

applicability of the findings. By positioning open collaborative learning within a well-structured methodological framework, this study contributes to contemporary international discussions on innovative teacher education and highlights the potential of COL as a sustainable approach for preparing future computer science teachers in modern digital learning environments.

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Amitova Zh.,^{1*}  Izbasarova R.,¹  Balgimbekov Sh.¹ 

¹Abai Kazakh National Pedagogical University, Almaty, Kazakhstan

DIAGNOSING THE EDUCATIONAL COMPONENT OF FUTURE BIOLOGY TEACHERS USHING THE 4C APPROACH

Abstract

The article explores the role of the 4C approach in contemporary education and analyzes the diagnostic results concerning the educational component of future biology teachers' professional competence. The study aims to determine the level of development of critical thinking, communication, collaboration, and creativity skills among future biology teachers and to examine the obtained results in relation to indicators of their professional preparation. The relevance of the research is associated with the growing need to prepare teachers who are able to perform professional tasks effectively, analyze information, make well-grounded decisions, interact productively with other participants in the educational process, and generate new pedagogical ideas in response to changing educational demands. Within the study, the four components of the 4C framework are regarded as significant indicators contributing to the professional competence of future teachers. The diagnostic findings demonstrate that these skills are developed unevenly among students and are characterized by different levels of proficiency. The obtained results emphasize the importance of purposefully developing 4C skills throughout the professional preparation of future biology teachers. The study concludes that the systematic integration of the 4C approach into educational content and practice-oriented learning activities can contribute to strengthening students' professional competence and preparing them to address current challenges in their future pedagogical practice.

Keywords: professional competence, 4C, communication, collaboration, critical thinking, creativity.

Ж.Т.Әмитова,^{1*}  Р.Ш.Избасарова,¹  Ш.А.Балгимбеков¹ 

¹Абай атындағы Қазақ Ұлттық педагогикалық университеті, Алматы қ., Қазақстан

ОҚЫТУДА 4С ӘДІСІН ҚОЛДАНУ НЕГІЗІНДЕ БОЛАШАҚ БИОЛОГИЯ МҰҒАЛІМДЕРІНІҢ БІЛІМДІК КОМПОНЕНТІН ДИАГНОСТИКАЛАУ

Аңдатпа

Мақалада қазіргі білім беру кеңістігінде ХХІ ғасыр дағдыларын қалыптастыруға бағытталған 4С тәсілін қолданудың маңыздылығы қарастырылып, болашақ биология мұғалімдерінің кәсіби құзыреттілігінің білімдік компонентін диагностикалау нәтижелері талданады. Зерттеудің мақсаты – болашақ биология мұғалімдерінің сыни ойлау, коммуникация, ынтымақтастық және креативтілік дағдыларының қалыптасу деңгейін анықтау және алынған нәтижелерді олардың кәсіби даярлық көрсеткіштерімен өзара байланыста бағалау. Зерттеудің өзектілігі білім беру жүйесіндегі өзгерістер жағдайында кәсіби міндеттерді тиімді орындай алатын, ақпаратты талдап, негізделген шешім қабылдайтын, топпен нәтижелі әрекеттесетін және жаңа педагогикалық идеяларды ұсына алатын мұғалімдерді даярлау қажеттілігімен айқындалады. Зерттеу барысында 4С компоненттері болашақ педагогтердің кәсіби құзыреттілігін сипаттайтын маңызды көрсеткіштер ретінде қарастырылды. Диагностикалық зерттеу нәтижелері студенттерде аталған дағдылардың біркелкі қалыптаспағанын және олардың даму деңгейлерінде белгілі бір айырмашылықтардың бар екенін көрсетті. Алынған деректер болашақ биология мұғалімдерін кәсіби даярлау барысында 4С дағдыларын мақсатты түрде дамытуға ерекше назар аудару қажеттігін негіздейді. Зерттеу нәтижелері 4С тәсілін оқу үдерісінің мазмұны мен практикалық тапсырмаларына жүйелі енгізу студенттердің кәсіби құзыреттілігін жетілдіруге және оларды қазіргі педагогикалық қызмет талаптарына бейімдеуге мүмкіндік беретінін көрсетеді.

