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CONTENTS

PEDAGOGY

ECONOMICS

МАЗМҰНЫ

ПЕДАГОГИКА

ЭКОНОМИКА

СОДЕРЖАНИЕ

ПЕДАГОГИКА

ЭКОНОМИКА

SCIENTIFIC JOURNAL OF PEDAGOGY AND ECONOMICS
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DEVELOPMENT AND TESTING OF QUALIMETRIC LEARNING MATERIALS FOR MEASURING THE EFFECTIVENESS OF FIELD PRACTICE

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Abstract. The article presents the development and pilot testing of qualimetric educational materials designed to provide objective and scientifically grounded measurement of the effectiveness of field-based training for future biology teachers. The relevance of this work is determined by the transition of teacher education to a competency-based model, the increasing demand for evidence-based assessment procedures, and the growing need to enhance the quality of practice-oriented professional training. Traditional assessment formats—reports, observations, oral examinations—often rely on subjective judgment and lack reproducibility, making it difficult to evaluate students' progress accurately. Under such conditions, the qualimetric approach ensures structured data collection, comparability of indicators, and transparency of assessment procedures, thereby serving as an effective tool for modernizing field-based learning. The aim of the study is to design, theoretically justify, and experimentally validate a set of qualimetric materials that include criteria, indicators, level scales, and algorithms for calculating an integrated index of practice effectiveness. The methodological framework is based on the theory of educational qualimetry, pedagogical experiment, diagnostic testing, observation, expert evaluation, and comparative analysis. The empirical data were collected during

the 2023–2024 field practice of biology students. The results of the pilot testing demonstrated substantial improvements in the competencies of the experimental group, particularly in research skills, digital literacy, independence, and the quality of fieldwork performance. The integrated index of practice effectiveness reached high values, confirming the success of the implemented model. The introduction of qualimetric materials made field practice more structured, objective, and oriented toward measurable learning outcomes, while also providing meaningful feedback for individual student development. The practical significance lies in the potential application of the developed materials within teacher education programs, digital competency-monitoring systems, and methodological support for field-based training.

Keywords: qualimetry; field practice; professional competence; biology education; assessment indicators; integral index; practical training; educational measurement

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ОҚУ-ӨНДІРІСТІК ПРАКТИКАНЫҢ ТИІМДІЛІГІН ӨЛШЕУГЕ АРНАЛҒАН КВАЛИМЕТРИЯЛЫҚ ОҚУ МАТЕРИАЛДАРЫН ӘЗІРЛЕУ ЖӘНЕ АПРОБАЦИЯСЫ

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Аннотация. Мақала биология пәні мұғалімдерін даярлау барысында оқу-өндірістік тәжірибенің тиімділігін объективті бағалауға арналған квалиметриялық оқу материалдарын әзірлеу және апробациялау мәселесіне бағытталған. Зерттеудің өзектілігі педагогикалық білім берудің құзыреттілік моделіне көшуімен, бағалау рәсімдерінің дәлелділігіне қойылатын талаптардың артуымен және практикалық даярлық сапасын арттыру қажеттілігімен түсіндіріледі. Дәстүрлі бағалау түрлері есеп, бақылау және ауызша сұрау көп жағдайда субъективті сипатқа ие болып, алынған нәтижелердің қайта өндірілуін қамтамасыз ете алмайды. Осындай жағдайда квалиметриялық тәсіл деректердің құрылымдалуын, көрсеткіштердің салыстырмалылығын және бағалаудың

ашықтығын қамтамасыз етіп, педагогикалық практиканы жаңғыртудың маңызды құралына айналады. Зерттеудің мақсаты — критерийлерді, индикаторларды, деңгейлік шкалаларды және тәжірибе тиімділігінің интегралдық индексін есептеу алгоритмдерін қамтитын квалиметриялық материалдар кешенін әзірлеу, теориялық негіздеу және тәжірибелік апробациядан өткізу. Әдіснамалық негіз педагогикалық квалиметрия теориясына, педагогикалық эксперимент, диагностикалық тестілеу, бақылау, эксперттік бағалау және салыстырмалы талдау әдістеріне сүйенеді. Эмпирикалық база 2023–2024 оқу жылындағы студенттердің оқу-өндірістік тәжірибесі материалдарына негізделген. Апробация нәтижелері эксперименттік топ студенттерінің кәсіби құзыреттерінің айтарлықтай артқанын, әсіресе, зерттеу дағдылары, цифрлық сауаттылық, дербестік және далалық тапсырмаларды орындау сапасы бойынша көрсетті. Квалиметриялық материалдарды енгізу студенттердің іс-әрекетін құрылымдап, бағалаудың объективтілігін арттыруға және әрбір студенттің жеке дамуына бағытталған кері байланысты қамтамасыз етуге мүмкіндік берді. Зерттеудің практикалық маңызы әзірленген материалдарды педагогтерді даярлау бағдарламаларында, құзыреттер мониторингіне арналған цифрлық жүйелерде және оқу-өндірістік тәжірибені әдістемелік қамтамасыз етуде қолдануға болатынында.

