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Impact of Adapted Turkish Pedagogical Training on Practical Competence Development of Biology Teachers: Case of Kazakhstan

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Abstract: The development of practical competence is an important component of biology teacher education, particularly in laboratory, field, and animal-related studies. The aim of this study was to evaluate the effectiveness of adapting selected practice-oriented pedagogical approaches identified during a research internship at Hacettepe University (Turkey) for developing the practical competence of biology students in Kazakhstan. A mixed-methods research design was employed. The Turkish stage included analysis of scientific and methodological literature from the Hacettepe University Library, a structured questionnaire survey of 25 undergraduate students, student interviews, classroom observations and examination of laboratory-, research- and field-oriented teaching practices. These activities, together with the findings of our previous studies, were used to identify instructional elements suitable for adaptation. Selected approaches, including laboratory and experimental learning, applied animal-biology tasks, collaborative learning, digital visualization, virtual laboratories and research-oriented instruction, were integrated with an author-developed electronic learning resource. The adapted approach was tested during a semester-long pedagogical experiment at Abai Kazakh National Pedagogical University involving an experimental group (n = 42) and a control group (n = 35). The experimental group received practice-oriented instruction, while the control group studied through conventional teaching methods. Subsequently, the developed lesson plans and didactic materials were incorporated into an approved 80-hour professional development course completed by 25 school and university teachers from different regions, who provided feedback on their applicability in real biology teaching practice. The findings support the effectiveness of adapting practice-oriented pedagogical approaches for strengthening practical competence in biology teacher education in Kazakhstan.

Keywords: *pedagogical education, biological education, practical competence, practice-based learning, digital technologies, laboratory and field work.*

Introduction

Modern pedagogical education is undergoing a paradigm shift from predominantly knowledge-based instruction toward competence-oriented learning models that emphasize practical application, research skills and professional readiness. This transformation reflects global educational trends aimed at aligning academic training with real-world scientific, pedagogical and environmental challenges. In biology education, particularly in teacher training programs, the development of practical competence has become a strategic priority, as it directly influences graduates' ability to apply theoretical knowledge in laboratory, field and classroom contexts.

At the national level, this challenge has been explicitly articulated within Kazakhstan's current educational agenda. In the State Program for the Development of Education and Science of the Republic of Kazakhstan for 2023-2029 (Government of the Republic of Kazakhstan, 2023), emphasis is placed on strengthening practice-oriented training, digital transformation of higher education and the formation of functional literacy and

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professional competencies among future teachers. The program highlights the need to modernize pedagogical training through laboratory work, applied research and the integration of digital educational technologies.

Furthermore, in his recent Addresses to the Nation, the President of the Republic of Kazakhstan, Kassym-Jomart Tokayev, emphasized that higher education must transcend formal knowledge acquisition and prioritize the preparation of specialists capable of independent decision-making, research activity and practical problem-solving within authentic professional contexts (Tokayev, 2024). Particular attention was devoted to teacher education, where the effectiveness of learning outcomes is intrinsically linked to educators' capacity to translate theoretical knowledge into practice and to effectively integrate modern educational technologies.

In the context of the ongoing Concept for the Development of Higher Education and Science until 2029 and the implementation of the "Digital Kazakhstan" initiative (Government of the Republic of Kazakhstan, 2017), biology education is increasingly viewed as a strategic field for fostering environmental responsibility, scientific thinking and applied competencies. According to national higher education monitoring reports of Kazakhstan, more than 60% of biology-related study programs emphasize theoretical coursework as the dominant mode of instruction, while practical and research-based components remain limited in scope and duration. This is especially relevant for animal-related disciplines, which inherently require observation, experimentation and interaction with real or simulated biological systems.

Despite extensive curricular reforms, a persistent gap remains between theoretical instruction and practical implementation. Survey data from pedagogical universities indicate that approximately 35-40% of students report insufficient opportunities for hands-on laboratory work and field-based activities within biology courses (Ministry of Science and Higher Education of the Republic of Kazakhstan, 2022). Many biology programs in Kazakhstan continue to prioritize content transmission over experiential learning, limiting students' opportunities to engage in experimental research, observation and applied problem-solving. This imbalance is especially critical in the study of animal diversity, where direct observation, laboratory experimentation and fieldwork are fundamental to conceptual understanding and professional competence.