Түйін сөздер: кәсіби құзыреттілік, 4С, коммуникация, ынтымақтастық, сыни ойлау, креативтілік

Амитова Ж.Т.,^{*1}  Избасарова Р.Ш.,¹  Балгимбеков Ш.А.¹ 

¹ Казахский национальный педагогический университет имени Абая,
г. Алматы, Казахстан

ОБУЧЕНИЕ НА ОСНОВЕ МЕТОДИКИ «4С» ДЛЯ ДИАГНОСТИКИ ОБРАЗОВАТЕЛЬНОГО КОМПОНЕНТА БУДУЩИХ УЧИТЕЛЕЙ БИОЛОГИИ

Аннотация

В статье рассматривается значение применения подхода 4С в современном образовательном пространстве и анализируются результаты диагностики образовательного компонента профессиональной компетентности будущих учителей биологии. Цель исследования заключается в определении уровня сформированности у будущих учителей биологии навыков критического мышления, коммуникации, сотрудничества и креативности, а также в оценке полученных результатов во взаимосвязи с показателями их профессиональной подготовки. Актуальность исследования обусловлена необходимостью подготовки педагогов, способных эффективно выполнять профессиональные задачи, анализировать информацию, принимать обоснованные решения, продуктивно взаимодействовать с другими участниками образовательного процесса и предлагать новые педагогические идеи в условиях трансформации современного образования. В исследовании компоненты 4С рассматриваются как значимые показатели профессиональной компетентности будущего педагога. Результаты проведенной диагностики показали, что исследуемые навыки сформированы у студентов неравномерно и характеризуются различными уровнями развития. Полученные данные подтверждают необходимость целенаправленного развития компонентов 4С в процессе профессиональной подготовки будущих учителей биологии. Результаты исследования позволяют заключить, что систематическое включение подхода 4С в содержание образовательного процесса и практические задания способствует совершенствованию профессиональной компетентности студентов и их подготовке к решению актуальных задач современной педагогической деятельности.

Ключевые слова: профессиональная компетентность, 4С, коммуникация, сотрудничество, критическое мышление, креативность.

Introduction. The demands placed on education are continually evolving in response to contemporary processes of globalization. Preparing future professionals therefore requires more than the acquisition of subject-specific knowledge; considerable attention should also be given to the development of professional and transferable skills. Socio-economic transformations, technological advancement, and increasing competition in the twenty-first-century labour market require graduates to

think critically, generate creative ideas, communicate effectively, and work collaboratively. These abilities have consequently become an important component of the professional preparation of future teachers.

Professional competence is particularly significant in the teaching profession. A teacher is expected not only to demonstrate a sound knowledge of the subject but also to communicate effectively with learners, organize the educational process, and make appropriate decisions in a variety of pedagogical situations. Teacher education should therefore provide opportunities for students to develop professional knowledge alongside the practical abilities required to apply that knowledge in their future work.

The origins of the 4C approach can be traced to concepts initially developed in the field of marketing. In *Basic Marketing: A Managerial Approach*, the marketing mix was described through the 4P framework comprising four elements (McCarthy & Perreault, 1987):

- product;
- price;
- promotion;
- place.

An alternative framework based on four customer-oriented components – cost, customer value, convenience, and communication – was subsequently proposed (Lauterborn, 1990). The concept of the 4Cs later acquired a different meaning in the educational context. In 2009, the US-based Partnership for 21st Century Skills presented a framework identifying the competencies required for learners to remain competitive in an increasingly global environment (Partnership for 21st Century Skills, 2009). Within the P21 Framework, the 4Cs were represented as critical thinking, communication, collaboration, and creativity. This development reflected a broader shift in education towards competency-oriented learning, with greater emphasis being placed on preparing graduates for the demands of employment and professional practice.

International organizations have also emphasized these competencies. UNESCO documents addressing twenty-first-century skills highlight critical thinking, communication, collaboration, and creativity as important abilities for contemporary learners (Miao et al., 2024). These competencies closely correspond to the core components of the educational 4C framework. Similarly, such abilities have been identified among those required for successful participation in a rapidly changing labour market (World Economic Forum, 2016). Consequently, the development of the 4Cs within educational settings has become an increasingly relevant area of research and practice.

The formation of twenty-first-century skills is now regarded as an important direction in contemporary education. Various countries have incorporated elements associated with the 4Cs into their educational practices. Particular attention to these competencies can be observed in the educational systems of the United Kingdom, Canada, China, South Korea, Poland, the United States, and Finland.

The role of the 4Cs in preparing future teachers has also received attention in domestic research. The relevance of incorporating the 4C framework into teacher education has been emphasized in recent studies (Salybekova et al., 2025). According to the authors, existing instructional practices do not always provide sufficient opportunities for the systematic development of these competencies.

The combined use of language and media literacy as a means of developing the 4Cs among Kazakh students has also been examined (Yelubayeva et al., 2024). The findings indicated that these competencies can contribute to the development of learners' abilities, facilitate interpersonal interaction, and broaden their future professional opportunities. These findings further demonstrate the importance of developing skills that students will require in their subsequent professional activities. In teacher education, this issue is closely related to the concept of professional competence.