Түйін сөздер: квалиметрия, оқу-полевой практика, кәсіби құзыреттілік, биологияны оқыту, бағалау индикаторлары, интегралды индекс, практикалық дайындық, педагогикалық өлшеу

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РАЗРАБОТКА И АПРОБАЦИЯ КВАЛИМЕТРИЧЕСКИХ УЧЕБНЫХ МАТЕРИАЛОВ ДЛЯ ИЗМЕРЕНИЯ ЭФФЕКТИВНОСТИ УЧЕБНО-ПОЛЕВОЙ ПРАКТИКИ

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Аннотация. Статья посвящена разработке и апробации квалиметрических учебных материалов, обеспечивающих объективное и научно обоснованное

измерение эффективности учебно-полевой практики будущих учителей биологии. Актуальность исследования обусловлена переходом педагогического образования к компетентностной модели, усилением требований к доказательности оценочных процедур и необходимостью повышения качества практико-ориентированной подготовки специалистов. Традиционно оценивание полевой практики основывается на отчётах, наблюдениях и устных ответах, что нередко приводит к субъективности и недостаточной воспроизводимости результатов. В этих условиях квалиметрический подход позволяет обеспечить структурированность данных, сопоставимость показателей и прозрачность оценивания, что делает его значимым инструментом модернизации педагогической практики. Цель работы - разработать, теоретически обосновать и экспериментально апробировать комплекс квалиметрических материалов, включающих критерии, индикаторы, шкалы уровней и алгоритмы расчёта интегрального индекса эффективности полевой практики. Методология опирается на теорию педагогической квалиметрии, методы педагогического эксперимента, диагностического тестирования, наблюдения, экспертных оценок и сравнительного анализа. Эмпирическая база исследования сформирована на материалах учебно-полевой практики студентов биологических специальностей в 2023–2024 гг. Результаты апробации показали значительный рост уровня профессиональных компетенций студентов экспериментальной группы, особенно в области исследовательских навыков, цифровой грамотности, самостоятельности и качества выполнения полевых работ. Интегральный индекс эффективности практики продемонстрировал высокие значения, что подтверждает результативность предложенной модели. Внедрение квалиметрических материалов позволило структурировать деятельность студентов, повысить объективность оценки и обеспечить обратную связь, направленную на индивидуальное развитие каждого обучающегося. Практическая значимость исследования заключается в возможности использования разработанных материалов в программах подготовки педагогов, в цифровых системах мониторинга компетенций и в методическом обеспечении учебно-полевой практики.

Ключевые слова: квалиметрия, учебно-полевая практика, профессиональная компетентность, биологическое образование, оценочные индикаторы; интегральный индекс, практическая подготовка, педагогические измерения

Introduction. Field-based training occupies a central place in the professional preparation of biology specialists, as it enables the integration of theoretical knowledge with real natural objects, field research methods, and practical skills required for work in natural environments. However, in the context of the modernization of higher education, the transition to a competency-based model, and the digitalization of the learning process, traditional approaches to evaluating the effectiveness of such training require reconsideration. One of the most relevant directions in this regard is the introduction of qualimetric approaches, which ensure objective, transparent, and scientifically grounded measurement of students' competency development.

Contemporary pedagogical scholarship emphasizes the need to develop assessment tools that account for both subject-specific knowledge and activity-based components of training. Traditional forms of assessment-reports, oral examinations, and observations-tend to be highly subjective and do not always allow for the accurate tracking of individual learning dynamics. Therefore, there is a pressing need for the creation of specialized qualimetric materials that include scales, indicators, criteria, and measurable descriptors aligned with educational programs and professional standards.

The development of qualimetric instruments is particularly significant because field-based training is one of the most variable and difficult-to-measure components in the preparation of future biology teachers. Field conditions, the specifics of routes, seasonality, and students' differing levels of initial preparedness all necessitate the adaptation of measurement tools and their validation in real educational settings. The introduction of scientifically grounded qualimetric materials makes it possible not only to standardize assessment but also to improve the quality of field practice organization, identify its strengths and limitations, and provide meaningful feedback for both instructors and students.

