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The potential of the integrated project-based and 4C-scaffolding (Pj4CS) learning model to increase prospective biology teachers' global 4C skills

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ABSTRACT
Research on identifying 4C skills using the Pj4CS model remains limited, especially in biology education. Preliminary studies indicate that the 4C skills of prospective biology teachers still need improvement and optimal utilization in classroom learning. This study aims to analyze the potential of the Integrated Project-Based and 4C-Scaffolding (Pj4CS) model to increase global 4C skills (Critical Thinking, Communication, Collaboration, and Creativity). This research type is a quasi-experiment. The research instrument was valid and reliable before data collection. The research results showed differences in 4C skills between the pretest and posttest in the Pj4CS model. The *t*-test results showed significance at the 0.000 level for critical thinking, communication, collaboration, and creativity. A significance value of less than 0.05 indicated that the Pj4CS model effectively improved students' critical thinking, communication, collaboration, and creativity. Providing appropriate scaffolding in project-based learning helps students produce more creative project products. The Pj4CS model has been shown to positively impact improving aspects of critical thinking, communication skills, collaboration skills, and creativity, which are important life skills that must be developed in today's learning. Students are trained to develop critical thinking and communication skills through collaborative project design. The syntax of the Pj4CS model positively empowers 4C skills in biology learning. The research concludes that the Pj4CS model can improve 4C global skills (critical thinking, communication, collaboration, and creativity).

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Introduction

The rapid development of the digital era presents challenges for universities in preparing globally competitive graduates with 21st-century skills (Asrizal et al., 2022; Haviz et al., 2020; Hrechanyk et al., 2023). Education in the 21st century aims to build students' intelligence competencies to learn and overcome surrounding problems and the challenges of the Industrial Revolution 4.0 (Asrizal et al., 2025; Effendi et al., 2020; Le et al., 2022; Proud & Potter, 2020). Intelligence in the real world is not only about what prospective teachers know, but also about their ability to solve problems in meaningful, contextual ways (Desgamalia & Syamsurizal, 2019; Van Laar et al., 2017; Villena Taranilla et al., 2019). Critical thinking, communication, collaboration, and creativity are soft skills needed in a career and in the future (Hunaidah et al., 2018; P21 (Partnership for 21st Century Skills), 2011; Tang et al., 2020; Triana et al., 2020). Students need comprehensive knowledge, skills, and attitudes to think and act appropriately (Abaniel, 2018; Ang, 2018; Kubitskyi et al., 2023; Malik, 2018). This can strengthen prospective biology teachers' global competence in facing the 21st-century challenges. Educators must consistently develop learning designs that accommodate 4C skills in delivering material in class (Jalinus et al., 2023; Sipayung et al., 2018; Teo, 2019).

In the principles of 21st-century learning, learning must be student-centered, collaborative, connected to the real world, and integrated with society (Asrizal et al., 2019; Supriyono & Prabowo, 2021; Wulandari et al., 2016). Communication and collaboration skills enable prospective biology teachers to interact competently and respectfully with others from various cultures, social backgrounds, and communities in the global era (Amin, Adiansyah, et al., 2023; Erdoğan, 2019). Collaboration and communication skills are essential for workplace success (Indrawati, 2021; Rosen et al., 2020). Authentic, real projects are crucial for providing opportunities to develop the skills needed in the job market (Arwizet & Saputra, 2019; Miller & Grooms, 2018). Through project implementation, prospective biology teachers can build knowledge and skills through inquiry. Integrating project-based strategies makes this learning method adaptable to students from various backgrounds, ages, and education levels (Nasir & Andrew, 2022). Effective learning should be designed to match graduates' capacity to apply knowledge in the workplace.

Job opportunities in the technology sector are currently increasing on an industrial scale. However, there remains a gap between job seekers' skills and the industry's competencies (Widarti et al., 2020). The low critical thinking skills of prospective biology teachers are caused by the learning process, which has not developed their reasoning skills (Amin & Adiansyah, 2023; Supena et al., 2021). The verbal and nonverbal communication skills of prospective biology teachers are still relatively low (Amin et al., 2022). Problems that occur in the learning process for prospective biology teachers include a lack of participation in asking questions and discussions, low courage to ask questions, low communication skills both verbally and in writing, and low problem-solving skills (Amin et al., 2020; Hastuti et al., 2022). Critical thinking skills do not develop automatically as they age and grow (Amin, Karmila, et al., 2023). This issue has widened the gap between the quality of graduates and the workforce's demand for 4C global competencies.

Mastering the 4C global skills (critical thinking, communication, collaboration, creativity) is necessary for students to develop the qualities needed for success in college, in their careers, and in citizenship in the 21st century. To direct learning towards 21st-century skills, educators must choose a learning model that involves students in teaching and learning to help them master the 4C skills. Educators must also design fun, creative, and innovative learning experiences and foster students' learning independence by integrating the 4C global skills into classroom instruction. Prospective teachers must compete and contribute to learning to achieve goals and success (All et al., 2021; Hwang, 2023; Li et al., 2021; Tapingkae et al., 2020). Project-based learning has been reported to contribute to deeper understanding and to the improvement of scientific attitudes in the classroom (Markula & Aksela, 2022). However, the Project-Based Learning model is not without its limitations. Several studies have identified various weaknesses in its implementation within classroom settings. For instance, prospective biology teachers often require extended time to plan and develop their projects (Grant, 2002). During Project-Based Learning, students frequently struggle to generate innovative ideas, collaborate effectively to develop them, and resolve intragroup conflicts through negotiation (Sumarni, 2015). To address these limitations, students can be guided toward greater independence by employing a modified project-based learning model that incorporates simplified learning stages while still fostering the development of 4C global competencies. This approach is embodied in the Pj4CS model.