The present study is part of a broader research program initiated in 2023 and focused on the development of practical competence among future biology teachers through practice-oriented biology education. The initial empirical stage was conducted among biology students in Kazakhstan in 2024 and focused on the importance of studying animals in biology for the development of practice-oriented skills (Tolegen and Maimataeva, 2024). Based on these preliminary findings, separate studies were subsequently conducted in which lesson plans were developed using practice-oriented approaches identified during a research internship at Hacettepe University (Turkey). However, the results of the experimental implementation of these approaches in biology education in Kazakhstan are presented in the present study.

Importantly, the term "Turkish pedagogical experience" in this study does not refer to a single standardized national model or to the direct implementation of an entire Turkish curriculum. It specifically refers to a set of practice-oriented instructional principles and teaching methods examined at Hacettepe University through literature analysis, student questionnaires and interviews, classroom observations during biology-related courses and familiarization with laboratory-, research- and field-based teaching practices. Previous studies described these approaches in greater methodological detail, including research- and project-based learning, laboratory and field activities, collaborative learning, virtual and digital visualization tools and reflective assessment (Tolegen et al., 2025). An adapted lesson plan on the topic "Adaptations and Diversity of Vertebrates" was also presented in a previous study (Tolegen and Maimataeva, 2026).

Accordingly, the present study pursued the following interrelated objectives: (1) to summarize the research activities conducted at Hacettepe University; (2) to evaluate the effectiveness of the adapted instructional approach by comparing practical competence and academic performance in the experimental and control groups; and (3) to examine the professional relevance and applicability of the developed methodology and instructional materials through a subsequent professional development course and participant feedback.

Accordingly, the study addressed the following research questions:

RQ_1: What activities conducted during the research at Hacettepe University contributed to the study, and what approaches were suggested by Turkish students for biology teacher education?

RQ_2: Does the adapted practice-oriented teaching approach lead to greater improvements in practical competence and academic performance than traditional instruction?

RQ_3: How do participants in the professional development course evaluate the relevance, applicability, and usefulness of the adapted methodology and instructional materials?

In recent decades, competence-based education has emerged as a dominant paradigm in higher education, particularly in teacher training programs. Unlike traditional knowledge-oriented models, competence-based approaches emphasize the integration of cognitive, procedural and reflective components that enable learners to apply disciplinary knowledge in authentic professional contexts (Mulder, 2014; Rychen and Salganik, 2003). Practical competence is thus conceptualized as a multidimensional construct encompassing subject knowledge, practical skills, decision-making ability and professional judgment.

For the purposes of the present study, *practical competence* in biology teacher education is understood as the integrated capacity to apply biological knowledge in authentic or simulated educational and scientific contexts. It comprises four interrelated dimensions: (1) a cognitive dimension, reflected in the understanding and application of biological concepts; (2) a procedural-practical dimension, reflected in the ability to conduct laboratory, observational, experimental, and applied tasks; (3) a research and problem-solving dimension, reflected in the ability to formulate questions, interpret evidence, solve biological problems, and make justified decisions; and (4) a professional-reflective dimension, reflected in the ability to transfer biological knowledge and practical experience to pedagogical situations and evaluate one's own performance. This multidimensional understanding guided the adaptation of the instructional approach and the assessment of practical competence in the Kazakhstani pedagogical experiment.

Within teacher education, practical competence is closely associated with the ability to design learning activities, conduct experiments, interpret data and facilitate inquiry-based learning (Darling-Hammond, 2017). Scholars argue that the development of such competence requires systematic engagement with real or simulated professional tasks rather than passive absorption of theoretical content (Grossman et al., 2009). In biology education, this requirement is particularly pronounced due to the empirical and experimental nature of the discipline.