Professional competence has been interpreted in different ways across the scholarly literature. An examination of existing approaches allows several perspectives to be distinguished:

- Teachers' professional competence is described as an integration of knowledge, skills, personal qualities, and motivation required to address various situations encountered in professional practice (Ahmed et al., 2025);

- Professional competence is associated with an individual's ability to make informed decisions within a particular professional field and to take responsibility for the outcomes of their actions (Antera, 2021);

- Professional competence is considered to include the ability to apply pedagogical knowledge in practice, organize the learning process, and make professionally appropriate decisions (González-Fernández et al., 2024);

- Competence is interpreted as the capacity to act effectively and perform practical tasks within a particular professional or educational context (Mannonen et al., 2025);

- Professional competence is related to a specialist's ability to perform professional responsibilities effectively and in accordance with the requirements of the relevant field (Issakova et al., 2021);

- Professional competence is viewed as a combination of knowledge, skills, abilities, and personal qualities that enable teachers to perform their professional duties effectively (Abiltayeva et al., 2025).

Taken together, these interpretations demonstrate that professional competence extends beyond the possession of theoretical knowledge. It develops through experience and is continuously enriched as individuals acquire new knowledge and skills. Accordingly, an essential aspect of professional preparation is the learner's ability to transfer acquired knowledge to situations encountered in future professional practice.

Research has also explored the application of the 4C framework in educational settings. For example, a study involving Grade 10 students divided into experimental and control groups was conducted to examine the effectiveness of the 4C approach (Berkinbayeva et al., 2023). Students in the experimental group participated in a course designed around the 4C approach and completed project-based activities. The findings indicated that integrating 4C competencies with language-related skills contributed to greater student participation in classroom activities and was accompanied by improvements in both language and subject-specific learning outcomes.

The experience of applying the 4C approach in teaching college students in Kyrgyzstan has also been examined (Baitokova & Baitokova, 2025). The study reported positive changes in students' interest and engagement in classroom activities, as well as improvements in communication and teamwork skills. These findings demonstrate the relevance of incorporating the 4C approach into the preparation of future professionals.

Drawing on the studies discussed above, the 4Cs can be regarded as an important component of professional preparation. For biology students, critical thinking is particularly relevant when analysing scientific information, while communication enables them to express and explain their ideas clearly. Collaboration is essential for laboratory activities and group-based assignments, whereas creativity enables students to generate new ideas and propose alternative solutions. Thus, the development of the 4Cs can be considered in close connection with the professional competence of future biology teachers.

The aim of the study was to examine the role of the 4Cs in the professional preparation of future biology teachers and to determine the current level of development of these skills.

Key principles. Future teachers need to be able to apply acquired knowledge in practice, communicate their ideas effectively, cooperate with others, and make informed decisions when addressing particular problems. These abilities are directly associated with the four components of the 4C framework. Therefore, the present study focused on assessing the current state of critical thinking, creativity, communication, and collaboration among future biology teachers. The diagnostic assessment was conducted to identify the areas in which students demonstrated stronger performance and the competencies that required further development.

The central idea of the study was to evaluate students' 4C skills within the context of their professional preparation. The obtained data were used to analyse the extent to which future biology teachers had developed these competencies.

Materials and Methods. An anonymous questionnaire was specifically developed to assess the level of professional competence among future biology teachers. The collected responses were analysed using descriptive statistical methods to provide an overview of the participants' current performance.

Purpose of the questionnaire. The survey aimed to identify the current development of students' 4C skills, provide an initial assessment of their proficiency in these competencies, and use the findings to determine the level of professional competence demonstrated by the participants. The respondents were third-year students enrolled in the Biology programme, including students from Kazakh, Russian, and English medium groups. The questionnaire focused on the four core competencies of the 4C framework and was intended to determine the extent to which these skills had been developed among the participating students. The questionnaire was completed online through a dedicated survey link.

Results and Discussion. The questionnaire findings provided an overview of the current level of 4C skill development among third-year students. The questionnaire consisted of 10 questions and was completed by a total of 123 students ($N = 123$). Participants were selected through purposive sampling. The collected data were processed in Microsoft Excel using percentage-based analysis and descriptive statistics, including the mean and standard deviation. The results were subsequently presented in graphical form. Female students constituted the majority of the study participants (Figure 1).