Pj4CS is a new learning model designed to facilitate critical thinking, communication, collaboration, and creativity by providing scaffolding for students' needs. There has not been much research on applying Pj4CS in biology learning. The Pj4CS model is expected to provide a new color in learning that is more independent, meaningful, and in line with the needs of 21st-century learning. In this learning model, educators serve primarily as facilitators and directors, while each collaborative group generates the project design and ideas. When students encounter difficulties, educators provide scaffolding tailored to individual needs. This support includes technical guidance on using digital tools such as Canva, Mendeley, AI applications, and other relevant technologies to enhance the creativity, structure, and visual quality of students' final products. The learning environment is intentionally structured to enable students to manage their own learning processes as they work toward completing their projects. This approach fosters student autonomy and supports the development of individuals who are not only academically capable but also adaptive, creative, and responsible (Amin & Karmila, 2024).

This result can contribute to science education in instructional learning, especially regarding new learning models. In biology education, this research can strengthen students' 4C skills by enhancing their biological scientific literacy. Apart from that, this research also enriches the theoretical repertoire regarding educators' (teachers and lecturers') professional skills in addressing the global challenges of the Industry 4.0 and Society 5.0 era. At the practical level, research can serve as a basis for designing new learning designs and for further research on implementing learning models in the classroom. This study aims to analyze the potential of the Integrated Project-Based and 4C-Scaffolding (Pj4CS) model to increase global 4C skills (Critical Thinking, Communication, Collaboration, and Creativity).

To guide our research, we propose the following research questions.

1. How does the Integrated Project-Based and 4C-Scaffolding (Pj4CS) model influence the critical thinking of pre-service biology students?
2. How does the Integrated Project-Based and 4C-Scaffolding (Pj4CS) model influence the communication skills of pre-service biology students?
3. How does the Integrated Project-Based and 4C-Scaffolding (Pj4CS) model influence collaboration skills among pre-service biology students?
4. How does the Integrated Project-Based and 4C-Scaffolding (Pj4CS) model promote creativity in pre-service biology students?

Literature Review

Critical thinking skills direct students to formulate, identify, and solve problems by providing logical arguments (Lestari et al., 2021; Novitra et al., 2021; M. A. Samsudin et al., 2020; Utaminingsih et al., 2024). The project-based learning model, integrated with 21st-century skills, guides prospective biology teachers to collaborate and form teams to complete planned projects (Anazifa & Djukri, 2017; Raiyn, 2016). Applying project-based learning integrated with 21st-century skills can improve higher-order thinking skills (Hujjatusnaini et al., 2022; Suryandari et al., 2021). The project-based learning model can train thinking skills, make them more critical of each problem, and help them analyze it based on their experience (Asman et al., 2022; Pratama et al., 2018).

To accommodate the needs for 4C skill development, project-based learning can be applied. Critical thinking skills are important for encouraging student independence and training their ability to solve scientific problems. Project-based learning can develop higher-order thinking skills by having students express ideas and arguments related to the project they work on (Choi et al., 2019; Rati et al., 2023; Szalay et al., 2024). The problems that arise prompt students to develop their projects and to formulate related basic questions (Bhakti et al., 2020; Kokotsaki et al., 2016). Students in project-based learning are trained to explore, analyze, interpret, synthesize, and evaluate information to improve thinking skills and learning success (Astra et al., 2019; Somphol et al., 2022).

Previous studies indicate that the Pj4CS learning model significantly enhances pupils' critical thinking skills (Hama & Amin, 2025). For instance, in experimental classes, the critical reading phase trained prospective biology teachers to engage actively and critically with the learning materials, such as e-books and handouts. This engagement fostered teachers' perspectives on collecting, processing, analyzing, and evaluating information critically (González-Cespón et al., 2024). In the study, critical thinking enabled the students to identify and select valid, relevant, high-quality, and verified sources of information.

The advantage of project-based learning combined with 4Cs skills is that it can motivate students to engage in critical thinking actively (Efendi et al., 2020; Listiqowati et al., 2022). Regional potential-based project learning has improved students' 4C skills (Syahril et al., 2022). Integrating project-based learning into science instruction has the advantage of improving critical thinking skills and of assessing biology teachers' perspectives (Maryuningsih et al., 2019).

In addition, the Pj4CS model has been shown to impact digital literacy positively (Amin et al., 2025). Scaffolding in the form of structured guidance, such as training in using digital tools like Canva and artificial intelligence applications, helped students enhance the quality and creativity of their project work. Students responded enthusiastically to these digital tools, especially when they were contextualized within biology learning. Furthermore, the Pj4CS model has proven effective in strengthening analytical thinking and communication-argumentation skills (Amin et al., 2025).

The Pj4CS model encourages prospective biology teachers to get involved in learning activities, thereby enhancing overall learning effectiveness. It has also been found to reduce biological misconceptions (Amin & Karmila, 2024). One of its core components, the *collaborative participation* phase, aims to foster a cooperative learning environment conducive to successful project development. During this phase, prospective biology teachers engage in activities such as observing, associating, experimenting, discussing, and exchanging ideas related to the project. Educators play a supportive role by facilitating group collaboration and guiding the effective use of digital tools and media to ensure the success of the project design (Amin & Karmila, 2024).

