior high school in Lamongan on the heat concept using the three-tier test. *Journal of Physics: Conference Series, 1806*, 0120. https://doi.org/10.1088/1742-6596/1806/1/012002

Hasnunidah, N., Susilo, H., Irawati, M., & Suwono, H. (2020). The contribution of argumentation and critical thinking skills on students' concept understanding in different learning models. *Journal of University Teaching and Learning Practice, 17*(1), 1-13. https://doi.org/https://doi.org/10.53761/1.17.1.6

Hidayat, C., Lengkana, A. S., Rohyana, A., Purwanto, D., & Rosalina, M. (2023). Motivating active learning in physical education: Critical thinking. *European Journal of Educational Research, 12*(2), 1137–1151. https://doi.org/10.12973/eu-jer.12.2.1137

Hyder, I., & Bhamani, S. (2016). Bloom's Taxonomy (cognitive domain) in higher education settings: Reflection brief. *Journal of Education and Educational Development, 3*(2), 288–300. https://doi.org/10.13140/RG.2.2.14634.62406

Ichsan, I. Z., Sigit, D. V., Miarsyah, M., Ali, A., Arif, W. P., & Prayitno, T. A. (2019). HOTS-AEP: Higher order thinking skills from elementary to master students in environmental learning. *European Journal of Educational Research, 8*(4), 935-942. https://doi.org/10.12973/eu-jer.8.4.935

Ilhan, A., & Akin, M. (2022). Analysis of contextual problem solutions, mathematical sentences, and misconceptions of pre-service mathematics teachers. *International Electronic Journal of Mathematics Education, 17*(1), em0666. https://doi.org/10.29333/iejme/11470

Imran, R., Zulyusri, Z., & Advinda, L. (2015). Misconceptions of material in biology textbooks for senior high school grade XI Semester I. *Jurnal Pendipa, 2*(2), 57-64.

Irham, Tolla, I., & Jabu, B. (2022). Development of the 4C teaching model to improve students' mathematical critical thinking skills. *International Journal of Educational Methodology, 8*(3), 493–504. https://doi.org/10.12973/ijem.8.3.493

Jammeh, A. L., Karegeya, C., & Ladage, S. (2023). Misconceptions on basic stoichiometry among the selected eleventh-grade students in the urban regions of the Gambia. *Journal of Baltic Science Education, 22*(2), 254-268. https://doi.org/https://doi.org/10.33225/jbse/23.22.254

Johar, R., Ramli, M., Sasalia, P., & Walker, H.-C. O. (2023). Preservice teachers' noticing skills in relation to student misconceptions in Algebra. *European Journal of Educational Research, 12*(2), 865–879. https://doi.org/10.12973/eu-jer.12.2.865

Kai, S., Chu, S. K. W., Zhang, Y., Chen, K., Chan, C. K., Lee, C. W. Y., . . . Lau, W. (2017). The effectiveness of wikis for project-based learning in different disciplines in higher education. *The Internet and Higher Education, 33*, 49-60. https://doi.org/10.1016/J.Iheduc.2017.01.005

Keleman, M., Rasul, M., & Jalaludin, N. A. (2021). Assessment of higher order thinking skills through stem integration project-based learning for elementary level. *International Journal of Social Science and Human Research, 4*(4), 835–846. https://doi.org/10.47191/ijsshr/v4-i4-40

Keleş, E., & Kefeli, P. (2010). Determination of student misconceptions in "photosynthesis and respiration" unit and correcting them with the help of cai material. *Procedia-Social and Behavioral Sciences, 2*(2), 3111-3118. https://doi.org/10.1016/j.sbspro.2010.03.474

Kirbulut, Z. D., & Geban, O. (2014). Using three-tier diagnostic test to assess students' misconceptions of states of matter. *Eurasia Journal of Mathematics, Science and Technology Education, 10*(5), 509-521. https://doi.org/10.12973/eurasia.2014.1128a

Kshetree, M. P., Acharya, B. R., Khanal, B., Panthi, R. K., & Belbase, S. (2021). Eighth grade students' misconceptions and errors in mathematics learning in Nepal. *European Journal of Educational Research, 10*(3), 1101-1121.

Lagoudakis, N., Vlachos, F., Christidou, V., Vavougios, D., & Batsila, M. (2023). The role of hemispheric preference in student misconceptions in biology. *European Journal of Educational Research, 12*(2), 749–758.

