frontiers in Education

TYPE Curriculum, Instruction, and Pedagogy
PUBLISHED 16 March 2026
DOI 10.3389/feduc.2026.1726102

OPEN ACCESS

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RECEIVED 15 October 2025
REVISED 04 February 2026
ACCEPTED 25 February 2026
PUBLISHED 16 March 2026

CITATION
Ramadani F, Çibukçiu B, Ismajli B and Pejchinovska-Stojkovikj M (2026) The role of practical laboratory work in stimulating students' interest in natural sciences. *Front. Educ.* 11:1726102. doi: 10.3389/feduc.2026.1726102

The role of practical laboratory work in stimulating students' interest in natural sciences

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This study examines the role of practical laboratory work in stimulating students' motivation and perceived learning effectiveness in natural science subjects in lower secondary schools in the Republic of Kosovo. Using quantitative research design, data were collected through structured questionnaires administered to 168 science teachers and 183 seventh grade students across 24 public lower secondary schools. The study focuses on the implementation of laboratory work, the availability and quality of laboratory equipment, and students' perceptions of learning in Biology, Chemistry, and Physics, within the framework of the national curriculum. Descriptive statistics and chi-square tests were used to examine associations between laboratory practices, instructional conditions, and student motivation. The findings show that participation in laboratory activities is positively associated with higher levels of student motivation and perceived learning effectiveness, with statistically significant differences across subjects. Chemistry demonstrates the strongest perceived benefits when laboratory conditions are adequate, whereas limitations in equipment and infrastructure constrain effective implementation in Physics and Biology. Overall, the results underline the pedagogical value of practical laboratory work while highlighting structural inequalities in access to laboratory resources. The study offers evidence-based recommendations for curriculum implementation, teacher professional development, and institutional investment to support more equitable laboratory-based science education in lower secondary schools.

KEYWORDS
lower secondary education, natural sciences, practical laboratory work, stimulate, student motivation

Introduction

The implementation of practical laboratory work in lower secondary schools constitutes a fundamental component of effective science education. As an integral part of the teaching process, laboratory-based instruction enables students to actively engage with scientific concepts and phenomena, fostering conceptual understanding, inquiry skills, and early scientific literacy. Through hands-on experimentation, learners are provided with opportunities to connect theoretical knowledge with observable phenomena, an approach widely recognized as central to meaningful learning in natural sciences.

A substantial body of research highlights both the pedagogical value and the challenges associated with laboratory work in lower secondary education. Empirical studies consistently demonstrate that well-designed laboratory activities can enhance students' motivation and interest in science, while also supporting the development of problem-solving abilities and critical thinking skills (Aldhahi et al., 2022; Beyessa, 2014; Douglas et al., 2017; Oliveira and Bonito, 2023). At the same time, the effectiveness of laboratory-based instruction is closely dependent on contextual factors such as the availability of appropriate equipment, institutional support, and teachers' professional preparation (Pejchinovska and Kamchevska, 2015).

In the context of the Republic of Kosovo, one of the principal challenges affecting the implementation of practical laboratory work relates to limited access to modern laboratory equipment and essential technical resources. Additionally, effective laboratory instruction requires teachers to possess not only subject-matter knowledge but also pedagogical competence, planning skills, and an understanding of safety procedures. Without adequate professional preparation and institutional support, laboratory activities risk being reduced to superficial demonstrations rather than student-centered experimental learning experiences.

Practical laboratory work plays a central role in the teaching of core natural science subjects, including Biology, Chemistry, and Physics, and is formally emphasized in many national science curricula. However, ongoing debates in literature question the educational impact of laboratory work when it is insufficiently supported or poorly integrated into classroom practice. While extensive research on laboratory-based science education has been conducted in contexts such as England and North America (Abrahams and Millar, 2008; Cullinane et al., 2019; Earle and Bianchi, 2023), empirical evidence from other educational settings remains more limited. Even in high-performing systems such as Finland, research focusing specifically on the systematic implementation of laboratory work at the lower secondary level is still developing (Jokiranta, 2014). These variations across contexts highlight the importance of context-sensitive research that considers structural and institutional conditions.

From a pedagogical perspective, a key responsibility of teachers is to support students in establishing meaningful connections between scientific theory and practical experience. Achieving this requires careful consideration of how students engage with laboratory activities and how abstract concepts are mediated through experimental learning. Research suggests that only when pedagogical, psychological, and contextual factors are aligned can laboratory work meaningfully transform students' learning in science.

Against this background, the present study examines the implementation of practical laboratory work in lower secondary schools in the Republic of Kosovo. The analysis focuses on teachers' competence in conducting laboratory activities, the availability and quality of laboratory equipment, students' perceptions of learning and motivation, and the classroom environment in which laboratory work is implemented across Biology, Chemistry, and Physics.