Research on the Pj4CS model remains limited, as it is a relatively new instructional approach developed by scholars. However, numerous studies have explored the integration of Project-Based Learning (PjBL) with various other instructional strategies. For example, combining prospective teachers' advanced thinking abilities can significantly improve their cognitive learning outcomes (Liline et al., 2024). Similarly, the use of science project-based learning modules can strengthen students' problem-solving skills in a collaborative learning environment, thereby fostering critical thinking, promoting teamwork, and improving academic performance (Ghazali et al., 2025).

Methods

Research Design

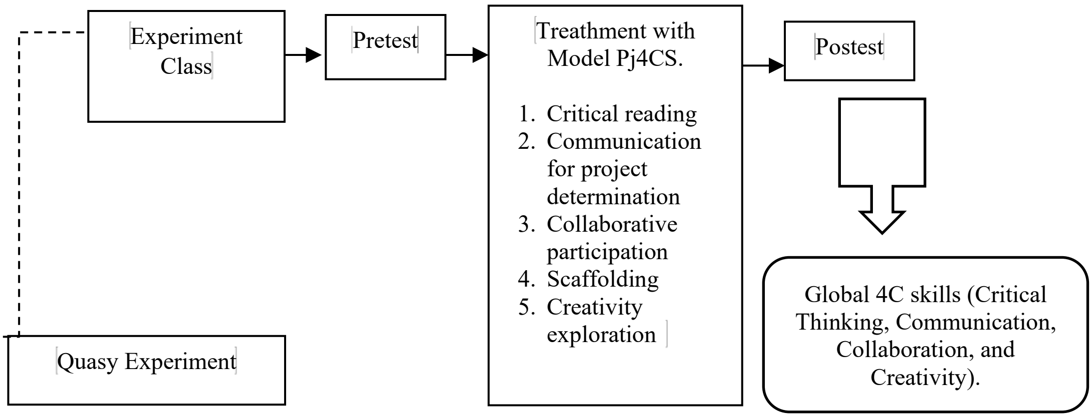
This research type is a quasi-experiment (Creswell & Clark, 2011). The experimental design used was a one-group pretest-posttest. The research sample was 22 prospective biology teachers. A pretest was conducted before learning to determine students' initial skills (Wisdom & Creswell, 2013).

Research Procedure

The experimental class was taught using the Pj4CS model. The steps of the Pj4CS learning model consist of critical reading, communication for project determination, collaborative participation, scaffolding, and creative exploration. At the critical reading stage, lecturers assigned students to read and analyze essential concepts/material, checked and identified their critical reading results, and provided reflections on essential concepts/material. During the project determination stage, the lecturer organized students into project groups and asked them to communicate internally to determine which project to design. At the collaborative participation stage, the lecturer assigned each project group to collaborate on implementing the project design and to search for project concepts and supporting materials online. At the scaffolding stage, the lecturer provided guidance and support for using media/ICT relevant to the group's needs. Guidance from lecturers took the form of using Canva, Mendeley, e-library, and other media applications. At the creativity exploration stage, the lecturer allowed each group to create products using the given material and display their results to the class. Lecturers rewarded each project group's achievements (Amin & Karmila, 2024). This Pj4CS learning syntax is applied to lectures on human body anatomy and physiology, covering the musculoskeletal, integumentary, nervous, endocrine, urinary, lymphatic, respiratory, digestive, circulatory, and reproductive systems. The research flowchart is shown in Figure 1 below.

Figure 1

Research flowchart



Research data are collected through several activities. The first activity was a pretest. The test used an essay question type. Questionnaires were also used to determine students' motivation. Students' initial critical thinking, communication, collaboration, and creativity skills were measured using tests. Measurement of these variables was conducted on 22 prospective biology teachers. After the pretest, the researcher conducted lectures using the Pj4CS learning syntax. Observations were conducted during lectures to collect data on the implementation of learning syntax and communication skills. At the critical reading stage, students are assigned e-books, e-modules, and journal articles on research findings to support learning in human anatomy and physiology. During the project-determination stage, students are grouped into five teams and assigned tasks to design projects related to human anatomy and physiology. At the collaborative participation stage, each group collaborates to realize their project design and conducts monitoring, including managing time and resources, finding and using learning resources, taking responsibility for each task, and maintaining consistency in implementing project stages according to plan. At the creativity exploration stage, each group presents the project's creative products and contributes to the class exhibition. One partner lecturer and two observers observe the Pj4CS learning process to review the implementation of the Pj4CS learning stages.

The researcher administered a posttest consisting of a questionnaire and an essay at the last meeting. Questionnaires were used to determine students' motivation. The student learning motivation questionnaire comprises 52 statement items, both positive and negative, covering aspects of attention, relevance, confidence, and satisfaction. This motivation questionnaire used a Likert scale.

Students' final critical thinking, communication, collaboration, and creativity skills were measured using tests. The next activity was to provide student response questionnaires on implementing the Integrated Project-Based and 4C-Scaffolding (Pj4CS) learning model. The series of activities closed with a learning reflection. Reflection aims to analyze prospective biology teachers' responses to the applied learning model and to evaluate the potential and shortcomings of the Pj4CS model. Table 1 presents the steps (syntax) of the Pj4CS learning model, outlining the specific activities carried out by both the lecturer and the students.