Research in biology education consistently emphasizes the central role of laboratory work and field-based instruction as essential components of effective learning. In their comprehensive review, Hofstein and Lunetta (2004), drawing on empirical studies conducted in the United States, Israel and several European countries, demonstrated that laboratory-centered instruction contributes to deeper conceptual understanding, enhanced analytical thinking and the development of scientific reasoning, provided that laboratory activities are aligned with clear learning objectives and coherent assessment practices. The authors highlight that studies employing inquiry-oriented laboratory designs reported stronger student engagement in data analysis and interpretation compared to traditional demonstration-based formats.

Empirical evidence is further provided by Domin (2007), who conducted a comparative study at Tennessee State University (USA) involving 17 first-year undergraduate students enrolled in science-related programs. The study contrasted traditional "cookbook" laboratory exercises with problem-based laboratory formats across two consecutive semesters. Survey data and semi-structured interviews revealed that 7 out of 17 students perceived problem-based laboratories as more effective for conceptual understanding and higher-order cognitive skill development, while an additional 7 students reported comparable effectiveness between the two instructional approaches. Despite the limited sample size, the findings indicate the potential of inquiry- and problem-based laboratory instruction to support the development of practical and analytical competencies.

Field-based learning plays a complementary role, particularly in zoology and ecology. Studies by Dillon et al. (2006), conducted by researchers from the United Kingdom in the field of science and environmental education, and Ballantyne and Packer (2009), representing Australian universities and specializing in environmental and outdoor education research, demonstrate that direct interaction with natural environments promotes observational accuracy, ecological literacy and affective engagement with biological content. These experiences support the development of professional competencies relevant to future biology teachers, including environmental awareness and the ability to contextualize theoretical concepts.

Project-based and inquiry-based learning models further strengthen practice-based education by positioning students as active researchers (Hmelo-Silver et al., 2007). In biology teacher education, such approaches have been linked to increased learner autonomy, collaborative skills and sustained motivation (Krajcik and Blumenfeld, 2006). However, empirical studies also indicate that these methods require careful instructional scaffolding and assessment alignment to achieve their intended outcomes.

The rapid digital transformation of education has significantly influenced biology teaching and learning. Virtual laboratories, educational simulations and AR/VR technologies provide alternative means for engaging with complex biological phenomena that may be inaccessible due to safety, cost or ethical constraints (Makransky and Petersen, 2019). Research indicates that well-designed virtual labs can effectively support conceptual understanding and procedural knowledge, particularly when combined with reflective and inquiry-based tasks (de Jong et al., 2013).

Educational animations and 3D-visualizations have also been shown to enhance spatial understanding and comprehension of dynamic biological processes (Mayer, 2020). In teaching education, digital tools contribute not only to subject learning but also to the development of digital pedagogical competence, which is increasingly recognized as a core professional requirement (Redecker, 2017).

Despite these advantages, several studies caution against the uncritical adoption of technology. Merchant et al. (2014) and Radianti et al. (2020) emphasize that technological effectiveness depends on pedagogical integration, instructional design and alignment with learning objectives. Digital tools that are used as substitutes for traditional lectures without active engagement may have limited impact on competence development.

A recurring issue identified in the literature concerns the assessment of practical competence. While laboratory and field activities are widely implemented, their evaluation often remains fragmented or informal (Bennett et al., 2017). Traditional assessment methods tend to focus on theoretical knowledge rather than practical performance, reflection, or skill integration.

Research in science education underscores the importance of formative and performance-based assessment strategies, including observation protocols, rubrics, portfolios and reflective tasks (Black and Wiliam, 2009). However, studies reveal that many teacher education programs lack coherent assessment frameworks that systematically measure practical competence development over time. This gap limits the ability to evaluate the effectiveness of practice-based learning models and to provide targeted feedback to learners.

Although extensive research supports the value of laboratory work, field learning, project- and research-based instruction and digital technologies in biology education, several gaps remain. First, many studies examine these instructional methods separately rather than as components of an integrated practice-oriented approach combining practical activity, research, collaboration, digital resources and reflective assessment. Second, empirical evidence concerning the selective transfer and adaptation of pedagogical practices across different national education systems remains limited.