Literature review

Practical laboratory work is widely regarded as a central component of effective science education due to its capacity to support active learning, inquiry, and the development of scientific understanding. Within natural sciences, laboratory-based instruction enables students to interact directly with physical, chemical, and biological phenomena, facilitating meaningful connections between abstract concepts and empirical observation. From a constructivist perspective, such learning environments promote active knowledge construction and deeper conceptual understanding (Jonassen, 1991; Hofstein and Lunetta, 2004).

Pedagogical value of laboratory work in science education

A substantial body of empirical research demonstrates that well-designed laboratory activities contribute to the development of essential scientific competencies. Hands-on experimentation has been shown to support critical thinking, problem-solving, collaboration, and scientific reasoning by engaging students in hypothesis formulation, experimentation, data interpretation, and reflective thinking (Cavas, 2011; Douglas et al., 2017). Through these processes, students experience science as an inquiry-driven discipline rather than a purely theoretical subject.

However, research also indicates that the educational benefits of laboratory work are not automatic. The effectiveness of practical activities depends strongly on pedagogical design and alignment with learning objectives. Abrahams and Millar (2008) emphasize that laboratory work enhances learning only when it is intentionally structured to support conceptual understanding. Similarly, Abrahams et al. (2013) highlight the importance of assessment practices that move beyond procedural skills to capture conceptual learning outcomes. These findings underscore the importance of instructional coherence and purposeful planning in laboratory-based science education.

Laboratory work and student motivation

Student motivation represents a key dimension in the literature on laboratory-based instruction. Motivation is a critical determinant of engagement, persistence, and achievement in science learning (Ryan and Deci, 2020). Empirical studies consistently show that laboratory activities can enhance intrinsic motivation by offering interactive, meaningful, and context-rich learning experiences (Hofstein and Lunetta, 2004; Cavas, 2011). When students perceive laboratory work as relevant and engaging, they are more likely to develop positive attitudes toward science and sustain long-term interest in science-related subjects.

Resource availability and teacher-related factors

Despite its pedagogical potential, the implementation of effective laboratory work remains challenging, particularly in lower secondary education. Limited access to modern laboratory facilities, outdated equipment, and insufficient instructional time are frequently reported barriers (Beyessa, 2014; Aldhahi et al., 2022). Teacher-related factors also play a decisive role. Effective laboratory instruction requires not only subject-matter knowledge but also pedagogical competence, classroom management skills, and a strong awareness of safety procedures (Endot et al., 2021). In the absence of sustained professional development and institutional support, laboratory activities risk becoming fragmented or superficial, reducing their educational impact.

Recent research further emphasizes the role of institutional resources and technological preparedness in shaping the quality of laboratory-based instruction. Access to appropriate technologies and collaborative learning environments can enhance students' engagement and support the development of creative and critical thinking skills (Fideli and Aliazas, 2022). In resource-constrained contexts, however, teachers often rely on simulations or demonstrations as substitutes for hands-on experimentation, which may limit opportunities for direct engagement with scientific materials.

International and regional perspectives

International research reveals considerable variation in how laboratory work is integrated into science curricula across educational systems. In contexts such as England and North America, laboratory-based instruction has been extensively examined, with sustained attention to pedagogical effectiveness, curriculum alignment, and assessment practices (Abrahams and Millar, 2008; Cullinane et al., 2019; Earle and Bianchi, 2023). In contrast, empirical research focusing specifically on the systematic implementation of laboratory work at the lower secondary level remains limited in other contexts, including some high-performing education systems such as Finland (Jokiranta, 2014). These differences highlight the need for context-sensitive research that accounts for institutional and structural conditions rather than assuming the universal effectiveness of laboratory-based approaches.

Context of the Republic of Kosovo and research gap

Within the Republic of Kosovo, empirical research on practical laboratory work in lower secondary science education remains scarce. National curriculum documents emphasize experimental and inquiry-based learning in natural sciences (Ministry of Education, Science, and Technology, 2017), and textbooks provide structured guidance for classroom instruction (Ajazaj et al., 2009). Nevertheless, limited evidence exists regarding how laboratory work is implemented in everyday classroom practice and how it is experienced by teachers and students across different science subjects.

Regional studies suggest that activity-based and student-centered approaches can positively influence engagement and learning when aligned with pedagogical principles and classroom realities (Pejchinovska, 2011; Pejchinovska and Kamchevska, 2016). More recent research highlights the importance of students' active participation as a foundation for meaningful learning experiences in both natural and social sciences (Pejchinovska and Kamchevska, 2015). Evidence from lower secondary education further indicates that experiment-based teaching can enhance students' understanding and performance in science subjects, particularly in chemistry (Ramadani and Pejchinovska-Stojkovikj, 2023).