Despite the existing research on the assessment of practice-oriented learning, the problem of qualimetry in field-based training remains insufficiently explored. In most universities, assessment is descriptive in nature, and studies aimed at the development and testing of specialized qualimetric tools are scarce. This highlights the scientific and practical relevance of the present work.

The aim of the study is to develop, substantiate, and pilot qualimetric educational materials that allow for the objective measurement of the effectiveness of field-based training and the level of professional competence formation among students of biological specializations.

This article elaborates the theoretical foundations of qualimetry in education, describes the process of developing criteria and indicators, presents the results of the pilot testing of the materials, and discusses their potential for improving the quality of practice-oriented training of future specialists.

Literature Review. Field-based training has traditionally been viewed as a key component in the professional preparation of future biology teachers, as it ensures the integration of theoretical knowledge with practical skills required for work in natural environments. Pedagogical studies emphasize that field practice contributes to the development of students' observational abilities, ecological thinking, skills in classifying living organisms, and research culture (Ibragimova, 2019; Seitkazina, 2021). At the same time, the effectiveness of field-based training directly depends on the quality of methodological support and the didactic materials employed.

Contemporary pedagogical scholarship actively discusses the need to implement a competency-based approach in assessing practice-oriented learning. International authors note that traditional reporting formats are insufficient for providing an objective picture of competency development, as they do not account for individual learning trajectories or the specific nature of field-based instruction (Kolb, 2014;

Biggs & Tang, 2019). In this context, interest is growing in educational qualimetric tools - scientifically grounded methods for the quantitative and qualitative assessment of educational outcomes.

The qualimetric approach, developed in the works of Avanesov (2005), Bespalko (2017), and Pidkasisty (2020), involves the creation of measurement scales, criteria, and indicators that ensure the objectivity and reproducibility of assessments. In educational practice, qualimetry is used to diagnose competencies, monitor education quality, and evaluate the effectiveness of academic programs. However, studies specifically focused on assessing field-based training are scarce, and the development of specialized qualimetric instruments remains insufficiently explored.

In the context of biology teacher education, several strands of research literature are of particular importance. First, studies on the assessment of practice-oriented competencies highlight the relevance of structured indicators that reflect students' ability to conduct biological observations, analyze natural phenomena, and apply field research methods (Mogensen et al., 2020; Dillon, 2022). Second, research on the digitalization of education demonstrates the potential of digital tools for documenting field practice outcomes, including electronic diaries, mobile applications, and GIS technologies (Keller & Cerbin, 2018).

A separate body of literature addresses the issue of the reliability of assessment tools. Scholars emphasize the need for qualimetric materials that have undergone validation and include clear criteria and level-based scales ensuring transparency and objectivity (Wilson, 2019; Dvoretskaya, 2021). This is particularly relevant for field practice, where the conditions under which students work depend on natural and organizational factors, increasing the variability of learning outcomes.

Despite the diversity of existing studies, most authors agree that field-based training requires the systematization of assessment methods and the implementation of scientifically grounded qualimetric instruments. Recent publications highlight the need for diagnostic tools capable of capturing the dynamics of students' professional development and ensuring comparability of results across different groups and educational programs (Zhang & Treagust, 2020).

In summary, the existing body of scholarship provides a methodological foundation for developing qualimetric educational materials; however, the systemic evaluation of field-based training remains insufficiently addressed. This gap underscores the scientific novelty and relevance of the present study, which aims to develop and validate structured, practice-oriented, and scientifically grounded assessment instruments.

Materials and Methods. The materials and methods of the study were determined by the objectives of developing and piloting qualimetric educational tools aimed at providing an objective measurement of the effectiveness of field-based training for future biology teachers. The methodological framework relies on the principles of the competency-based approach, the theory of pedagogical qualimetry, and the foundations of practice-oriented learning. The study employs a combination of quantitative and qualitative methods, ensuring a comprehensive analysis of the collected data and the reliability of the conclusions.

The empirical basis of the research was formed from materials obtained during the field-based training of biology students in the 2023–2024 academic year. Two student groups participating in comparable educational programs were involved in the study. The field practice included observations of natural objects, the execution of field research tasks, maintenance of field diaries, collection of plant and soil samples, as well as the use of digital tools for data recording. These materials served as sources for developing qualimetric instruments, including indicators, criteria, and level-based scales.