Table 1

Pj4CS syntax/learning stages

Syntax	Learning Activities	
	Lecturer	Students
Step 1. *Critical Reading*	1. Assigns students to read and analyze essential concepts/materials. 2. Checks and identifies the results of students' critical reading process and provides reflection on essential concepts/materials.	1. Read and analyze essential concepts/materials. 2. Clarify the identification results from the critical reading process.
Step 2. *Communication for project determination*	1. Organizes students into project groups 2. Asks students to communicate with each other within their respective groups to determine the project	1. Students sit in groups 2. Communicate project design ideas in their respective groups
Step 3. *Collaborative participation*	1. Assign students to collaborate in groups and complete the assigned project tasks. 2. Asks each group to search for concepts/material to support the project on the internet	1. Students work together in groups and collaborate to complete pre-designed project assignments. 2. Search for concepts/supporting project materials via the internet.
Step 4. *Scaffolding*	1. Provides scaffolding according to the needs of each project group. 2. Guides the use of media/ICT, AI applications that are relevant to the needs of the group. Guidance can take the form of showing students how to use Canva, Mendeley, the e-library, AI, and other media.	1. Follow the scaffolding provided by the lecturer. 2. Ask for the lecturer's guidance that is relevant to the group's needs.

Syntax	Learning Activities	
	Lecturer	Students
Step 5. *Creativity Exploration*	1. Offers each group the opportunity to be creative in producing products after understanding the material. 2. Asks each group to display their products in front of the class and award each group's achievements.	1. Each group explores its creativity to produce projects such as learning posters, e-modules, brochures, learning videos, and others. 2. Display the products in front of the class.

Research Instrument

The research instruments measured critical thinking, communication, collaboration, and creativity skills. Data on critical thinking skill scores are obtained through an essay test. Critical thinking skills scores were obtained using the critical thinking skills scoring guide developed by Zubaidah et al. (2015 which is an adaptation of the Illinois Critical Thinking Essay Test and Scoring Guidelines. The assessment consists of 5 scales (0-5). Communication skills data are collected through observation sheets during the discussion and presentation. The guide was an adaptation of NEA and P21, which includes four indicators: speaking, listening, writing, and non-verbal (NEA, 2012; P21 (Partnership for 21st Century Skills), 2011).

Collaboration skill data refers to indicators of responsibility, respect for others, contributions, ability to organize work, and working as a team. Meanwhile, creativity data refers to indicators of originality, fluency, flexibility, elaboration, and risk-taking. The assessment was carried out through questions and observation sheets. The prepared questions are high-level reasoning essay questions that assess originality, fluency, flexibility, elaboration, and risk-taking in the material on human anatomy and physiology. Previously, a question grid was prepared that referenced the creativity indicators, learning objective achievement, and the cognitive level of the questions. Meanwhile, the observation sheet is used to assess the project process and product which is reflected by the originality indicators (new and unique ideas generated during the project assignment), elaboration (the ability used in working on the project and producing project products), fluency (the number of creative and innovative ideas that are relevant to the project assignment problem), flexibility (the ability to change the approach used if the problem requires a new approach in completing the project task), risk taking (willing to try new things in completing the project task on time). The creativity observation sheet is conducted throughout the learning process, with assistance from partner lecturers and two observers.

The research instrument underwent expert and empirical validation. Three biology education lecturers carried out expert validation. The following summarizes the average expert validation scores.

Table 2

The average scores of expert validation

Research Instrument	Average Score of Expert Validation	Category
Critical Thinking	3.63	Valid
Communication	3.75	Valid
Collaboration	3,68	Valid
Creativity	3,71	Valid

The validity test of the research instrument was conducted by correlating each item score with the total score using the Pearson product-moment correlation coefficient. The test criterion is that if the correlation coefficient exceeds the Product-Moment r-table, the questionnaire items are valid data-collection instruments. From the validity test with a sample size of n = 21 and a significance level ∝ = 0.05, the r-table value is 0.433. Questionnaire reliability was assessed using the Alpha-Cronbach formula. The test criteria state that the questionnaire items are reliable if the Cronbach's alpha is greater than 0.6. The following summarizes the research instrument's empirical validation and reliability test results.

Table 3

Results of the empirical validity and reliability test of the research instrument

Research Instrument	Validity Test Result	Reliability Test Result
Critical Thinking	0.626 (all items are valid)	0.774 (all items are consistent or reliable)
Communication	0.613 (all items are valid)	0.974 (all items are consistent or reliable)
Collaboration	0.585 (all items are valid)	0.939 (all items are consistent or reliable)
Creativity	0.518 (all items are valid)	0.945 (all items are consistent or reliable)

Data Analysis

Research data are analyzed descriptively and inferentially. Descriptive analysis provided a profile description of critical thinking, communication, collaboration, and creativity skills. The inferential analysis tested the influence of the Pj4CS model on critical thinking, communication, collaboration, and creativity, to assess its potential as a predictor of the dependent variable. Data were analyzed using a paired *t*-test with a significance level of 5%.

Findings

The following presents the average scores for the 4C skills (critical thinking, communication, collaboration, and creativity).