Despite these contributions, there remains a lack of empirical research examining students' perceptions, teachers' practices, and resource-related constraints associated with laboratory work in lower secondary schools in Kosovo. Addressing this gap is essential for developing contextually grounded strategies that support effective, equitable, and curriculum-aligned science education. The present study responds to this need by examining the implementation of practical laboratory work across Biology, Chemistry, and Physics, with particular attention to students' motivation, perceived learning outcomes, and institutional conditions.

Alignment of practical laboratory work with curriculum standards in natural sciences in Kosovo

The Kosovo Curriculum Framework for pre-university education emphasizes competency-based learning, inquiry-oriented instruction, and the integration of theory with practice in natural science subjects (Ministry of Education, Science, and Technology, 2017). Within this framework, practical laboratory work is positioned as a key pedagogical mechanism for developing scientific literacy, problem-solving abilities, and students' active engagement in learning across Physics, Chemistry, and Biology.

In Physics, the Kosovo curriculum recommends the use of experimental activities to support students' understanding of physical laws through observation, measurement, and experimentation (Ministry of Education, Science, and Technology, 2017). However, the findings of the present study indicate that the implementation of laboratory work in Physics is often constrained by limited access to laboratory equipment and safety-related considerations. As a result, practical activities are frequently reduced to teacher-led demonstrations rather than hands-on student experimentation, which limits alignment with curriculum expectations regarding active student participation and inquiry-based learning.

The Chemistry curriculum places strong emphasis on experimental learning and structured laboratory activities that enable students to explore chemical reactions, material properties, and scientific processes through direct experimentation (Ministry

of Education, Science, and Technology, 2017). Consistent with these curricular intentions, the findings show that laboratory work in Chemistry is associated with higher levels of student motivation and perceived learning effectiveness when appropriate conditions are in place. At the same time, Chemistry emerges as the subject most affected by infrastructural and resource-related constraints, as insufficient equipment and laboratory facilities restrict the regular implementation of curriculum-prescribed experimental activities.

In Biology, the curriculum allows for greater flexibility in the organization of practical work, including observational studies, field-based activities, and the use of accessible materials to explore biological phenomena (Ministry of Education, Science, and Technology, 2017). This curricular flexibility may partly explain the more frequent inclusion of laboratory-related activities reported by teachers. Nevertheless, the findings reveal that disparities between schools persist, suggesting that the depth and quality of practical work in Biology remain dependent on institutional resources and teacher preparedness rather than curriculum design alone.

Overall, the results point to a partial misalignment between curriculum standards and classroom practice in the teaching of natural sciences in Kosovo. While the national curriculum consistently promotes practical laboratory work as a central component of science education, its implementation is shaped primarily by systemic factors such as school infrastructure, availability of laboratory equipment, and institutional support. These findings suggest that deviations from curriculum expectations are not pedagogical in nature but structural, underscoring the need for targeted policy measures and investment to ensure that curriculum objectives related to practical laboratory work are realized consistently and equitably across Physics, Chemistry, and Biology.

Methodology

Research design

The study adopted a quantitative research design to examine the implementation of practical laboratory work in natural science subjects and its perceived role in enhancing students' interest and motivation in lower secondary education in the Republic of Kosovo. A survey-based approach was employed to capture the perceptions of science teachers and students regarding laboratory practices, instructional conditions, and learning experiences in Biology, Chemistry, and Physics.

Instrumentation and data collection

Data were collected using two structured questionnaires, one administered to science teachers and one to students. The instruments were developed based on prior empirical research on laboratory-based learning and student motivation and were aligned with the objectives of the study. The science teacher questionnaire addressed four main dimensions: (1) frequency of integrating laboratory work in instruction, (2) availability and quality of laboratory equipment, (3) the relationship between laboratory resources and instructional practices, and (4) perceptions of the impact of practical work on student motivation and learning.

The student questionnaire focused on learners' perceptions of the influence of laboratory activities on learning effectiveness, academic achievement, and motivation in natural science subjects. Both questionnaires consisted exclusively of closed-ended items to facilitate quantitative analysis. Content validity was ensured through expert review by specialists in science education, and minor revisions were made following feedback. The questionnaires were administered in paper format during regular school hours. Participation was voluntary, anonymity was guaranteed, and ethical standards for educational research were observed.

TABLE 1 Distribution of survey participants: schools, teachers, and students by gender.