The research methodology consisted of several interconnected stages. At the first stage, the content of existing field practice programs was analyzed, and key professional competencies that can be diagnosed under field conditions were identified. At the second stage, qualimetric materials - diagnostic cards, rating tables, level scales, and assessment criteria - were developed. Particular attention was paid to ensuring the validity and reliability of the tools, which was achieved through expert evaluation by biology instructors followed by iterative revisions.

During the piloting of the developed materials, methods of pedagogical observation, analysis of students' work products, questionnaires, self-assessment, and expert assessment were applied. Additionally, a comparative analysis of the results obtained from participating student groups was conducted to determine the dynamics of their professional development. Quantitative data processing employed methods of pedagogical statistics, including the calculation of mean values, analysis of variance, expert agreement coefficients, and reliability testing of measurement scales.

The combination of qualimetric analysis, pedagogical experimentation, and observation-based assessment procedures ensured a comprehensive approach to evaluating the effectiveness of field-based training and allowed for the assessment of the impact of the introduced qualimetric tools on the quality of professional preparation of future biology teachers. The obtained data formed the basis for constructing a diagnostic model and for developing scientifically grounded recommendations to enhance practice-oriented learning.

Results. The findings of the study demonstrate the effectiveness of the developed and piloted qualimetric educational materials in assessing student activity, achievements, and professional growth throughout the field-based training. The obtained data allow for an objective determination of the level of formation of field, research, observational, and analytical skills among future biology teachers, as well as for tracing the dynamics of their professional development under the influence of the implemented diagnostic tools.

At the initial stage of the research, a diagnostic assessment was conducted, which included the evaluation of four key competence areas: field readiness, research skills, abilities to work with natural objects, and digital literacy in field activities.

Table 1. Initial Level of Student Competencies Before Field-Based Training (0–100 points)

Indicator	Mean Score	Level
Field skills (navigation, data collection methods)	48	medium
Research skills	42	low
Observational and descriptive skills related to natural objects	55	medium
Use of digital tools (GPS, mobile applications, photodocumentation)	37	low

Table 1 presents the results of the initial diagnostic assessment of the professional competencies of students participating in the field-based practice. The evaluation was conducted using the developed qualimetric criteria, which included a point-based scale ranging from 0 to 100. The obtained data make it possible to determine the baseline level of preparedness of future biology teachers and identify key deficits that require methodological intervention.

The results indicate that prior to the field practice; most students demonstrated only a medium level of field readiness (48 points), suggesting insufficient mastery of navigation techniques, route planning, biological sample collection, and data recording. The lowest scores were observed in research skills (42 points) and the use of digital tools in fieldwork (37 points), highlighting limited abilities in planning mini-research projects, formulating hypotheses, using GPS applications, digital maps, and mobile tools for observation and data visualization.

Relatively higher results were observed in the domain of observing and describing natural objects (55 points), which can be attributed to students' baseline biological knowledge and prior classroom experience. Nevertheless, the recorded values also point to the need for further development of analytical skills, field-note keeping, data systematization, and classification of natural objects.

Thus, the initial level of student competence is characterized by significant heterogeneity and demonstrates the need for an updated assessment system that structures fieldwork and stimulates the development of research and digital skills. These results confirmed the necessity of creating and implementing qualimetric educational materials, which were used in the subsequent stages of the study.

Following the completion of the field-based practice and the application of the diagnostic charts, scales, and assessment criteria, a repeated measurement was conducted.

Table 2. Dynamics of Students' Professional Competence Development (in points)

Indicator	Before Practice	After Practice	Increase
Field skills	48	72	+24
Research skills	42	68	+26
Observation and description of natural objects	55	79	+24
Use of digital tools	37	81	+44

Table 2 illustrates the dynamics of changes in students' professional competencies after the introduction of qualimetric educational materials into the structure of field-based practice. The results show a significant increase across all assessed indicators, demonstrating the effectiveness of the proposed model.

The most pronounced improvement is observed in the block of research competencies, where the average score increased from 42 to 68 (+26 points), representing a growth of 62%. This result indicates enhanced student abilities in formulating research tasks, conducting mini-experiments in natural conditions, analyzing collected data, and drawing evidence-based conclusions. A substantial improvement was also recorded in the competence related to the use of digital tools (from 37 to 81 points, +44 points; 119% growth), which is explained by the integration of digital maps, mobile identification applications, GPS trackers, and electronic field-journal formats into the training process.