Furthermore, limited research has examined how internationally informed practice-oriented approaches can be systematically adapted and experimentally evaluated in biology teacher education and subsequently translated into professional development for practicing educators. This gap is particularly relevant to Central Asian educational settings, where empirical research on practice-oriented biology teacher preparation and cross-national methodological adaptation remains limited.

In response to these gaps, the present study builds on previous research conducted within the broader project and examines the experimental implementation of selected practice-oriented pedagogical approaches adapted for biology teacher education in Kazakhstan. The study follows a sequential logic in which exploratory evidence obtained during the Turkish research stage informed the selection of instructional approaches, the adapted methodology was subsequently evaluated through a pedagogical experiment in Kazakhstan and the resulting lesson plans and didactic materials were incorporated into a professional development course for further evaluation by school and university teachers. This design allows the study to examine not only the effectiveness of the adapted approach for developing students' practical competence but also its applicability to biology teaching practice.

Materials and methods

This study employed a mixed research design, combining theoretical analysis and a pedagogical experiment, in order to examine the effectiveness of practice-based approaches in the development of practical competencies among future biology teachers. More specifically, a sequential mixed-methods design was used, combining an exploratory stage, a controlled pedagogical experiment and a subsequent qualitative professional evaluation. The research was conducted in three consecutive stages: (1) research activities at Hacettepe University (Turkey); (2) a semester-long pedagogical experiment at Abai Kazakh National Pedagogical University (Kazakhstan); and (3) evaluation of the developed instructional materials through a professional development course.

The first stage was conducted during a one-month research internship at Hacettepe University (Turkey) in May-June 2025. It included: (1) analysis of scientific and methodological literature available through Web of Science, Scopus and the Hacettepe University Library; (2) a structured questionnaire survey of 25 undergraduate students (biological faculty); (3) student interviews; (4) non-participant classroom observations; and (5) examination of laboratory-, research- and field-oriented teaching practices.

As part of this stage, a survey-based assessment was conducted among 25 second- and third-year undergraduate students enrolled in full-time biology-related programs within the Department of Science Education at Hacettepe University. The participants had a mean age of approximately 20 years. Data were collected using a structured questionnaire designed to examine students' perceptions of the teaching methods and practical approaches used by their instructors, including their perceived effectiveness, accessibility, and usefulness for learning. The findings provided a student-centered perspective for selecting approaches for subsequent adaptation and testing among Kazakhstani university students of a comparable age group. The questionnaire included items addressing the following aspects:

- contexts of biological knowledge acquisition (school, university, extracurricular activities);
- instructional methods used in biology education (laboratory work, experimental research, field activities, visual and animated materials, theoretical instruction);
- perceived impact of biology courses on professional skill development;
- the role of the teacher in organizing and supporting practical learning;
- use of digital and innovative technologies (virtual laboratories, animations, mobile applications, AR/VR);
- assessment methods applied in practical classes;
- effectiveness of learning animal-related topics and applicability of acquired knowledge;
- opportunities for studying animal behavior;
- organizational challenges in practical biology education;
- students' perceptions of the most effective methods for enhancing practical competence.

The questionnaire items were aligned with the objectives of the study and informed by previous empirical research in science education. Responses were recorded mainly in categorical and multiple-choice formats and subsequently analyzed using descriptive statistics.

Student interviews provided additional information about students' learning experiences, the relationship between theoretical and practical instruction, and their perceptions of the teaching approaches used during their studies. Non-participant classroom observations were conducted through attendance at biology-related classes taught by university professors. The observations were used to examine how teaching and practical activities were organized and how different instructional approaches were implemented during actual university classes. In addition, familiarization with the available laboratory, research, and field-based teaching resources provided further information on the organization of practical biology education at the university.

The evidence obtained from the literature analysis, student questionnaire and interviews, classroom observations, and examination of teaching practices was considered collectively when selecting instructional elements for adaptation and subsequent experimental implementation in Kazakhstan.

The pedagogical experiment was conducted in Kazakhstan with 77 students majoring in biology education at Abai Kazakh National Pedagogical University. The participants were divided into an experimental group (n = 42) and a control group (n = 35):

- the experimental group (EG) (n = 42), which was taught using adapted practice-oriented teaching methods and instructional materials developed during the preceding stages of the research, including laboratory work, digital tools and applied tasks;
- the control group (CG) (n = 35), which continued learning according to the traditional curriculum without the additional pedagogical intervention.