Participant group	Total	Female (f)	Male (m)
Schools	24	–	–
Teachers	168	99	69
Students	183	107	76

f, female; m, male. Schools refer to public lower secondary schools participating in the survey.

Sampling procedure and participants

A non-random, school-based sampling approach was employed due to institutional access constraints. The study included 24 public lower secondary schools from different regions of the Republic of Kosovo, allowing for variation in school infrastructure and access to laboratory resources. Although the sampling strategy does not support statistical generalization, it provides contextually relevant insights into laboratory-based science teaching practices.

The final sample comprised 168 science teachers and 183 seventh-grade students. Science teachers represented the subject areas of Physics, Chemistry, and Biology, and their professional experience ranged from early-career to highly experienced practitioners, enabling comparative analysis across different stages of professional development.

Student participants were enrolled in the seventh grade and were typically between 12 and 13 years of age, consistent with the national education system. All students attended public lower secondary schools and followed the national curriculum for natural sciences. Schools from urban and semi-urban areas were included, allowing consideration of contextual differences related to institutional resources (Table 1).

Data analysis

Data were analyzed using IBM SPSS software. Descriptive statistics were used to summarize frequencies and percentages related to the implementation of practical laboratory work, availability of laboratory resources, and students' perceptions of motivation and learning.

To examine relationships between categorical variables, chi-square goodness-of-fit tests were conducted, including associations between science teachers' work experience, laboratory equipment availability, and students' reported motivation and perceived learning effectiveness. The level of statistical significance was set at $p < 0.05$. Given the categorical nature of the data and the use of closed-ended questionnaire items, chi-square analysis was considered the most appropriate inferential technique for addressing the research questions.

Alignment of practical laboratory work with curriculum standards in natural sciences

To better contextualize the findings of this study, it is necessary to examine the extent to which the reported implementation of practical laboratory work aligns with the national curriculum standards for Physics, Chemistry, and Biology in lower secondary education in the Republic of Kosovo. The official curriculum framework emphasizes experimental learning and recommends regular laboratory-based activities to support conceptual understanding, scientific reasoning, and inquiry-based learning. However, the findings of this study indicate that the actual frequency and quality of laboratory work carried out in schools may vary from the intended curricular standards. While the curriculum prescribes structured practical activities across all three subjects, the reported implementation appears to be influenced by factors such as availability of laboratory equipment, school infrastructure, and teacher preparedness. This discrepancy suggests that deviations from curricular expectations are not pedagogical in nature but rather systemic, reflecting material and organizational constraints within schools. Differences observed across Physics, Chemistry, and Biology further highlight that the realization of laboratory-based instruction depends on subject-specific requirements and resource intensity. Consequently, the alignment between curriculum standards and classroom practice remains uneven, underscoring the need for targeted institutional support to ensure consistent implementation of practical laboratory work across all natural science subjects.

Findings

This section presents the findings of the study on the role of practical laboratory work in enhancing students' interest, motivation, and perceived learning effectiveness in natural science subjects in lower secondary schools in the Republic of Kosovo. The results are organized around teachers' instructional practices, availability of laboratory resources, and students' perceptions across Biology, Chemistry, and Physics.

Frequency of laboratory work integration by science teachers

Teachers' reported frequency of integrating practical laboratory work into teaching is summarized in Table 2. Overall, the results indicate that practical laboratory work is most commonly included either regularly and systematically or occasionally, regardless of teachers' work experience.

TABLE 2 Frequency of laboratory work integration in lessons by teachers.

Work experience	Frequency % (a)	(b)	(c)	(d)	Total
Obtained frequency					
Up to 10 years	10 (5.9)	7 (4.1)	5 (2.9)	5 (2.9)	27 (16)
From 10 to 20 years	19 (11.3)	11 (6.5)	7 (4.1)	6 (3.5)	43 (25.5)
From 20 to 30 years	21 (12.5)	19 (11.3)	12 (7.1)	10 (5.9)	62 (36.9)
Over 30	7 (4.1)	18 (10.7)	6 (3.5)	5 (2.9)	36 (21.4)
Total	57 (33.9)	55 (32.7)	30 (17.8)	26 (15.4)	168 (100)
Expected frequency					
Up to 10 years	9.16	8.84	4.82	4.18	27
From 10 to 20 years	14.59	14.08	7.68	6.65	43
From 20 to 30 years	21.04	20.30	11.07	9.60	62
Over 30	12.21	11.79	6.43	5.57	36
Total	57	55	30	26	168

(a) Practical laboratory work is included regularly and systematically in teaching.
(b) Practical laboratory work is included occasionally.
(c) Practical laboratory work is rarely included.
(d) Practical laboratory work is not included at all.