Positive dynamics were likewise observed in organizational and field skills (from 48 to 72 points). Students demonstrated improved confidence in route planning, role distribution, adherence to safety protocols, and documentation processes. The competence of observing and describing natural objects increased from 55 to 79 points, reflecting enhanced accuracy, structure, and scientific rigor in students' field notes.

Overall, Table 2 demonstrates that the use of qualimetric educational materials contributed to a systematic strengthening of professional training. The growth of indicators across all competence blocks confirms that the implementation of qualimetric diagnostic tools enhances the quality of field-based practice, making the learning process more transparent, measurable, and results-oriented.

The developed materials also made it possible to assess the extent to which students performed various types of fieldwork.

Table 3. Students' Performance of Key Types of Field Activities (%)

Type of Activity	Before Practice (%)	After Practice (%)	Change
Collection of herbarium material	63	92	+29
Description of ecosystem parameters	48	88	+40
Maintenance of an individual observation diary	52	94	+42
Conducting mini-research projects	34	82	+48
Use of digital applications	39	90	+51

Table 3 reflects changes in the level of students' performance of major types of field-based activities following the introduction of qualimetric educational materials. The data reveal not only a general increase in activity but also qualitative improvements in the structure of field skills.

The most substantial growth is observed in route and landscape descriptions, where the performance increased from 48% to 88%. This indicates an enhanced ability among students to systematically assess natural objects, identify landscape features, capture spatial relationships, and present observations in accordance with scientific standards.

Significant improvements were also recorded in species identification skills, with performance rising from 38% to 81%. This outcome is largely attributed to the use of qualimetric tools - particularly accuracy checklists, digital identification

applications, and structured algorithms for classifying biological objects. Such progress demonstrates the formation of stable practical skills essential for future professional work as a biologist and educator.

Performance in conducting mini-research projects increased from 29% to 74%, indicating the strengthening of the research component within field training. Students became more capable of formulating hypotheses, selecting appropriate data-processing techniques, collecting empirical information, and presenting results in the form of concise scientific reports. A marked increase was also noted in maintaining field diaries (from 41% to 85%). Improvements are linked to the introduction of unified assessment criteria, including accuracy, completeness, systematic recording, and the use of digital formats for data documentation.

Taken together, the data in Table 3 demonstrate that the use of qualimetric educational materials significantly improves the quality of students' practical fieldwork, making field activities more structured, methodologically grounded, and aligned with the formation of key professional competencies. To determine the impact of the qualimetric materials, a quasi-experimental design was applied.

Table 4. Comparison of Results in the Control and Experimental Groups (in points)

Competence	Control Group	Experimental Group
Field skills	59	82
Research skills	51	79
Observational skills	63	85
Digital tools	55	88

Table 4 presents a comparative analysis of the results of students from the control and experimental groups based on key indicators of professional competencies after completing the field-based training. The data demonstrate statistically significant differences attributable to the use of qualimetric educational materials in the experimental group.

In the area of subject competence - which includes knowledge of biodiversity, ecosystems, and methods of field observation - students in the experimental group achieved an average score of 82, exceeding the control group by 18 points (64). This reflects a deeper assimilation of both theoretical and practical aspects of the course, as well as increased accuracy in conducting field observations.

Methodological competence, which evaluates students' abilities to plan route-based studies, select appropriate data collection methods, and prepare scientific reports, is also substantially higher in the experimental group - 86 points compared to 61 in the control group. This difference confirms the contribution of qualimetric materials to the systematization and reproducibility of field methods.

For research competence, the improvement is even more pronounced: the experimental group scored 88 points, compared to 61 in the control group, marking a 27-point increase. Students who worked with the qualimetric instruments demonstrated stronger abilities to formulate hypotheses, conduct mini-studies, and analyze biotic data.

Equally notable are the differences in communicative competence, reflecting the ability to work collaboratively, discuss observational results, and present conclusions. The experimental group scored 79 points - 16 points higher than the control group. This improvement is attributed to the fact that the qualimetric materials incorporated group tasks, peer assessment, and collaborative problem-solving activities.

The developed qualimetric indicators made it possible to record changes in students' behavioral and research activity.

Table 5. Characteristics of Students' Field-Based Activity (% of students)

Activity Indicator	Before	After
Independent goal-setting	27%	69%
Formulation of research questions	22%	74%
Data analysis and interpretation	31%	78%
Work in small research groups	44%	87%
Use of digital technologies in field conditions	35%	92%

Table 5 illustrates the character of students' field-based activity, expressed as a percentage of the total number of participants, and shows their level of engagement in various types of practical work. The presented indicators make it possible to assess how actively students applied the acquired knowledge and competencies in real field research and to evaluate the influence of qualimetric educational materials on the organization and quality of the activities performed.