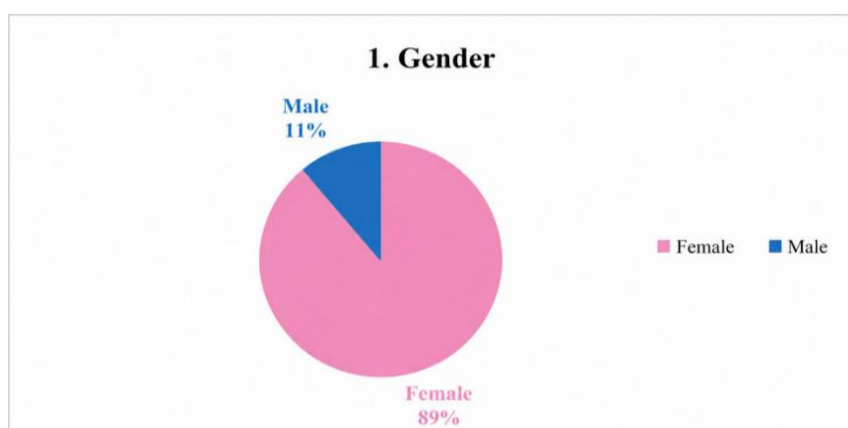


Figure 1. Pie chart illustrating the gender distribution of the students who participated in the survey

Question 1. A total of 123 students participated in the survey. Of these, 110 (89%) were female and 13 (11%) were male.

Question 2 was designed to determine whether instructors had previously incorporated the 4C approach into their teaching practices. According to the responses, 81 students (66%) indicated that the approach had been used during classes, while 17 students (14%) reported that it had not been applied. A further 25 respondents (20%) stated that instructors used the approach occasionally (Figure 2).

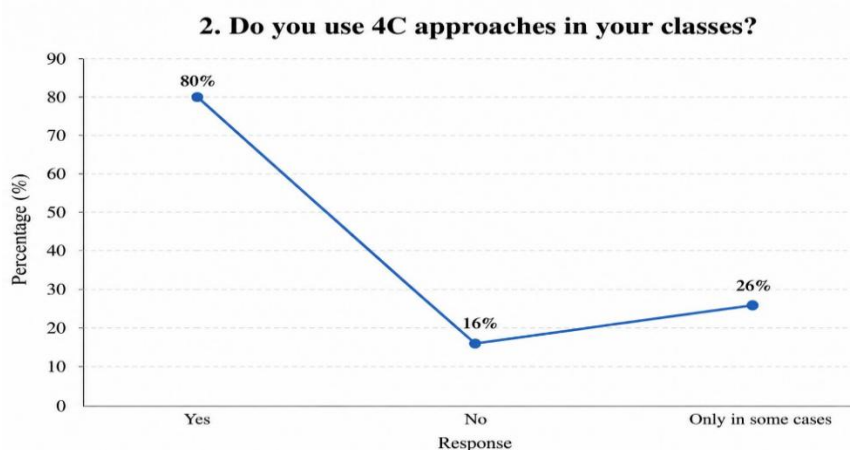


Figure 2. Line chart illustrating the use of the 4C approach by instructors during classroom activities

Question 3 was included to assess students' understanding of the concept of critical thinking and their ability to distinguish its correct meaning from the alternative definitions provided. The survey findings showed that the majority of respondents, 91 students (74%), selected the correct definition. In contrast, 32 students (25.2%) chose an incorrect response, while 1 student (0.8%) provided an alternative answer (Figure 3).

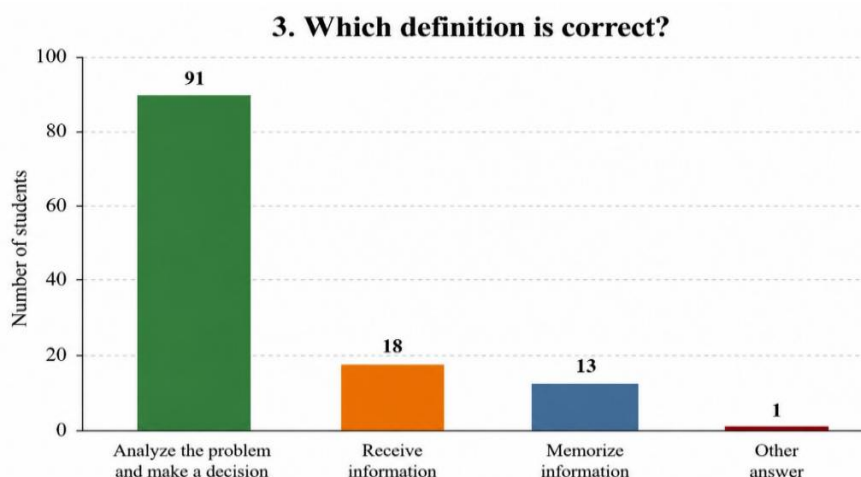


Figure 3. Level of Understanding of the Concept of Critical Thinking

Question 4 focused on determining how well students understood the concept of creativity. Analysis of the responses revealed that 30 students (24%) selected the correct answer, whereas 93 respondents (76%) answered incorrectly. The findings indicate that a considerable proportion of the participants had not yet developed a clear understanding of the concept of creativity (Figure 4).