TABLE 3 Chi-square goodness-of-fit test results.

Statistic	Value
Degrees of freedom (df)	9
Chi-square value (χ^2)	8.53
p-value	0.48212
Critical value χ^2 (0.05)	16.92
Critical value χ^2 (0.01)	21.67

χ^2 = chi-square test statistic.

Across all experience groups, the highest frequencies were observed for categories (a) (regular and systematic inclusion) and (b) (occasional inclusion). Teachers with 20–30 years of work experience constituted the largest group (36.9%) and reported the highest levels of regular and occasional laboratory work integration. Teachers with more than 30 years of experience also predominantly reported regular or occasional inclusion, while less frequent or absent laboratory work was reported by a smaller proportion of respondents.

To examine whether the frequency of laboratory work integration differs according to teachers' work experience, a chi-square goodness-of-fit test was conducted (Table 3). The results indicate that the observed chi-square value ($\chi^2 = 8.53$) is lower

than the critical values at both the 0.05 and 0.01 significance levels, and the p-value ($p = 0.482$) exceeds the conventional threshold of statistical significance. This finding suggests that the frequency with which science teachers include practical laboratory work in their lessons does not depend significantly on their work experience. Consequently, the hypothesis that laboratory work implementation is independent of teachers' years of service is supported.

Availability of laboratory equipment in schools

Teachers' perceptions of the availability of laboratory equipment for teaching natural science subjects are presented in Table 4. The findings reveal considerable variation in reported levels of school laboratory resources.

Approximately one quarter of teachers (25.5%) reported that their schools are well-equipped with modern laboratory equipment, indicating favorable conditions for conducting practical activities. The largest proportion of respondents (34.5%) described the available equipment as average, noting that while some resources are present, they do not fully meet instructional needs. A further 23.8% of teachers indicated that their schools lack adequate laboratory equipment, and 16% reported the complete absence of laboratory facilities. These responses highlight persistent structural challenges that may restrict the effective implementation of laboratory-based instruction in natural sciences.

The chi-square test examining differences in teachers' perceptions of laboratory equipment availability across experience groups is reported in Table 5. The results show no statistically significant differences ($\chi^2 = 4.31$, $p = 0.890$), indicating that perceptions of equipment availability are broadly shared among science teachers, regardless of their professional experience.

TABLE 4 Teachers' opinion about the school's equipment with laboratory equipment for the subject of natural sciences they teach.

Work experience	Frequency % (a)	(b)	(c)	(d)	Total
Obtained frequency					
Up to 10 years	7 (4.1)	6 (3.5)	8 (4.7)	6 (3.5)	27 (16)
From 10 to 20 years	9 (5.3)	17 (10.1)	10 (5.9)	7 (4.1)	43 (25.5)
From 20 to 30 years	19 (11.3)	21 (12.5)	13 (7.7)	9 (5.3)	62 (36.9)
Over 30	8 (4.7)	14 (8.3)	9 (5.3)	5 (2.9)	36 (21.4)
Total	43 (25.5)	58 (34.5)	40 (23.8)	27 (16)	168 (100)
Expected frequency					
Up to 10 years	6.91	9.32	6.43	4.34	27
From 10 to 20 years	11.01	14.85	10.24	6.91	43
From 20 to 30 years	15.87	21.40	14.76	9.96	62
Over 30	9.21	12.43	8.57	5.79	36
Total	43	58	40	27	168

(a) Practical laboratory work is included regularly and systematically in teaching.
(b) Practical laboratory work is included occasionally.
(c) Practical laboratory work is rarely included.
(d) Practical laboratory work is not included at all.

TABLE 5 Chi-square goodness-of-fit test results.

Statistic	Value
Degrees of freedom (df)	9
Chi-square value (χ^2)	4.31
p-value	0.89020
Critical value χ^2 (0.05)	16.92
Critical value χ^2 (0.01)	21.67

χ^2 = chi-square test statistic.

Relationship between laboratory equipment and the integration of practical work

Table 6 presents teachers' views on how the availability and quality of laboratory equipment influence the integration of practical laboratory work into teaching. The results suggest that laboratory equipment plays a central role in shaping instructional practices. A substantial proportion of teachers indicated that laboratory work can be effectively integrated through carefully selected, curriculum-aligned experiments, particularly when adequate resources are available. At the same time, a notable group of respondents reported that laboratory work is included only occasionally or irregularly due to limited or inadequate equipment. These findings point to the dependence of instructional practices on institutional resources.