Latif, F. H., Mursalin, Buhungo, T. J., & Odja, A. H. (2021). Analysis of students' misconceptions using the certainty of response index (CRI) on the concept of work and energy in SMA Negeri 1 Gorontalo Utara after online learning. *Advances in Social Science, Education and Humanities Research, 528*, 511–515. https://doi.org/10.2991/assehr.k.210305.075

Lillo, E. A. G. (2023). Tutors' and students' views on learning and feedback in problem-based learning. *European Journal of Educational Research, 12*(2), 705–717. https://doi.org/10.12973/eu-jer.12.2.705

Lin, Y.-C., Yang, D.-C., & Li, M.-N. (2016). Diagnosing students' misconceptions in number sense via a web-based two-tier test. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(1), 41-55. https://doi.org/10.12973/eurasia.2016.1420a

Love, B., Hodge, A., Corritore, C., & Ernst, D. C. (2015). Inquiry-based learning and the flipped classroom model. *Primus, 25*(8), 745-762. https://doi.org/10.1080/10511970.2015.1046005

Maimunah. (2016). *Development of mathematics learning model through problem solving to develop mathematical reasoning*. Disertasi tidak diterbitkan. Malang: Pascasarjana Universitas Negeri Malang.

Maison, Hidayat, M., Kurniawan, D. A., Yolviansyah, F., Sandra, R. O., & Iqbal, M. (2022). How Critical Thinking Skills Influence Misconception in Electric Field. *International Journal of Educational Methodology, 8*(2), 377-390. https://doi.org/10.12973/ijem.8.2.377

Markula, A., & Aksela, M. (2022). The key characteristics of project-based learning: How teachers implement projects in K-12 science education. *Disciplinary and Interdisciplinary Science Education Research, 4*(1), 2. https://doi.org/10.1186/s43031-021-00042-x

Marsiti, C. I. R., Santyasa, I. W., Sudatha, I. G. W., & Sudarma, I. K. (2023). The effect of project-based blended learning and students' creativity on eleventh-grade students' learning achievement. *International Journal of Instruction, 16*(4), 805-826.

Movahedzadeh, F., Patwell, R., Rieker, J. E., & Gonzalez, T. (2012). Project-based learning to promote effective learning in biotechnology courses. *Education Research International, 2012*(1), 536024. https://doi.org/10.1155/2012/536024

Mtebe, J. S., & Raphael, C. (2018). Eliciting in-service teachers' technological pedagogical content knowledge for 21st-century skills in Tanzania. *Journal of Learning for Development, 5*(3), 263-279.

Mubarokah, F. D., Mulyanı, S., & Indrıyantı, N. Y. (2018). Identifying students' misconceptions of acid-base concepts using a three-tier diagnostic test: A case of ındonesia and thailand. *Journal of Turkish Science Education, 15*(STEM Special Issue), 51-58. https://eric.ed.gov/?id=EJ1313775

Nga, L. P., Huy, N. Q., & Tam, P. T. (2024). Applying structural equation modelling for assessing factors influencing innovation capacity and business efficiency. *Journal of Applied Data Sciences, 5*(3), 961-979.

Nijat, D. U. S. (2021). *Project-based learning in biology lessons*. Paper presented at the International Nowruz Conference on Scientific Research March 18-21, Karabagh, Azerbaijan, 470–410.

Nurdin. (2007). *Mathematics learning models that develop metacognitive abilities to master learning tools*. Disertasi tidak dipublikasikan. Surabaya: Program Pascasarjana Universitas Negeri Surabaya.

Nurhidayah, I., Wibowo, F., & Astra, I. (2021). *Project based learning (PjBL) learning model in science learning: Literature review*. Paper presented at the Journal of Physics: Conference Series.

Plomp, T. (2007). *Educational design research: An introduction. In J. van den Akker, B. Bannan, A. E. Kelly, N. Nieveen, & T. Plomp (Eds.), An introduction to educational design research*. Paper presented at the Proceedings of the Seminar Conducted at the East China Normal University, Shanghai (PR China), November 23–26, 2007 (pp. 1–8). Enschede, Netherlands: Stichting Leerplan Ontwikkeling (SLO).