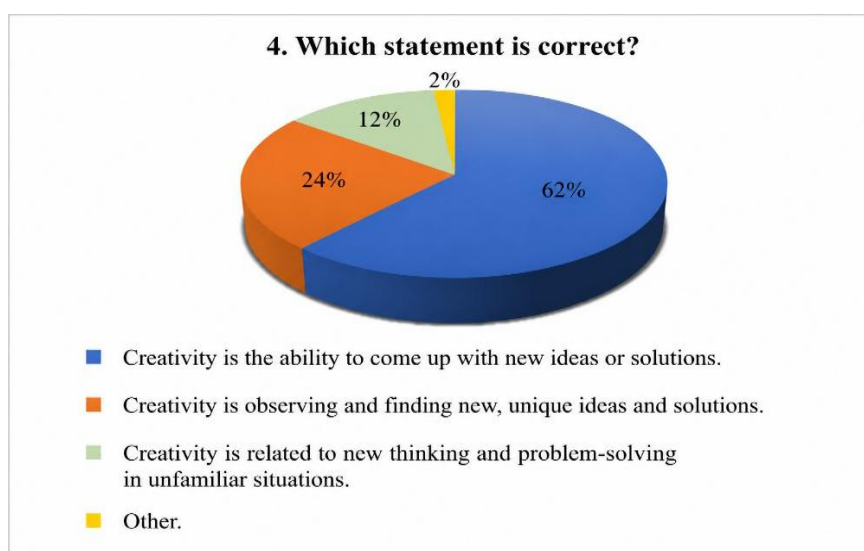


Figure 4. Pie chart illustrating students' level of understanding of the concept of creativity

Question 5 was designed to assess students' ability to complete tasks related to communication skills. The results showed that 68 students (55%) responded "Yes," while 28 respondents (23%) selected "No." A further 26 students (21%) chose "I do not know," and 1 participant (1%) provided an alternative response (Figure 5).

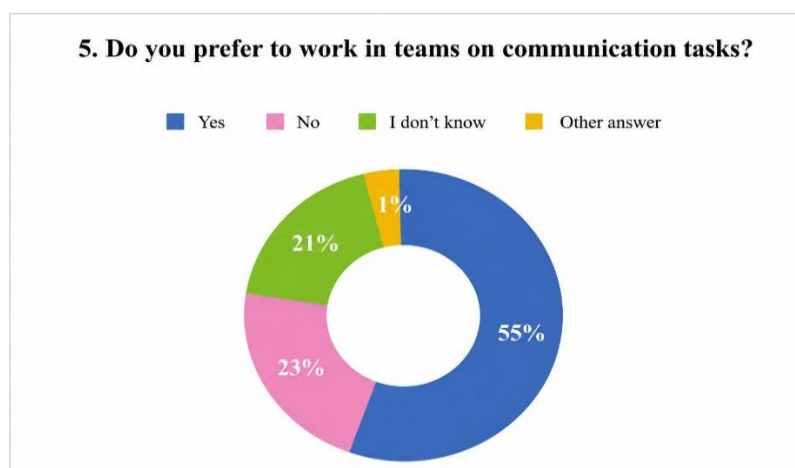


Figure 5. Doughnut chart illustrating students' ability to complete communication-related tasks

Question 6 focused on students' actual level of participation during classroom activities. The findings showed that 72 students (59%) were actively involved in group work. In contrast, 25 respondents (20%) reported that they did not participate in discussions, while 26 students (21%) indicated that they were willing to become more actively involved in classroom activities (Figure 6).

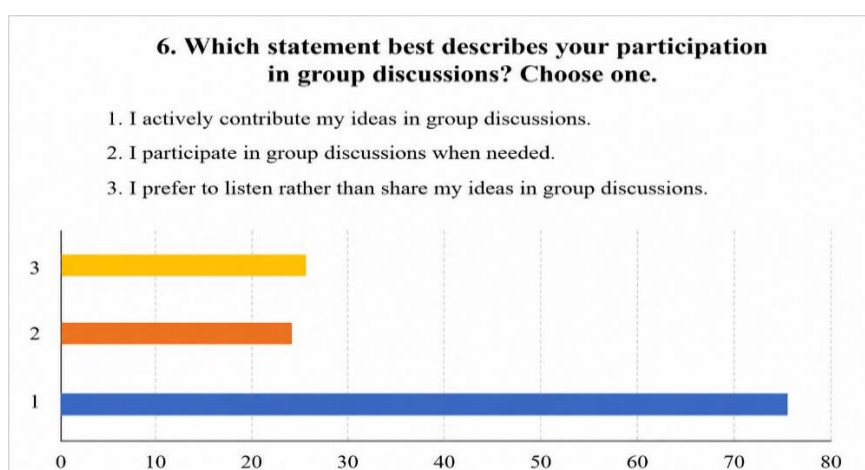


Figure 6. Bar chart illustrating students' level of participation in classroom activities

Question 7 was designed to assess students' ability to analyse information logically and make reasoned decisions during classroom activities. The results showed that 68 students (55%) reported analysing information before accepting it. In addition, 31 respondents (25%) indicated that they compared several possible options before solving a problem, while 24 students (20%) stated that they relied on evidence when making decisions (Figure 7).