The statistical significance of this relationship was confirmed through a chi-square test (Table 7). The obtained chi-square value ($\chi^2 = 22.00$) exceeds the critical values at both the 0.05 and 0.01 significance levels, with a corresponding p-value below 0.01. This result indicates a statistically significant association between teachers' perceptions of school equipment and the extent to which practical laboratory work is integrated into science teaching. The findings emphasize the importance of adequate laboratory resources for meaningful implementation of practical activities.

Teachers' perceptions of the impact of laboratory work on student motivation

Teachers' perceptions regarding the impact of laboratory activities on students' motivation and learning across subjects are presented in Table 8. The majority of responses indicate that participation in laboratory activities significantly or partially enhances students' motivation and learning.

Differences across subjects are evident, with Chemistry showing the highest proportion of responses indicating strong motivational benefits, followed by Physics and Biology.

TABLE 6 Teachers' opinion about the dependence of the inclusion of practical laboratory work on the equipment and quality of the laboratory equipment and natural science resources of lower secondary schools in the Republic of Kosovo.

Which of the following answers best describes your opinion about the school's equipment with laboratory equipment for the natural sciences subject you teach:	Practical laboratory work can be integrated into the teaching process through: (a)	(b)	(c)	(d)	Total
Obtained frequency					
(a)	16 (9.5)	11 (6.5)	9 (5.3)	7 (4.1)	43 (25.5)
(b)	9 (5.3)	12 (7.1)	28 (16.6)	9 (5.3)	58 (34.5)
(c)	10 (5.9)	7 (4.1)	8 (4.7)	15 (8.9)	40 (23.8)
(d)	8 (4.7)	6 (3.5)	5 (2.9)	8 (4.7)	27 (16)
Total	43 (25.5)	36 (21.4)	50 (29.7)	39 (23.2)	168 (100)
Expected frequency					
(a)	11.01	9.21	12.80	9.98	43
(b)	14.85	12.43	17.26	13.46	58
(c)	10.24	8.57	11.90	9.29	40
(d)	6.90	5.80	8.10	6.20	27
Total	42.00	36.01	50.06	38.93	168

(a) Laboratory work is integrated through carefully selected curriculum-aligned experiments.
(b) Laboratory work is integrated occasionally depending on available resources.
(c) Laboratory work is integrated in a limited and irregular manner.
(d) Laboratory work is rarely or not integrated due to lack of equipment.

TABLE 7 Chi-square goodness-of-fit test results.

Statistic	Value
Degrees of freedom (df)	9
Chi-square value (χ^2)	22.00
p-value	0.00887
Critical value χ^2 (0.05)	16.92
Critical value χ^2 (0.01)	21.67

χ^2 = chi-square test statistic.

Only a relatively small proportion of responses suggest that laboratory activities do not substantially affect motivation and learning.

The chi-square test results (Table 9) reveal statistically significant differences in teachers' perceptions ($\chi^2 = 20.88$, $p < 0.001$), indicating that the perceived motivational impact of laboratory work varies across subjects. These findings support the hypothesis that the influence of practical laboratory activities on student motivation is subject-dependent. Chi-square test results related to teachers' perceptions are shown in Table 9.

Students' perceptions of learning effectiveness across subjects

Students' perceptions of how laboratory activities contribute to effective learning and achievement are summarized in Table 10. Overall, students reported positive evaluations of laboratory-based learning, with the highest levels of perceived effectiveness observed in Chemistry and Biology. In Physics, a larger proportion of students indicated partial or limited learning benefits, which may reflect differences in instructional approaches or resource availability across subjects. Nonetheless, across all three disciplines, the majority of students perceived laboratory activities as contributing positively to their learning.

TABLE 8 To what extent does students' participation in laboratory activities increase learning motivation and improve achievement in science subjects?

Subject	Frequency % (a)	(b)	(c)	Total
Obtained frequency				
Chemistry	49 (8.9)	79 (14.3)	55 (10)	183 (33.3)
Physics	64 (11.6)	72 (13.1)	47 (8.5)	183 (33.3)
Biology	82 (14.9)	43 (7.8)	58 (10.5)	183 (33.3)
Total	195 (35.5)	194 (35.3)	160 (29.1)	549 (100)
Expected frequency				
Chemistry	65.00	64.67	53.33	183
Physics	65.00	64.67	53.33	183
Biology	65.00	64.67	53.33	183
Total	195	194	160	549

(a) Participation in laboratory activities significantly increases motivation and learning.
(b) Participation partially increases motivation and learning.
(c) Participation does not significantly affect motivation and learning.

TABLE 9 Chi-square goodness-of-fit test results.

Statistic	Value
Degrees of freedom (df)	4
Chi-square value (χ^2)	20.88
p-value	0.00033
Critical value χ^2 (0.05)	9.49
Critical value χ^2 (0.01)	13.28

χ^2 = chi-square test statistic.