Table 4

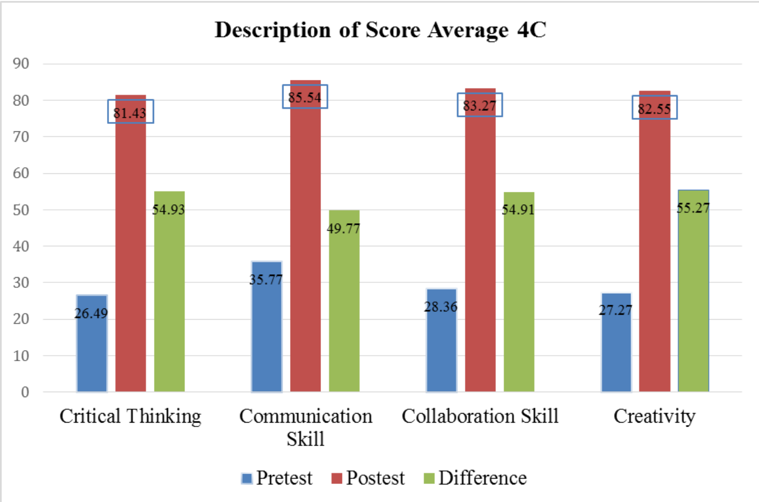
The average scores of 4C skills

Variable	Average			t count	P value	N Gain
	Pretest	Postest	Difference			
Critical Thinking	26.49	81.43	54.93	42.657	0.000	0.747
Communication	35.77	85.54	49.77	179.208	0.000	0.774
Collaboration	28.36	83.27	54.91	36.219	0.000	0.766
Creativity	27.27	82.55	55.27	34.698	0.000	0.760

Based on Table 4, students' 4C skills (critical thinking, communication, collaboration, and creativity) have increased after implementing the Pj4CS model. The difference obtained for the critical thinking skills is 54.93, the communication skills are 49.77, the collaboration skills are 54.91, and the creativity is 55.27. Before the hypothesis test, prerequisite tests, namely the normality and homogeneity-of-variance tests, were conducted. Based on the results of the normality test using the Kolmogorov-Smirnov test and the decision-making criteria with $\alpha = 0.05$, the significance values (p-values) for the pretest and posttest on all variables were greater than 0.05 ($p>0.05$). This shows that the data on critical thinking, communication, collaboration, and creativity are normally distributed. Meanwhile, the homogeneity test produced a significance value (p-value) for the Levene test greater than 0.05 ($p>0.05$), so the pretest and posttest data for critical thinking, communication, collaboration, and creativity have homogeneous values. All variables had a significance of 0.000, which is less than 0.05. Therefore, H_0, which states that there is no difference between the pretest and posttest scores on 4C skills in the Pj4CS Model, is rejected. Thus, the research hypothesis is accepted. The comparison of average 4C skills after implementing the Pj4CS model is shown in the following figure.

Figure 2

The comparison of the score average 4C Skills after applying the Pj4CS learning model



Based on Figure 2, the highest post-test score was in communication, and the largest increase in difference was in creativity.

Discussion

The syntax of the Pj4CS learning model is proven to stimulate students' 4C skills. The critical reading stage in Pj4CS learning changes students' thinking skills. This opportunity affects students' classroom readiness. They have adequate prior knowledge to contribute actively to the next stage of Pj4CS learning. Students with critical thinking skills can write something essential and substantive because they can clearly and critically express various ideas (Cossu et al., 2024; Saad et al., 2024; Suteja & Setiawan, 2022). Critical thinking skills play an important role in analyzing decision-making and in making quality arguments to defend opinions, so that, in the future, students can survive in the working world (Islamiyati et al., 2023; Susilo et al., 2023). Students with strong reading skills also tend to have better reasoning skills (Zulyusri et al., 2023). Critical thinking must continue to be empowered in learning because it is the core of scientific development (Isra & Mufit, 2023). The development of cognitive skills is important for students' future academic and professional growth (Suryawati et al., 2024). Students’ prior knowledge is increasingly recognized as a determining factor in science learning (A. Samsudin et al., 2024). The stages of the Pj4CS model have demonstrated effectiveness in stimulating students' critical thinking skills (Hama & Amin, 2025).

Educators in the second activity of the Pj4CS model, communication for project determination, act as facilitators and supervisors. Educators ensure that each group communicates internally during project design. The groups formed were heterogeneous, consisting of students with high, medium, and low prior academic knowledge. Excellent and effective communication skills will enable students to build strong relationships with others and the world (Fitriati et al., 2023; Omodan, 2023; Rati et al., 2023). One can quickly enter new situations using knowledge and good communication skills (Afikah et al., 2023; Alawamleh et al., 2022). If others cannot receive, understand, and listen to the message, communication cannot occur (Ilinitska et al., 2023; Munthe et al., 2023; Rahaman & Luczynski, 2024). Communication skills can only be achieved when discussion and confrontation of ideas among learners are promoted, with the need to convince themselves and others of the truth of their statements grounded in quality arguments (Rico et al., 2023). Prospective teachers need to be encouraged to develop scientific and communication skills so that future learning can be of higher quality and globally competitive (Baigabylov et al., 2025; Silverio et al., 2024). Understanding scientific concepts is one indicator of success in science learning (Winarni et al., 2024). Students with strong information and communication literacy skills exhibit greater capacity to access, assess, and use relevant information effectively (Akhtar et al., 2024; Nuraini et al., 2025). Research has demonstrated the effectiveness of the Pj4CS model in enhancing students’ information processing and digital literacy, thereby fostering greater autonomy in project design (Amin et al., 2025).

Educators in this activity guide each group in building active collaboration and utilizing media and IT resources to support the design's success. This activity has been proven to increase group members' cooperation. Students in the experimental class are trained to observe, associate, compare, discuss, and communicate essential things that support project design. 21st-century learning requires students to be literate in developing and advancing information and communication technology and 4C skills (Muliyati et al., 2023; Pramasdyahsari et al., 2023; Siebers & Cobley, 2024). Project-based learning provides both independent and direct learning experiences for students, enabling them to develop 4C skills (Chang et al., 2024; Imansari et al., 2022; Shukor et al., 2023). Students' active collaboration and participation in learning can be seen in effective work activities, productivity, collaborative participation, and successful learning strategies (Ajani, 2023; Kuhlmann et al., 2023; Nahar et al., 2022). Student collaboration and active participation in learning can be seen in effective work activities, productivity, evaluation, and role-sharing and collaboration (Nahar et al., 2022). Fostering active student engagement and facilitating knowledge acquisition at higher cognitive levels necessitate complex interactions, often driven by significant innovations in instructional practices (Chohan et al., 2024; Labak et al., 2024).