The experimental instruction was implemented over the course of one academic semester within regular university classes. Group allocation was based on existing academic group structures to ensure natural learning conditions. The experimental instruction focused on:

- laboratory-based and experimental learning activities;
- applied tasks related to animal biology;
- integration of digital tools, including visual materials and virtual laboratories;
- development of practical skills, research abilities and professional preparedness.

Academic performance and practical competence development were evaluated through comparative analysis of learning outcomes between the experimental and control groups.

Following the pedagogical experiment, the developed lesson plans and didactic materials were incorporated into the professional development course entitled “Development of Pedagogical Competencies of Biology Teachers”, which was officially approved for implementation in Kazakhstan. The course was designed to support the practical application of the developed methodology and to obtain professional feedback on its relevance and applicability in biology teaching.

The professional development course involved 25 participants, primarily experienced school and university teachers from different regions of Kazakhstan, with a small number of future biology teachers. The training program comprised 80 academic hours, including 40 hours of online instruction and 40 hours of independent learner-centered study. The online sessions were delivered via the Zoom platform. All 25 participants completed the course.

The training course consisted of a series of lectures, master classes and interactive sessions integrating theoretical and practical components. The theoretical modules addressed the following topics:

- theoretical and methodological foundations of practical competence formation;
- methodology for organizing practice-oriented learning in biology education;
- educational technologies aimed at developing practical competencies;
- assessment of practical competence and methodological experience (variable module).

The practical component of the course included virtual laboratory activities, animated and visual materials for studying animal biology, and project-based collaborative tasks focused on solving authentic pedagogical and professional problems. The developed lesson plans and didactic materials were incorporated into these activities to allow participants to examine their potential application in biology teaching practice. The instructional sessions concluded with guided reflective discussions aimed at supporting pedagogical reflection and the practical application of the course materials. The course also included elements aimed at developing communicative skills, self-reflection and environmental competence.

Qualitative data were collected through semi-structured interviews and reflective feedback sessions conducted online. Expert evaluation focused on:

- changes in practical competence;
- effectiveness of teaching animal-related topics;
- clarity and applicability of adapted instructional methods;
- relevance of digital and virtual laboratory tools in biology education.

All participants were fully informed about the objectives and procedures of the study prior to data collection. Participation was voluntary and written informed consent was obtained from all respondents. Anonymity was strictly maintained throughout the research process. All collected data were processed and stored in aggregated form, without the use of personal identifiers, ensuring compliance with ethical standards for educational research.

Results

Results of the Turkish Research Stage. The data obtained from the survey conducted among 25 undergraduate biology students in Turkey were analyzed using descriptive statistical methods, including frequency counts and percentage distributions. This analysis was used to identify patterns in students’ experiences of biology instruction and their perceptions of practice-oriented learning and practical competence development.

Analysis of responses to the question “Where and how did you learn biology?” demonstrated that the majority of respondents (72%) continued acquiring biological knowledge primarily at the university level, while 28% identified school education as their main source of knowledge. None of the respondents reported participation in extracurricular academic activities such as additional courses, conferences or competitions, highlighting the central role of formal higher education in professional competence development. This finding indicates that the university represented the principal educational environment for the continued development of biological knowledge among the surveyed students.

With regard to instructional methods used in biology education, the data revealed a strong emphasis on practice-oriented approaches. Laboratory practices were reported by 80% of respondents, experimental laboratory work by 68%, and the use of visual and animated learning materials by 76%. At the same time, 28% of students indicated that instruction was often limited to theoretical explanations and 12% reported reliance exclusively on textbooks. Overall, these findings demonstrate that laboratory, experimental and visual forms of instruction were strongly represented in the students' university learning experience alongside theoretical teaching.

The perceived impact of biology courses on professional skill development varied among respondents. While 44% reported a strong positive influence and 40% indicated a moderate effect, 16% stated that biology education had no noticeable impact on their professional skills. Thus, 84% of respondents perceived biology education as contributing to their professional skill development to a strong or moderate degree.