**7. Which statement best describes how you make decisions in class?
Choose one.**

1. I do not make decisions with available information, I first think carefully.
2. I compare several options before making a decision.
3. I rely on my intuition when making decisions.

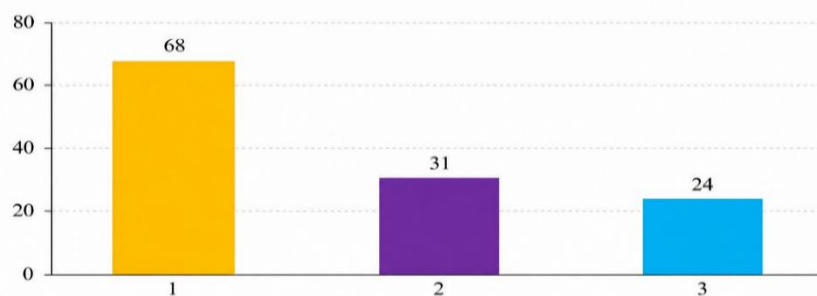


Figure 7. Bar chart illustrating students' level of critical thinking skills

Question 8 was intended to explore students' views on the relevance of the 4C skills to their future profession. In particular, respondents were asked whether future biology teachers need to develop critical thinking, communication, collaboration, and creativity skills. The results showed that 60 students (49%) agreed that these competencies are necessary for their future professional activities. In contrast, 38 respondents (31%) answered "No," while 23 students (19%) selected "I do not know." The remaining 2 participants (2%) provided an alternative response (Figure 8).

**8. In your opinion, to what extent do the following skills need to be developed in school biology lessons:
critical thinking, communication, collaboration, creativity?**

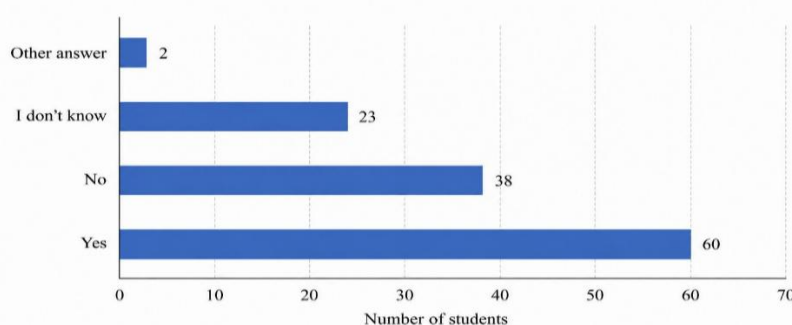


Figure 8. Results of students' assessment of the importance of the 4C components for future biology teachers

Question 9 was designed to assess students' perceived ability to apply the 4C approach in teaching. Respondents rated their level on a scale from 1 to 10. Based on the obtained scores, the results were classified into three categories: high, medium, and low levels (Table 1).

Table 1. Descriptive statistical indicators of students' professional competence levels

Level	N	Mean	Median	SD	Min	Max
Low	65	5,23	5	0,95	1	6
Medium	40	7,48	7	0,51	7	8
High	18	9,11	9	0,32	9	10
Total	123	6,53	6	1,66	1	10

Question 10 asked students to assess their own level of 4C skills on a 10-point scale. The scores were divided into three categories: 1–6 points represented a low level, 7–8 points a medium level, and 9–10 points a high level.

According to the results, students in the low-level group (N = 65) gave relatively low ratings to their ability to apply the 4C approach, with a mean score of $M = 5.23$. The medium-level group (N = 40) achieved a mean score of $M = 7.48$, whereas students classified at the high level (N = 18) reached a mean value of $M = 9.11$. These findings demonstrate noticeable differences in students' perceived readiness to use the 4C approach in practice (Figure 9).