In scaffolding activities within the Pj4CS model, educators guide each project group based on needs. Each group in the experimental class communicates the progress of their design and the obstacles they face in realizing it. Educators can also guide IT on project design and product needs, such as using the Canva application for designing project product presentations, citation management with Mendeley, e-library access, Artificial Intelligence (AI), and other structured guidance. High-performing learners generally demonstrate higher cognitive abilities in acquiring, integrating, and applying knowledge to projects (Mou, 2023; Tian et al., 2023). Students' performance is evaluated from five aspects: cognitive load, learning attitude, learning engagement, level of scientific knowledge, and skills (Kocsis & Molnár, 2024; Shaninah & Mohd Noor, 2024; Zhong et al., 2024). Prospective teachers must develop content knowledge and pedagogical strategies during their pre-professional practice, which is essential for their future teaching practice (Hernandez & Barrera, 2024). The use of IT in learning plays a very important role in the effectiveness of access to information and in the development of science skills (Rusdiyana et al., 2024). The syntax of the Pj4CS model can accommodate these learning needs.

The final activity, creativity exploration, in the Pj4CS model has been shown to stimulate and increase the creativity of students in experimental classes. At this stage, educators explore each student's potential so they can actively contribute creative ideas when designing products for their group projects. During project design discussions, students in each group express creative ideas and communicate with their group members to determine the project design. The project learning model stimulates students to produce creative and critical ideas and increases team collaboration to solve problems effectively (Crawford et al., 2024; Sugiharto et al., 2024; Syahril et al., 2022). Students require sufficient time to engage in the design and development of innovations and to navigate the challenges encountered throughout the project design process (Jituafua, 2024). The final phase of the Pj4CS model offers learners the opportunity to showcase their creativity and innovation by producing final outputs (Amin & Karmila, 2024).

The findings in the research are that the Pj4CS model positively influences critical thinking, communication, collaboration, and creativity, which are life skills that are important to cultivate in current learning. Implementing the Pj4CS model requires a fast adaptation pattern and adequate cognitive accommodation capabilities for students. The challenge for educators today is how to move from old learning patterns towards independent learning. The Pj4CS model has the advantage of having specific scaffolding stages at the learning stage. Educators and students must work together to achieve holistic, independent, and globally competitive learning success. Successful programs combine active learning, collaboration, and reflection, are often longitudinal and comprehensive, and impact student attitudes, knowledge, self-efficacy, and skills (Almonacid-Fierro et al., 2023; Langelaan et al., 2024; Nguyen et al., 2024). Improving students' critical thinking, communication, and argumentation skills can be achieved in a meaningful way when students' and educators' beliefs and motivations are integrated (Mavuru, 2024). Biological knowledge and pedagogical competence are essential for prospective biology teachers to develop effective teaching plans (Parmin et al., 2024). Learners can actively develop their understanding by engaging in real-world problems and achieving their goals through social interaction and sharing (Özkan et al., 2024). The Pj4CS model is well-suited to support these learning needs.

The Pj4CS model can serve as a learning model that accommodates 21st-century learning needs. Implementing the Pj4CS model development design can contribute to the development of classroom teaching and learning strategies. The Pj4CS learning model can improve aspects of life, such as science and technology. Learning syntax can strengthen students' scientific, digital, and life skills. The integration of critical thinking, communication, collaboration, and creativity aligns with the application of biology learning principles, enabling students to develop independence and a more vital scientific process attitude as they construct their knowledge and understanding. This research also contributes to previous findings on the role of scaffolding in students' development. Scaffolding affects students cognitively and emotionally; it impacts not only their skills and knowledge but also their motivation and confidence when undertaking project tasks. The application of the Pj4CS model is reviewed to support project-based learning and appropriate scaffolding. The application of this model can, in theory, contribute to education, especially by strengthening Vygotsky's learning theory and instructional practice. In practice, research results inform the development of applied research in biology education. The Pj4CS model can also serve as an alternative learning approach to support the development of digital literacy in secondary schools and universities (Amin et al., 2025).

Conclusion and Implications

The research hypothesis is accepted based on the research results and data analysis. The Integrated Project-Based and 4C-Scaffolding (Pj4CS) learning model significantly increases critical thinking, communication, collaboration, and creativity. Activities in Pj4CS learning can improve 4C skills. Students in biology education have more robust literacy, increased learning activities, and greater creativity and collaboration, fostering positive social attitudes that support learning success. The application of this model can, in theory, contribute to education, especially by strengthening Vygotsky's learning theory and instructional practice. At the practical level, this research can serve as a reference and basis for designing new learning designs and for supporting further research on implementing learning models in the classroom. It is hoped that the Pj4CS model can be implemented widely on a larger, more global scale. The Pj4CS model can serve as an alternative for educators across countries to address the gap between students' global skills and the needs of careers in the Industry 4.0 and Society 5.0 era. Future researchers can conduct studies using moderator variables to evaluate the potential of the Pj4CS model, such as gender, academic ability, and multiculturalism.