TABLE 10 Students' opinion about how much their participation in laboratory activities enables more effective learning and achievement in natural science subjects.

Subject	Frequency %			Total
	(a)	(b)	(c)	
Obtained frequency				
Chemistry	68 (12.3)	79 (14.3)	36 (6.5)	183 (33.3)
Physics	49 (8.9)	62 (11.2)	72 (13.1)	183 (33.3)
Biology	69 (12.5)	58 (10.5)	56 (10.2)	183 (33.3)
Total	186 (33.8)	199 (36.2)	164 (29.8)	549 (100)
Expected frequency				
Chemistry	62.00	66.33	54.67	183
Physics	62.00	66.33	54.67	183
Biology	62.00	66.33	54.67	183
Total	186	199	164	549

(a) Participation in laboratory activities significantly increases motivation and learning.
(b) Participation partially increases motivation and learning.
(c) Participation does not significantly affect motivation and learning.

TABLE 11 Chi-square goodness-of-fit test results.

Statistic	Value
Degrees of freedom (df)	4
Chi-square value (χ^2)	23.84
p-value	0.00056
Critical value χ^2 (0.05)	9.49
Critical value χ^2 (0.01)	13.28

χ^2 = chi-square test statistic.

The chi-square analysis reported in Table 11 confirms statistically significant differences in students' perceptions across subjects ($\chi^2 = 23.84$, $p < 0.001$). These results demonstrate that the effectiveness of laboratory work, as perceived by students, varies by subject and is closely linked to the quality of laboratory equipment and resources.

Taken together, the findings indicate that practical laboratory work has a significant and positive impact on students' motivation and perceived learning effectiveness in natural sciences. At the same time, the results highlight the mediating role of institutional resources, suggesting that the educational benefits of laboratory work are contingent upon adequate equipment, infrastructure, and instructional conditions.

Discussions and conclusions

This study examined the role of practical laboratory work in enhancing students' interest, motivation, and perceived learning effectiveness in natural science subjects in lower secondary schools in the Republic of Kosovo. The findings provide empirical support for the pedagogical value of laboratory-based instruction, while also revealing structural and institutional constraints that shape its implementation in everyday school practice.

Overall, the results align with established research in educational psychology and science education, which identifies student interest and motivation as critical determinants of learning engagement and academic success (Beyessa, 2014; Pejchinovska and Kamchevska, 2016; Chuter, 2020; Aldhahi et al., 2022). Consistent with these perspectives, both teachers and students in the present study reported that participation in laboratory activities contributes positively to motivation and learning in Biology, Chemistry, and Physics. These findings reinforce the view that practical laboratory work functions not merely as a supplementary instructional strategy, but as a central pedagogical mechanism for fostering meaningful engagement with scientific content.

The results further demonstrate that the effectiveness of laboratory work is not uniform across subjects. Chemistry emerged as the subject in which laboratory activities are most strongly associated with increased student motivation and perceived learning effectiveness, particularly when adequate equipment and resources are available. In contrast, Physics and Biology showed more constrained implementation, reflecting differences in infrastructural requirements and safety considerations. These subject-specific differences are consistent with prior research indicating that the educational impact of laboratory work depends on the nature of the discipline and the material conditions under which experimentation is conducted (Hofstein and Lunetta, 2004; Cavas, 2011).

A central contribution of this study lies in highlighting the decisive role of institutional resources. The findings indicate a statistically significant relationship between the availability and quality of laboratory equipment and the extent to which practical laboratory work is integrated into teaching. Teachers' attitudes toward laboratory work were closely linked to material conditions, suggesting that pedagogical intentions alone are insufficient in the absence of adequate infrastructure. This finding supports existing literature emphasizing that limitations in equipment, facilities, and institutional support can undermine even well-designed curricular objectives (Aldhahi et al., 2022; Pejchinovska and Kamchevska, 2015).

Importantly, the results suggest that observed discrepancies between curriculum expectations and classroom practice are not pedagogical in nature but structural. While the national curriculum in Kosovo explicitly promotes inquiry-based and experimental learning in natural sciences, the realization of these goals is uneven and contingent upon school-level resources and administrative support. This partial misalignment underscores the need for targeted educational policy measures aimed at ensuring minimum laboratory standards across schools.

From an educational equity perspective, the findings reveal that unequal access to laboratory facilities may contribute to disparities in students' learning experiences and opportunities.

Students attending schools with limited laboratory resources are less likely to benefit from experiential learning approaches that support motivation, scientific reasoning, and conceptual understanding. These inequities challenge the principles of inclusive and high-quality education and directly relate to broader global priorities such as Sustainable Development Goal 4 (Quality Education), which emphasizes equitable access to effective learning environments.