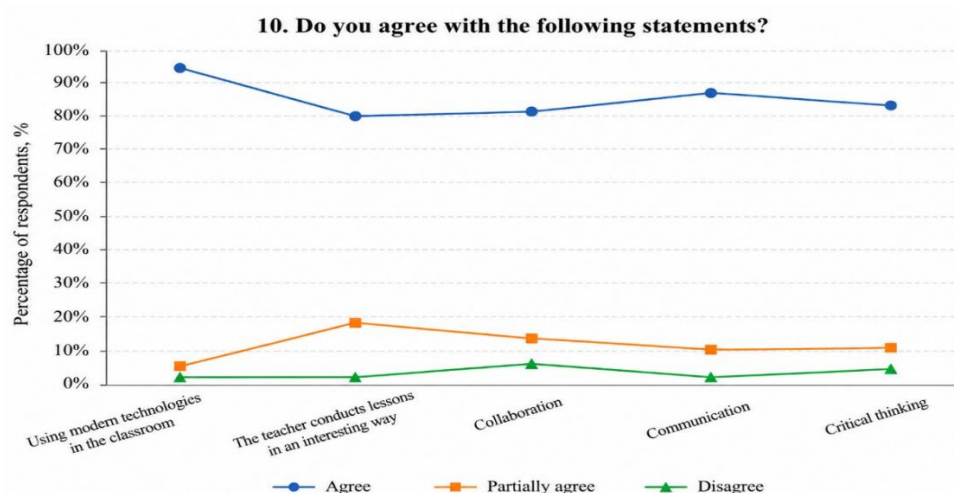


Figure 9. Students' level of agreement with statements related to the 4C components

The questionnaire included several statements concerning students' perceptions of the 4C skills. Overall, the responses demonstrated a predominantly positive attitude towards these competencies. The use of new technologies in classroom instruction was supported by 94.3% of the respondents, while 4.1% partially agreed and 1.6% disagreed. Regarding the role of creative teaching, 80.5% expressed agreement, 17.9% partially agreed, and 1.6% disagreed.

The importance of collaboration in completing shared tasks was acknowledged by 81.3% of the students. A further 13% partially agreed with this statement, whereas 5.7% expressed disagreement. Communication received an even higher level of support: 87.8% of respondents agreed with its importance, 10.6% partially agreed, and only 1.6% disagreed. Critical thinking was considered necessary by 83.7% of the students, while 11.4% partially agreed and 4.9% disagreed. Based on the overall pattern of responses, students' results were subsequently classified into three categories representing low, medium, and high levels (Table 2).

Table 2. Overall distribution of students by level based on the survey results

level	(%)	Description
Low	28–30%	Skills are insufficiently developed
Medium	30–35%	Understanding is present but inconsistent
High	35–40%	Supports and is ready to apply the skills

At the next stage of the study, students' academic performance was analysed with particular attention to the extent to which they had developed the 4C skills. For this purpose, the learning outcomes of third-year students enrolled in the «Human and Animal Physiology» course were examined.

When designing the assessment tasks, the four core components of the 4C framework – critical thinking, communication, collaboration, and creativity – were taken into consideration. Rather than requiring students simply to reproduce previously acquired knowledge of physiology, the tasks encouraged them to analyse information, explain physiological processes, and apply their knowledge to specific situations.

Tasks related to critical thinking required students to identify the causes of physiological phenomena, explain their possible consequences, and analyse relationships among different processes occurring within the organism. Such activities enabled students to connect the functions of organs with their structural characteristics and to examine how regulatory mechanisms influence physiological functions.

Communication skills were assessed through students' ability to express scientific ideas clearly and accurately. Particular attention was paid to the appropriate use of physiological terminology, the logical explanation of physiological processes, and the ability to formulate conclusions based on the obtained information.

Activities addressing collaboration focused on students' interaction while completing shared tasks. Their ability to distribute responsibilities within a group, contribute to collective decision-making, fulfil assigned roles, and discuss the final results together was considered when evaluating teamwork skills.

For the creativity component, students were encouraged to represent physiological processes through diagrams, models, and other forms of visualization. These activities provided opportunities to move beyond the reproduction of existing information and to demonstrate acquired knowledge through individually developed approaches, thereby promoting a deeper understanding of relationships between physiological processes.

Thus, tasks incorporating the four components of the 4C framework were used not only to assess students' subject knowledge but also to examine their ability to interpret and analyse information, cooperate with others, and transfer acquired knowledge to new situations.

The academic performance of third-year students in the «Human and Animal Physiology» course during the first semester was also analysed. The results obtained before the implementation of activities specifically aimed at developing the 4C skills were used as baseline indicators. These included scores from the first and second midterm assessments, examination results, and final course grades. A summary of these academic indicators is presented in Table 3.

Table 3. Overall first-semester academic performance of third-year students in the «Human and Animal Physiology» course

Group	Midterm Assessment 1	Midterm Assessment 2	Exam	Final result
Biology Kazakh group	65,4	68,2	68,3	67,3
Biology Russian group	75,1	78,2	80,3	77,8
Biology English group	80,1	80,1	80,2	80,1
Overall Result	73,5	75,5	76,3	75,1

The overall first-semester performance of third-year students in the «Human and Animal Physiology» course was analysed. The mean score for the first midterm assessment (MT1) was 73.5 points, while the corresponding value for the second midterm assessment (MT2) was 77.5 points. The average examination score reached 76.3 points, and the overall mean final grade for the semester was 75.1 points.