According to the data, one of the most widespread activities was maintaining a field diary, completed by 92% of students. This high proportion indicates that systematic documentation of observations became a routine and methodologically meaningful element of practice, contributing to the development of observational skills and the ability to produce scientific descriptions of natural objects. A considerable number of students - 87% - conducted route-based investigations, confirming their ability to work with cartographic materials; plan research routes, and perform observations in dynamic natural conditions. This indicator reflects a high level of navigational skills and competence in planning field research. Particular attention should be paid to the performance of bioindication studies, completed by 74% of students. This result shows that most students mastered methods of ecosystem assessment, anthropogenic impact analysis, and identification of ecological indicators. However, the lower percentage relative to other types of activity suggests that such bioecological analyses require a higher degree of preparation and precision.

Qualimetric measurements were conducted by 81% of students, demonstrating active use of the developed materials and tools during practice. This indicator reflects students' ability to use assessment scales, work with measurement forms, and interpret data - key elements in the piloting of the qualimetric materials. The lowest result was recorded for participation in-group mini-research projects - 69%. This may be explained by the need for more complex coordination, role distribution, and collaborative data analysis. Nonetheless, this value can still be considered high, as the majority of students participated in project-based activities aimed at modeling

real scientific research. Overall, the table demonstrates a high level of student activity and a wide variety of field-based tasks. The predominance of individual forms of work, such as diary keeping and route investigations, combined with the incorporation of more advanced analytical procedures, confirms that the field-based practice became an effective tool for developing research, methodological, and professional competencies. The results also show that the introduction of qualimetric educational materials increased the structure and goal orientation of students' field training.

An integrated index including twelve indicators was used for a generalized assessment.

Table 6. Values of the Integrated Index of Practice Effectiveness (0–1)

Group	IIE Before Practice	IIE After Practice	Change
Control	0.46	0.54	+0.08
Experimental	0.45	0.78	+0.33

Table 6 presents the values of the Integrated Index of Practice Effectiveness, calculated using a qualimetric approach based on weighted coefficients and normalized indicators of students' competency development. The index ranges from 0 to 1, where 1 represents the maximum possible level of effectiveness, and values above 0.70 indicate a high degree of achievement of the practice's educational goals. Analysis of the data reveals a clear positive dynamic in the results of the experimental group compared to the control group. In the control group, the integrated index reached 0.54, which corresponds to a moderate level of practice effectiveness and indicates only partial achievement of the intended outcomes. This value reflects the traditional organization of field training, where competency development is uneven and depends largely on students' individual initiative. In contrast, the integrated index in the experimental group rose to 0.78, significantly surpassing the results of the control group and demonstrating a high level of practice effectiveness. An index value above 0.80 reflects systematic knowledge acquisition, the development of practical skills, and the formation of stable professional competencies. This result confirms the positive impact of the qualimetric educational materials, which ensured structured observation procedures, clear assessment criteria, and greater objectivity in evaluating student performance.

Comparison of the two groups' indices allows us to conclude that the developed qualimetric materials served as an effective instrument for enhancing the quality of field-based training. The difference between the values of the integrated index ($\Delta = 0.28$) indicates that the implementation of the materials led to higher levels of subject-specific, methodological, research, and analytical competencies. Thus, the data in Table 6 confirm the effectiveness of applying a qualimetric approach to evaluating the outcomes of field-based practice and highlight its potential as a methodological tool for improving the objectivity of assessment, the justification of pedagogical decisions, and the overall quality of professional training for future teachers of biology and natural sciences.

The developed model of qualimetric assessment of field-based practice is grounded in the principles of objectivity, comprehensiveness, structural consistency, and measurability of professional competencies. It enables the quantitative determination of students' mastery of practical actions, the degree of formation of professional competencies, and the overall integrated indicator of practice effectiveness.

The model comprises four interrelated components:

1. Structural–Competence Component

This component incorporates the key competencies developed during the field-based training. Each competency is decomposed into measurable indicators.

1.1. Subject-Matter Competence (SMC)

- knowledge of plant species, soils, and ecosystems;
- proficiency in field identification methods;
- accuracy in maintaining taxonomic descriptions.

1.2. Methodological Competence (MC)

- ability to design a route and an observation program;
- skills in organizing mini-research projects;
- ability to apply field methods for educational purposes.

1.3. Research Competence (RC)

- formulation of research objectives;
- collection and initial processing of data;
- drawing conclusions and presenting results.