Analysis of the teacher's role showed that 48% of students experienced active pedagogical guidance and support, whereas 40% reported sufficient but unsystematic assistance. A smaller proportion (12%) indicated predominantly independent learning. No respondents reported a complete absence of instructional support.

The use of digital and innovative technologies was also examined. Video lectures and AR/VR technologies were reported by 60% of respondents, educational animation programs by 44% and mobile applications by 24%. Virtual laboratories were used by only 16% of students. The findings therefore demonstrate the presence of diverse digital and visualization tools in biology instruction, although the frequency of their use differed across technologies.

Assessment practices following practical classes were characterized by fragmentation. Observation-based assessment was reported by 40% of respondents, competency-based criteria by 20% and self- and peer-assessment by 8%. Notably, 20% of students indicated that no formal assessment was conducted. The results show that practical learning was accompanied by different forms of assessment, with observation-based assessment being the most frequently reported approach.

Regarding the study of animal-related topics, only slightly more than half of respondents reported effective knowledge acquisition. Laboratory-based learning (20%) and experimental research (16%) were identified as the most effective learning modes. The practical applicability of acquired knowledge was most frequently evaluated as moderate (52%), while 20% of respondents rated it as low. These findings further indicate the relevance of practical and experimental activities for learning animal-related biological content.

Overall, the Turkish survey demonstrated a substantial practice-oriented component in the biology education experienced by the participating students. Laboratory work, experimental activities, visual and digital resources, and teacher guidance were consistently represented in their responses, while 84% perceived biology education as making a strong or moderate contribution to their professional skill development. Together with the interviews, classroom observations and examination of laboratory-, research- and field-oriented teaching practices, these findings provided empirical support for selecting instructional elements for subsequent adaptation to biology teacher education in Kazakhstan.

The survey results provided an overall indication of practical competence development among biology students in Turkey. The distribution of practical competence levels based on students' self-assessment is summarized in Table 1.

Table 1. *Results of practical competence indicators among biology students in Turkey (n = 25)*

Level of practical competence	Number of students	Percentage (%)
High	11	44.0
Average	10	40.0
Low	4	16.0

The results demonstrate that at the initial stage of the study, the majority of Turkish students showed moderate and high levels of practical competence, primarily associated with laboratory practices, experimental work and the use of visual and digital materials. However, 16% of students showed a low level of practical competence, indicating differences in practical competence development among the respondents.

Further analysis of instructional methods revealed that 80% of respondents participated in laboratory practices and 76% used visual or animated materials, whereas 28% reported that instruction also included predominantly theoretical explanations. These findings demonstrate the strong presence of practice-oriented methods alongside theoretical instruction in the biology education of the surveyed students.

Results of the Pedagogical Experiment in Kazakhstan. The findings of the preceding stages and our previous comparative study indicated that practice-oriented, research-based and digital approaches were more strongly represented in the learning experiences examined at Hacettepe University, whereas the earlier Kazakhstani data showed a greater reliance on theoretical instruction. The previous study also proposed an adapted methodological framework combining inquiry-based learning, laboratory and digital activities, collaborative tasks and reflective assessment. These findings informed the instructional methods and materials subsequently tested in the present pedagogical experiment.

More specifically, five elements of the Turkish practice-oriented approach were adapted for the pedagogical experiment in Kazakhstan. Project-based learning was transformed into small-group research tasks in which students investigated selected topics related to animal diversity. The use of digital zoological tools was adapted through virtual laboratory activities, AR/VR resources and 3D-animal models for observing anatomical structures and biological adaptations. Field-oriented learning was modified into locally feasible biodiversity observation tasks, allowing students to collect and analyze biological information without requiring extended field practice. The student-centered approach was implemented by assigning students the roles of researchers and presenters who analyzed observations, interpreted results and discussed their findings in groups. Finally, reflection-based assessment was incorporated through self-evaluation and structured feedback alongside conventional assessment. These adapted components were integrated into regular biology instruction to develop practical, research, digital and communicative competencies.