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Declaration of Interest

No conflict of interest.

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Appendix

Lesson Plan (Pj4CS Model)

Course Name	Human Anatomy and Physiology
Credit Hours/Semester	2 SKS/ VI
Course Description	*Human Anatomy and Physiology* is a compulsory 2-credit course offered in the even semester. It provides an in-depth study of the structural and functional organization of the human body. Key topics include levels of biological organization, anatomical and physiological terminology, homeostasis and feedback mechanisms, and the structure and function of major body systems. The course covers the nervous system (including neurons, neuroglia, central, peripheral, and autonomic components), special senses, integumentary, skeletal, muscular, and endocrine systems. Emphasis is placed on the anatomy and hormonal mechanisms of major endocrine glands, including the hypothalamus, pituitary, thyroid, parathyroid, pineal, thymus, pancreas, adrenal glands, and gonads.
Study Program Objectives	S1: Students are devoted to God Almighty and able to demonstrate a religious attitude. S9: Students demonstrate a responsible attitude towards work in their field of expertise independently. P10: The study program facilitates the development of students' biological science potential optimally KU 1: Students are able to apply logical, critical, systematic, and innovative thinking in developing or implementing science and technology that pays attention to and applies humanities values that are in accordance with their field of expertise. KU 2: Students are able to demonstrate independent, quality, and measurable performance. KU9: Students are able to document, store, secure, and rediscover data to ensure validity and avoid plagiarism. KK4: The study program facilitates the development of students' biological sciences to actualize their abilities and skills in the field of biology in real life at school/*madrasah* and in society.
Course Objectives	*CPMK* (Graduate Learning Outcomes Assigned to Courses) By the end of this course, students will be able to:

	1. Explain the levels of biological organization and apply anatomical and physiological terminology to describe the human body comprehensively. 2. Describe the principles of homeostasis and the mechanisms of feedback regulation. 3. Analyze the anatomy of neurons and neuroglia and explain the physiological basis of neural activity. 4. Identify and describe the normal anatomy and physiology of the central nervous system. 5. Identify and describe the anatomy and physiology of the peripheral nervous system. 6. Explain the structure and function of the autonomic nervous system. 7. Describe the anatomy and physiology of the special sensory organs. 8. Identify the structure and function of the integumentary system. 9. Describe the anatomical structure and physiological roles of the skeletal system. 10. Explain the anatomy and physiology of the muscular system. 11. Differentiate between endocrine and exocrine glands and explain the mechanisms of hormone action. 12. Identify the anatomy of the hypothalamus and pituitary glands and explain the hormonal regulation mechanisms involved. 13. Describe the anatomical structures of the thyroid, parathyroid, pineal, and thymus glands and the functional mechanisms of their respective hormones. 14. Examine the anatomy of the pancreas, adrenal glands, and gonads, and explain the mechanisms of action of the hormones they produce.
Learning Materials	1. Levels of organization in living organisms; terminology related to human anatomy and physiology. 2. Principles of homeostasis and feedback mechanisms. 3. Anatomy of neurons and neuroglia; mechanisms of neural activity. 4. Normal anatomy and physiology of the central nervous system. 5. Anatomy and physiology of the peripheral nervous system. 6. Anatomy and physiology of the autonomic nervous system. 7. Anatomy and physiology of the special senses. 8. Anatomy and physiology of the integumentary system. 9. Anatomy and physiology of the skeletal system. 10. Anatomy and physiology of the muscular system. 11. Structure and function of endocrine and exocrine glands; mechanisms of hormone action, with emphasis on the pancreas. 12. Anatomy of the hypothalamus and pituitary glands; hormonal regulation and mechanisms of hormone action. 13. Anatomy of the thyroid, parathyroid, pineal, and thymus glands; mechanisms of hormone production and function. 14. Anatomy of the pancreas, adrenal glands, and gonads; mechanisms of hormone production and action.
Learning Model	Pj4CS Model
Learning Methods	1. Question and answer method. 2. Integrated lecture method 3. Exploration method. 4. Problem-solving method. 5. Argumentative discussion method

Learning Media	**Software**: *PowerPoint files, animations, and learning videos related to human anatomy and physiology materials, biology learning charts, and* learning posters. **Hardware:** LCD & projector.
References	1. Tortora, Gerrard J., & Derrickson, B. (2013). *Principles of Anatomy and Physiology, 14th edition*. Wiley 2. Martini, F. H., E. F., Bartholomew, J. L., & Nath. (2017). *Fundamentals of Anatomy & Physiology*, 11th edition. Pearson. 3. Sherwood, L. (2014). Fisiologi Manusia dari Sel ke Sistem, Edisi 8. Penerbit EGC. 4. Campbell, *et.al.* 2008. *Biologi Jilid 3 Edisi Kedelapan.* Erlangga: Jakarta 5. Research journals related to human anatomy and physiology.

Learning Activities for the Integrated Project-Based Learning and 4C Global Competence-Scaffolding (Pj4CS)

No	Learning Activities (Syntax)	Lecturer's Activities	Student's Activities
	Warm-up Activities		
	Opening	1. Opens the lesson with greetings, a prayer, student attendance, and an apperception activity to activate prior knowledge. 2. Provides motivation by presenting animations relevant to the lecture material. 3. Communicates the learning objectives and explains the assessment methods to be used.	1. Listen to and follow the lecturer's instructions during the opening activities, including greetings, prayer, attendance, and apperception. 2. Pay attention to the motivational remarks and introductory statements delivered by the lecturer. 3. Listen to the explanation of learning objectives and assessment techniques.
	Main Activities		
	Step 1. *Critical Reading*	1. Assigns students to read and analyze essential concepts/materials. 2. Checks and identifies the results of students' critical reading process. 3. Provides reflection on essential concepts/materials.	1. Read and analyze essential concepts/materials. 2. Clarify the identification results from the critical reading process. 3. Listen to the reflection of essential concepts/materials carried out by the lecturer.