Analysis of the first-semester results indicated a need to further improve students' learning outcomes and strengthen the professional competencies required by future biology teachers. In this context, the incorporation of the 4C approach into the educational process was considered as one of the possible ways to support their professional development. Based on the questionnaire findings, students' 4C skill development was examined across three categories: high, medium, and low.

Students classified at the high level demonstrated an understanding of the 4C skills and readiness to apply them both during their studies and in future professional practice. This category was characterised by the following findings:

- 74% of students demonstrated an appropriate understanding of critical thinking;
- 94.3% supported the use of new technologies in classroom instruction;
- 80.5% acknowledged the positive influence of creative teaching on learning motivation;

- 81–88% recognised the importance of collaboration and communication;
- 5% rated their mastery of the 4C approach at 9–10 points.

Taken together, the proportion associated with the high level was estimated at 35–40%. Students within this category demonstrated comparatively strong readiness for further development and practical application of the 4C skills.

The medium-level group included students who recognised the value of the 4C skills but were less consistent or confident in applying them. The following indicators were observed:

- 21% participated in group work but did not demonstrate consistent active involvement;
- 20–25% tended to rely on a single approach when analysing information or making decisions;
- 33% assessed their level of 4C proficiency at 7–8 points.

The overall proportion of students within the medium category was estimated at 30–35%. These students demonstrated potential for further development, although more structured learning activities and pedagogical support may be required to strengthen their practical use of the 4C skills.

Students assigned to the low-level category demonstrated limited understanding of certain 4C components or uncertainty regarding their practical application. The following results contributed to this classification:

- 76% were unable to identify the correct meaning of creativity;
- 53% gave a low self-assessment of their ability to apply the 4C approach;
- 52% either questioned the relevance of the 4C skills to their future professional activities or were unable to provide a definite response;
- 20–23% demonstrated limited participation in discussions and other interactive activities.

The proportion corresponding to the low level was estimated at 28–30%. The findings suggest that students in this category require additional methodological guidance and practical opportunities to strengthen their 4C skills. The overall distribution of students according to the identified levels is presented in Figure 10.

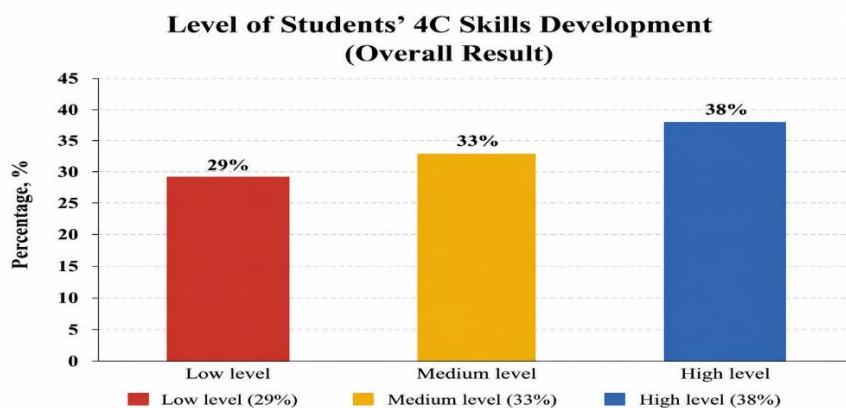


Figure 10. Overall results of the student survey

Conclusion. The findings of the study demonstrate that the 4C framework has considerable potential for supporting the professional development of future biology teachers. Although the questionnaire responses generally reflected positive attitudes towards critical thinking, communication, collaboration, and creativity, the degree to which these skills had been developed varied among the participating students. Based on the collected data, students were classified into three levels of professional competence: low (28–30%), medium (30–35%), and high (35–40%). Students in the high-level category demonstrated a stronger understanding of the 4C skills and greater readiness to apply them in academic and future professional contexts. Those classified at the medium level recognised the importance of these competencies but showed less consistency in their practical application. In the low-level group, difficulties were observed in understanding certain components of the 4C framework, together with

lower confidence in using these skills in professional situations. The integration of 4C elements into the «Human and Animal Physiology» course was also associated with increased student engagement and improved learning outcomes. These observations suggest that the 4C framework can serve as a useful approach for strengthening competencies relevant to the professional preparation of future teachers.

Overall, the diagnostic assessment based on the 4C framework made it possible to identify the initial level of students' professional development, determine areas of relative strength and those requiring further improvement, and provide a basis for refining instructional content and teaching practices. Therefore, the systematic integration of critical thinking, communication, collaboration, and creativity into teacher education programmes may contribute to more practice-oriented professional preparation of future biology teachers.

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