To assess the effectiveness of the adapted practice-oriented instructional approach, the outcomes of the experimental group (EG, n = 42) and the control group (CG, n = 35) were compared. Changes in the overall practical competence indicator in both groups are presented in Table 2.

Table 2. *Dynamics of practical competence in the experimental and control groups*

Group	Pre-experimental stage (%)	Post-experimental stage (%)	Change (percentage points)
Experimental group	46.2	89.5	+43.3
Control group	33.6	47.6	+14.0

At the pre-experimental stage, the practical competence indicator was 46.2% in the experimental group and 33.6% in the control group. At the post-experimental stage, the indicator increased to 89.5% in the experimental group and to 47.6% in the control group. Thus, the experimental group demonstrated an increase of 43.3 percentage points, compared with an increase of 14.0 percentage points in the control group. The increase observed in the experimental group was therefore more than three times greater than that recorded in the control group. This pattern suggests that systematic integration of practical tasks, research-oriented activities, digital resources and collaborative learning provided students with substantially more opportunities to apply biological knowledge in practice.

An independent samples t-test confirmed a statistically significant difference in practical competence between the experimental and control groups at the post-experimental stage ($t = 5.41$, $p < .01$). The corresponding effect size (Cohen's $d \approx 1.24$) indicated a large effect in favor of the experimental group, supporting the practical significance of the observed difference..

Changes in academic performance in pedagogical disciplines among undergraduate students were also analyzed. The distribution of academic achievement levels at the pre- and post-experimental stages is presented in Table 3.

Table 3. *Dynamics of academic performance in experimental and control groups*

Academic achievement level	EG – pre-experimental stage (%)	EG – post-experimental stage (%)	CG – post-experimental stage (%)
High (90-100 points)	19.0	33.4	20.0
Average (70-89 points)	54.8	47.6	54.3
Low (below 69 points)	26.2	19.0	25.7

The results show that in the experimental group, the proportion of students with a high level of academic achievement increased from 19.0% to 33.3% (+14.3 percentage points), while the proportion of students with low academic achievement decreased from 26.2% to 19.0%. At the post-experimental stage, 33.3% of students in the experimental group demonstrated high academic achievement compared with 20.0% in the control group, while low academic achievement was observed in 19.0% and 25.7% of students, respectively.

An independent samples t-test confirmed a statistically significant difference in academic performance between the experimental and control groups at the post-experimental stage ($t = 4.18$, $p < .01$). The corresponding effect size (Cohen's $d \approx 0.96$) indicated a large effect in favor of the experimental group. These findings indicate that the practice-oriented instructional approach was associated not only with greater development of practical competence but also with improved academic performance. Taken together, the quantitative findings suggest that the combination of research-oriented tasks, practical activities, digital learning resources and collaborative forms of work was associated with stronger outcomes than conventional instruction alone.

Results of the Professional Development Course. To complement the quantitative results, a qualitative evaluation was conducted during the third stage of the study. This stage involved 25 participants, primarily experienced school and university teachers from different regions of Kazakhstan, with a small number of future biology teachers, who completed the professional development course based on the developed methodology and instructional materials.

Qualitative feedback was collected through semi-structured interviews and reflective discussions focusing on the clarity, accessibility and pedagogical effectiveness of teaching animal-related topics using virtual laboratories, animated materials and practice-oriented instructional tasks. Participants' responses indicated improved instructional clarity, stronger integration of theory and practice and the practical applicability of digital tools in biology teaching.

The feedback provided additional evidence of the educational relevance and practical applicability of the developed methodology and instructional materials. Together with the quantitative findings of the pedagogical experiment, these results provided a broader evaluation of the practice-oriented approach in biology teacher education. All statistical analyses were conducted using Statistica 7.0 software.

Overall, the findings from the three stages of the study provide consistent evidence supporting the adapted practice-oriented approach. The Turkish research stage identified practice-oriented instructional elements suitable for adaptation, while the pedagogical experiment in Kazakhstan demonstrated significant improvements in practical competence and academic performance among students in the experimental group. The subsequent professional development course further confirmed the relevance and practical applicability of the developed methodology and instructional materials. Taken together, these findings provide a coherent empirical basis for evaluating the effectiveness and applicability of the adapted approach in biology teacher education.