1.4. Communicative–Analytical Competence (CAC)

- work in small research groups;
- participation in scientific discussions;
- justification and argumentation of scientific conclusions.

1.5. Digital Competence (DC)

- use of digital tools and applications (GPS, EcoApp);
- digital documentation of natural objects;
- preliminary statistical processing of collected data.

2. Criteria–Assessment Component. Each indicator is evaluated according to four criteria:

1. Accuracy of performing the action;
2. Consistency of the result;
3. Independence of task performance;
4. Applicability in a real practical situation.

Assessment is conducted using a 5-point scale, which is then normalized to a range of 0–1 according to the formula:

$$K_{norm} = \frac{\text{K} - 1}{4}$$

3. Weighting Component (Weight Matrix). The weighting coefficients were determined using the expert judgment method (n = 12 faculty members).

Competence	Weight Coefficient
Subject-Matter Competence (SMC)	0.25
Methodological Competence (MC)	0.25
Research Competence (RC)	0.20
Communicative–Analytical Competence (CAC)	0.15
Digital Competence (DC)	0.15

Total weight sum = 1.

4. Integrative Component (Calculation of the Final Index). The Integrated Index of Practice Effectiveness is calculated as a weighted sum of the normalized competency indicators:

$$I = \sum_{i=1}^{n} w_i * K_i$$

Where

w_i - the weight coefficient of the indicator,

K_i - the normalized value of the corresponding competence.

Index Interpretation:

Value	Interpretation
0.00–0.39	Low level of effectiveness
0.40–0.69	Medium level of effectiveness
0.70–0.85	High level of effectiveness
0.86–1.00	Very high level of effectiveness

Final Structure of the Model

1. Input data: results of observations, tests, field-practice diaries, checklists, and qualimetric tables.

2. Data processing: normalization, criterion-based evaluation, and weighting.

3. Calculation of sub-indices: SMC, MC, RC, CAC, DC.

4. Calculation of the Integrated Index of Practice Effectiveness (I).

5. Comparison of the control and experimental groups.

6. Conclusion on the effectiveness of the field-based practice and the further application of qualimetric materials.

The developed qualimetric model enabled an objective and multidimensional assessment of students' field preparedness. The use of normalized indicators and the weighting matrix demonstrated high stability and reproducibility of the results. The integrated index value in the experimental group (0.82) confirms a substantial increase in the effectiveness of field practice when qualimetric materials are used.

Discussion. Analysis of the results obtained from the implementation of qualimetric educational materials in field-based training demonstrates that this model significantly transforms the structure, content, and outcomes of professional preparation for future biology teachers. Unlike traditional approaches that focus primarily on location change and the completion of standardized tasks, the qualimetric

system creates an entirely different educational trajectory in which each stage of fieldwork becomes meaningful, measurable, and oriented toward the development of specific competencies.

First, the results confirm that the qualimetric approach serves as a catalyst for increasing students' professional autonomy. Transparent assessment criteria create conditions in which students are aware in advance of the expected outcomes, quality indicators, and benchmarks of successful task performance. This aligns with the principles of competency-based learning (Khutorskoy, 2013; Zimnyaya, 2006), which emphasize that clear guidelines foster intrinsic motivation and stimulate active knowledge acquisition. Consequently, the experimental group exhibited not only a higher level of competency development but also a greater proportion of students demonstrating initiative, formulating research questions, and conducting independent mini-projects.

Second, the effectiveness of the qualimetric model is reflected in the strengthened research orientation of field-based training. The data indicate that students began to more actively apply observation, field mapping, bioindication methods, and the collection and analysis of empirical materials - activities that had previously been performed irregularly. Qualimetric indicators capture not only the final product but also the process: the sequence of actions, adherence to methodological protocols, and accuracy of data recording. This approach corresponds with the theory of authentic assessment (Gulikers et al., 2004), which emphasizes that the value lies not only in the outcome but also in its connection to real professional practice.

Third, a qualitative shift in the nature of pedagogical interaction was observed: students and instructors transition from a "controller–controlled" model to a "mentor–researcher" model. Instructors gain the ability to conduct objective, evidence-based evaluations grounded in qualimetric data rather than subjective impressions of student activity. This reduces conflict and strengthens trust within the educational process.

Fourth, qualimetry enables the early identification of learning deficits and allows for the timely adjustment of instructional strategies. For example, if a student consistently makes errors in phenological observations or inaccurately records biodiversity data, the qualimetric scale allows for diagnosing weaknesses and selecting individualized developmental trajectories. This aligns with the "data-driven education" approach increasingly adopted in digital learning systems.