No	Learning Activities (Syntax)	Lecturer's Activities	Student's Activities
	Step 2. *Communication for project determination*	1. Organizes students into project groups. 2. Asks students to communicate with each other within their respective groups to determine the project	1. Listen to the lecturer while s/he forms the groups. 2. Communicate project design ideas in their respective groups
	Step 3. *Collaborative participation*	1. Assigns students to collaborate to realize the project's design 2. Asks each group to search for concepts/material to support the project on the internet	1. Collaborate to realize the previously determined project design. 2. Search for concepts/supporting project materials via the internet.
	Step 4. *Scaffolding*	1. Provides scaffolding according to the needs of each project group. 2. Provides guidance on the use of media/ICT, AI applications that are relevant to the needs of the group. Guidance can be in the form of showing students how to use the Canva application, Mendeley, e-library, AI, and other media.	1. Follow the scaffolding provided by the lecturer. 2. Ask for the lecturer's guidance that is relevant to the group's needs.
	Step 5. *Creativity Exploration*	1. Offers each group the opportunity to be creative in producing products after understanding the material. 2. Asks each group to display their products in front of the class. 3. Gives rewards for the group achievement.	1. Produce creative biology-related products. 2. Display the products in front of the class. 3. Appreciate the rewards given by the lecturer.
	Wrapping Up		
	Closing	Coincludes the lecture by assigning tasks, encouraging students, and offering closing remarks	Listen attentively as the lecturer provides homework assignments, offers motivational messages, and concludes the session with closing remarks.

Assessment Rubric

No	Evaluated Elements	Maximum Score	Assessment
	Assessment of the critical reading process		
1	Students engage in careful reading of the assigned lecture materials.	**10**	
2	Students complete all required materials as instructed.	**10**	
3	Students make an effort to critically analyze the reading materials	**10**	
	Assessment of the questions asked		
1	The questions are constructed using proper and correct Indonesian.	**10**	
2	Each question is clearly worded and avoids ambiguity	**10**	
3	The questions are rational.	**10**	
4	The questions are selective.	**10**	
5	The questions reflect a comprehensive understanding of the subject matter.	**10**	
6	The questions demonstrate appropriate reasoning and cognitive skills.	**10**	
7	The validity of the reasoning is evident, supporting the formulation of further questions.	**10**	
8	The questions reflect cognitive levels: C1 ☐ C2 ☐ C3 ☐ C4 ☐ C5 ☐ C6 ☐	**10**	
	Assessment of the answers submitted.		
.1	Answers are written in proper and correct Indonesian.	**10**	
2	Answers are relevant to the questions.	**10**	
3	Answers demonstrate concepts clearly and accurately.	**10**	
4	The structure of the answers is coherent, systematic, and logically organized.	**10**	
5	Answers demonstrate a thorough understanding of the material being studied.	**10**	
6	Arguments provided are strong, well-reasoned, and clearly articulated.	**10**	
7	Answers reflect appropriate and accurate thinking skills.	**10**	
8	Answers demonstrate an integrated, reflective, and well-developed thought process.	**10**	
9	Answers reflect cognitive levels: C1 ☐ C2 ☐ C3 ☐ C4 ☐ C5 ☐ C6 ☐	**10**	

No	Evaluated Elements	Maximum Score	Assessment
	Assessment of Group Discussions		
1	Students actively discuss in groups.	**10**	
2	Students respect differences of opinion in group discussions.	**10**	
3	Students are willing to accept opinions and criticism in group discussions.	**10**	
4	Students note important things obtained from group discussions.	**10**	
5	Students are willing to provide explanations if there are still group members who do not understand the discussion topic.	**10**	
	Assessment of Argumentative Production		
1	The argumentative discourse is written using proper and correct Indonesian.	**10**	
2	Sentences are clearly structured, avoiding ambiguity or multiple interpretations.	**10**	
3	The discourse is representative, supported by strong arguments.	**10**	
4	The discourse demonstrates a logical and integrated thought process.	**10**	
5	Answers reflect cognitive levels: C1 ☐ C2 ☐ C3 ☐ C4 ☐ C5 ☐ C6 ☐	**10**	
	Total Score		

Critical Thinking Skills Questions

Questions:

1. Considering the control role of negative feedback and the function of the respiratory system, what changes in respiratory rate and depth would you expect in response to decreased levels of carbon dioxide in the internal environment?
2. Body temperature is maintained through homeostatic regulation around a set point. Based on your understanding of negative feedback and thermoregulation, would you expect cutaneous blood vessels to constrict or dilate during vigorous physical activity? Explain your reasoning.
3. Given that the olfactory receptor cells are not directly affected by the common cold, why is the sense of smell typically diminished during such an illness?
4. Why does regular aerobic exercise offer more substantial cardiovascular benefits compared to resistance training?
5. Why do you think air enters the lungs during inspiration and exits during expiration?
6. Why is it recommended that patients with stomach cancer or severe gastric disturbances consume small, frequent meals rather than follow the typical pattern of three larger meals per day?
7. How do you think vomiting occurs? What are the causes and consequences of vomiting, diarrhea, and constipation?