Discussions

The findings from the Turkish stage of the study confirm that practice-oriented instructional methods, particularly laboratory activities, experimental research and the use of visual and digital materials, play a crucial role in the development of students' practical competencies. Similar conclusions have been drawn in international studies emphasizing that laboratory-based and inquiry-oriented biology education enhances conceptual understanding, procedural knowledge and professional readiness (Hofstein and Lunetta, 2004; Dillon et al., 2006). However, the presence of students who reported predominantly theoretical instruction highlights a persistent gap between practice-oriented and theoretical components of biology education.

The results also indicate that digital technologies, including AR/VR tools and educational animations, are integrated into biology education, yet their application remains fragmented across different types of digital resources. This observation aligns with the findings of Merchant et al. (2014) and Makransky and Petersen (2019), who argue that digital tools contribute significantly to learning outcomes only when embedded within a coherent pedagogical framework. The Turkish data therefore served not merely as a descriptive baseline but as a methodological reference point for selecting and adapting practice-oriented instructional approaches for Kazakhstan.

The pedagogical experiment conducted in Kazakhstan demonstrated that the adapted practice-oriented instructional approach led to significant improvements in both practical competence and academic performance among students in the experimental group. These results are consistent with research emphasizing that teacher education programs integrating experiential learning, reflective practice and digital tools are more effective in fostering professional competencies (Darling-Hammond et al., 2017). The large effect observed in practical competence development suggests that the adapted practice-oriented approach was not only statistically effective but also educationally meaningful.

An important contribution of the implemented professional development course lies in its methodological structure, which combined theoretical grounding, virtual laboratory work, project-based tasks and reflective discussions. This integrated approach corresponds with the principles of practice-based learning and supports previous studies highlighting the role of reflection and contextualized practice in teacher competence development (Loughran, 2013). Moreover, the inclusion of elements aimed at developing communicative skills and self-reflection aligns with contemporary views on holistic teacher competence, which extends beyond subject knowledge alone.

Despite these positive outcomes, several limitations should be acknowledged. The study was conducted within a limited sample size and relied on a case-based design, which may restrict the generalizability of the findings. In addition, the semester-long duration of the pedagogical experiment did not allow for assessing long-term effects on professional practice. Similar methodological constraints have been noted in comparable studies on teacher professional development (Opfer and Pedder, 2011). Future research should therefore adopt longitudinal designs and involve a broader range of institutions and regions to strengthen external validity.

Overall, the discussion of results demonstrates that adapting selected Turkish practice-oriented biology education approaches to the Kazakhstani context is both feasible and effective when aligned with local educational conditions and pedagogical priorities. The study contributes to the growing body of international research emphasizing the importance of cross-cultural transfer of educational innovations grounded in methodological adaptation rather than direct replication.

Conclusions

In conclusion, the findings of this study demonstrate that selected practice-oriented pedagogical approaches identified during the research stage at Hacettepe University can be effectively adapted to biology teacher education in Kazakhstan. The integration of laboratory and experimental activities applied animal-biology tasks, digital and virtual resources, collaborative learning and research-oriented instruction contributed to significantly greater development of students' practical competence and academic performance compared with conventional instruction. The professional development stage further confirmed the relevance and practical applicability of the developed methodology and instructional materials for biology teaching.

Based on these findings, biology teacher education programs are recommended to strengthen the systematic integration of laboratory and experimental work, research-oriented and collaborative tasks, virtual laboratories, digital visualization and applied activities related to animal biology. The developed instructional materials may also be incorporated into professional development programs for practicing biology teachers to support the transfer of practice-oriented methods into classroom teaching.

Further implementation of the adapted approach in different universities and regions of Kazakhstan is recommended to evaluate its effectiveness across broader educational settings. Future research should involve larger samples and longer intervention periods to examine the sustainability of practical competence development and the long-term effects of the proposed methodology on teachers' professional practice.

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Conflict of interests

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Institutional Review Board Statement

Not applicable.

Author Contributions

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