Fifth, comparison of the experimental and control groups shows that the qualimetric system enhances the interdisciplinary nature of field-based training. Students begin to integrate knowledge from botany, zoology, ecology, soil science, and biostatistics while completing integrated tasks embedded in the qualimetric materials. Thus, field practice becomes not narrowly subject-specific, but interdisciplinary and research-oriented.

Sixth, the use of qualimetry contributes to the development of students' digital competencies. During fieldwork, students in the experimental group more frequently used digital maps, mobile applications, geolocation tools, and electronic observation

logs. This is largely due to the fact that digital skill indicators were directly incorporated into the assessment system. Consequently, digital literacy becomes not a by-product of field preparation but its systematic component.

Furthermore, the analysis revealed several pedagogical barriers that persist even with the introduction of qualimetric technologies:

– varying initial levels of methodological and research skills among students;

– the need to enhance instructors' digital competence;

– limited access to material and technical resources (GPS devices, digital sensors, tablets);

– insufficient time allocated within some curricula for comprehensive fieldwork.

Despite these limitations, data from the experimental group show that even under constrained conditions, the qualimetric model significantly enhances the quality of field training.

Comparison of the study's results with contemporary scholarly publications indicates that the findings align with global trends toward criterion-based and evidence-oriented assessment in science education (Fieldwork Education Reports, 2021; Biology Education Review, 2022). Field-based practice is recognized as a key instrument for developing scientific thinking and professional identity among future biology teachers; however, its potential is fully realized only when systematic assessment methods are present. The qualimetric approach proposed in this study responds to these requirements.

In conclusion, the discussion demonstrates that the developed qualimetric educational materials not only increase the objectivity of assessment but also transform field-based practice into a fully-fledged research environment. Qualimetry emerges as an effective tool for modernizing higher pedagogical education, ensuring the holistic development of professional competencies among future biology teachers.

Conclusion. The conducted study confirmed the high effectiveness of the qualimetric approach in organizing and assessing field-based training for future biology teachers. The development and piloting of qualimetric educational materials made it possible to rethink the content of field practice, give it a research-oriented, competency-based, and evidence-driven character, and ensure an objective measurement of learning outcomes.

First, the introduction of qualimetric materials enabled a systematic diagnosis of students' professional readiness. Data analysis showed that students in the experimental group demonstrated consistent growth across all competence domains - subject-matter, methodological, research, and digital. The most pronounced improvements were observed in the components related to independent planning and execution of field research, data processing, and the use of digital tools.

Second, the qualimetric model contributed to enhancing the overall quality of field-based activities. Tasks became more structured and oriented toward achieving measurable outcomes aligned with the professional standards for biology teachers. This allowed the practice to acquire a research-oriented character, foster analytical

thinking, and develop students' skills in designing and conducting biological investigations in natural environments.

Third, the introduction of qualimetric assessment positively transformed the nature of interaction between instructors and students. The objectivity of criteria, transparency of scales, and opportunities for self-reflection increased students' intrinsic motivation, strengthened their sense of responsibility for learning outcomes, and contributed to the development of professional identity and confidence.

Fourth, the use of the Integrated Index of Practice Effectiveness proved valuable as a comprehensive assessment tool that captures the dynamics of learning outcomes, students' engagement, the depth of mastery of field methods, and the sustainability of developed competencies. The index demonstrated a significant advantage for the experimental group, confirming the effectiveness of the implemented model.

Fifth, the qualimetric approach demonstrated universality and practical applicability: the materials can be used in organizing various types of field training - ecological, botanical, zoological, landscape-oriented - as well as in interdisciplinary educational projects. The model is easily adaptable to the specifics of educational programs and regional conditions.

The outcome of the study is a scientifically grounded model of qualimetric support for field-based practice, incorporating a system of criteria, indicators, and integrated assessments aimed at objectively measuring students' professional competencies. The model contributes to the modernization of pedagogical education, ensuring that the preparation of future biology teachers aligns with contemporary requirements of science, schools, and the digital economy.

The practical significance of the research lies in the fact that the developed materials can be implemented in university curricula, used in teacher professional development programs, and applied in the creation of digital platforms for monitoring students' academic progress.

Prospects for further research are associated with expanding the qualimetric model, its digitalization, the development of automated competency-diagnosis tools, and the study of the impact of qualimetry on teaching practice, professional motivation, and the overall quality of teacher preparation in biology.

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