Putra, A. P., Akrim, A., & Dalle, J. (2020). Integration of high-tech communication practices in teaching of biology in Indonesian higher education institutions. *International Journal of Education and Practice, 8*(4), 746-758. https://doi.org/10.18488/journal.61.2020.84.746.758

Rahmawanti, M. R., & Umam, A. (2019). Integrating web 2.0 tools in writing class to promote assessment for learning. *JEES (Journal of English Educators Society), 4*(2), 53-59. https://doi.org/https://doi.org/10.21070/jees.v4i2.2516

Ritter, S. M., & Mostert, N. (2017). Enhancement of creative thinking skills using a cognitive-based creativity training. *Journal of Cognitive enhancement, 1*, 243-253. https://doi.org/https://doi.org/10.1007/s41465-016-0002-3

Sabel, J. L. (2020). Using the FRAMER scaffold design framework to support students in learning & understanding biology. *The American Biology Teacher, 82*(3), 150-155. https://doi.org/10.1525/abt.2020.82.3.150

Sholahuddin, A., Anjuni, N., & Faikhamta, C. (2023). Project-based and flipped learning in the classroom: A strategy for enhancing students' scientific literacy. *European Journal of Educational Research, 12*(1), 239–251. https://doi.org/10.12973/eu-jer.12.1.239

Sugiharto, B., Corebima, A. D., & Susilo, H. (2019). The pre-service biology teacher readiness in blended collaborative problem based learning (BCPBL). *International Journal of Instruction, 12*(4), 113-130. https://doi.org/10.29333/iji.2019.1248a

Sukmawati, F., Setyosari, P., Sulton, S., & Purnomo, P. (2019). The effect of project-based collaborative learning and social skills on learning outcomes in biology learning. *Journal for the Education of Gifted Young Scientists, 7*(4), 1325-1344. https://doi.org/http://dx.doi.org/10.17478/jegys.630693

Sumarni, W. (2015). The strengths and weaknesses of the implementation of project based learning: A review. *International Journal of Science and Research, 4*(3), 478-484.

Susilowati, D., Degeng, I. N. S., Setyosari, P., & Ulfa, S. (2019). Effect of collaborative problem solving assisted by advance organisers and cognitive style on learning outcomes in computer programming. *World Transactions on Engineering and Technoogy Education, 17*(1), 35-41.

Syawaludin, A., Prasetyo, Z. K., Jabar, C. S. A., & Retnawati, H. (2022). The effect of project-based learning model and online learning setting to analytical skills of discovery learning, interactive demonstrations, and inquiry lessons on the pre-service elementary teachers. *Journal of Turkish Science Education, 19*(2), 608-621.

Thompson, F., & Logue, S. (2006). An exploration of common student misconceptions in science. *International Education Journal, 7*(4), 553-559.

Vermeulen, C., & Meyer, B. (2017). The equal sign: teachers' knowledge and students' misconceptions. *African Journal of Research in Mathematics, Science and Technology Education, 21*(2), 136-147.

Vitharana, P. (2021). Secondary school learners conceptions of the structure and function of the human circulatory system. *International Journal of Humanities, Social Sciences and Education, 8*(4), 283-292.

Wancham, K., Tangdhanakanond, K., & Kanjanawasee, S. (2023). Sex and grade issues in influencing misconceptions about force and laws of motion: An application of cognitively diagnostic assessment. *International Journal of Instruction, 16*(2), 437-456. https://doi.org/10.29333/iji.2023.16224a

Wu, H. L., Weng, H. L., & She, H. C. (2016). Effects of scaffolds and scientific reasoning ability on web-based scientific inquiry. *International Journal of Contemporary Educational Research, 3*(1), 12–12.

Yangin, S., Sidekli, S., & Gokbulut, Y. (2014). Prospective teachers' misconceptions about classification of plants and changes in their misconceptions during pre-service education. *Journal of Baltic Science Education*, *13*(1), 105. https://doi.org/10.33225/jbse/14.13.105

Yates, T. B., & Marek, E. A. (2015). A study identifying biological evolution-related misconceptions held by prebiology high school students. *Creative Education*, *6*(8), 811-834. https://doi.org/10.4236/ce.2015.68085

Zlatkin-Troitschanskaia, O., Shavelson, R. J., & Kuhn, C. (2015). The international state of research on measurement of competency in higher education. *Studies in Higher Education*, *40*(3), 393-411. https://doi.org/10.1080/03075079.2015.1004241