In conclusion, the study provides empirical evidence that practical laboratory work plays a significant role in enhancing students' motivation and perceived learning effectiveness in natural sciences in lower secondary education. However, its educational potential is highly dependent on systemic conditions, including resource availability, institutional support, and teacher preparedness. The findings suggest that improving laboratory infrastructure, investing in teacher professional development, and aligning curricular intentions with material conditions are essential steps toward strengthening science education in Kosovo.

Future research should extend this work by employing mixed-methods designs that incorporate classroom observations and interviews to gain deeper insight into pedagogical practices and student experiences. Further investigation into the role of laboratory work in developing higher-order skills, such as critical thinking and scientific reasoning, would also contribute to a more comprehensive understanding of laboratory-based learning in lower secondary education.

Practical laboratory work, SDG 4 (quality education), and educational equity

Equality in education constitutes a fundamental principle of contemporary educational policy and practice. The results of this study suggest that unequal access to laboratory facilities and practical learning opportunities may create significant disparities in students' educational experiences. Students attending schools with limited or no laboratory resources are less likely to benefit from experiential learning approaches that foster motivation, scientific thinking, and conceptual understanding. These inequalities are not attributable to students' abilities or teachers' pedagogical intentions but rather to systemic differences in school infrastructure and resource allocation. As a result, students are provided with unequal conditions for developing scientific competencies, which may influence both academic achievement and long-term interest in science-related fields. Addressing these disparities requires policy-level interventions aimed at ensuring minimum laboratory standards across schools, thereby promoting equal learning opportunities and supporting inclusive quality education.

Limitations

Despite the strengths of the quantitative design and the inclusion of both teachers and students, this study has several limitations. First, the exclusive reliance on closed-ended questionnaires limits the depth of insight into classroom practices and students' lived learning experiences. As a result, the findings reflect participants' perceptions rather than direct observations of instructional quality.

Second, the use of a non-random, school-based sample restricts the generalisability of the results beyond the participating schools. Although regional variation was considered, the findings should be interpreted within the specific institutional and contextual conditions of lower secondary education in Kosovo.

Finally, the absence of qualitative methods, such as classroom observations or interviews, limits the exploration of how laboratory activities are pedagogically implemented and experienced in practice. Future research could adopt mixed-methods designs to triangulate quantitative findings and provide a more nuanced understanding of laboratory-based learning in science education.

Recommendations

In order to address this issue, it is suggested to introduce strategies and programs for training teachers for the successful application of practical laboratory work in the teaching process. This could be done if there is the right preparation of curricula and models for the inclusion of practical laboratory work in all subjects in the field of natural sciences. Furthermore, investing in quality laboratory equipment and resources is necessary to ensure the reliable and efficient performance of laboratory activities. Moreover, based on the evidence presented, it is recommended that schools should support the exchange of experiences between teachers and the creation of forums and workshops for sharing successful examples from practice in the introduction of practical laboratory work. Also, it is advisable to prepare special programs and activities for students that aim to encourage them to actively participate in laboratory work and increase their interest. In addition, the research indicates that it may be beneficial to support students to participate in project activities and research that include practical laboratory work, in order to raise their level of engagement and motivation. Besides, preparation of resources and teaching materials that will support teachers and students in the realization of successful laboratory activities should be conducted. It is also suggested to build mechanisms for precise analysis and evaluation of the effectiveness of laboratory work, including student outcomes and their understanding of concepts. The creation of interactive and pedagogically oriented laboratory spaces is recommended to improve the educational atmosphere and support more effective laboratory learning experiences.

Additionally, schools should have continuous support for developing and including creative methods and technology in laboratory work, which will contribute to increasing the interest of students. As a final point, further investigation is recommended to be done in the preparation of specific programs for mentoring students who show interest and talent for the natural sciences in order to stimulate their personal and scientific ambitions. Beyond

teachers and schools, families and local communities play an important role in fostering students' interest in science by supporting learning outside the classroom. Moreover, school administrators are key actors in resource allocation, infrastructure development, and institutional support for laboratory-based instruction.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The approval was obtained by the Municipal Directorate of Education in Pristina, as part of a series of research projects. Accordingly, the informed consent forms were provided to the school principals, who then distributed them to parents and teachers for their approvals and signatures.

Author contributions

FR: Methodology, Writing – original draft, Writing – review & editing, Conceptualization, Supervision. BÇ: Methodology, Writing – original draft, Writing – review & editing, Project administration, Validation. BI: Data curation, Investigation, Resources, Writing – review & editing. MP-S: Methodology, Supervision, Validation, Writing – review & editing.

Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

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