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The Impact of Interactive Biology Teaching on Learning Outcomes in Primary Schools: A Mixed-Methods Study

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Abstract

This study examines the impact of interactive teaching methods in biology on students' learning outcomes in primary schools in Bosnia and Herzegovina. Drawing on constructivist, socio-cognitive, and self-determination theories, the research explores how interactive approaches—such as group work, laboratory exercises, and educational games—affect student engagement, motivation, classroom atmosphere, and satisfaction with academic achievement.

A mixed-methods design was employed, combining quantitative data from a structured questionnaire (N = 102 students, grades 6 and 8) with qualitative insights from open-ended responses. Statistical analyses (chi-square, Pearson correlations, regression, and ANOVA) revealed that interactive methods significantly enhance both cognitive and social skills. Group work showed a strong correlation with the development of social competences ($r = 0.866$, $p < 0.01$), while laboratory exercises were the strongest predictor of a positive classroom atmosphere ($\beta = 0.390$, $p < 0.01$). Students who preferred interactive teaching reported higher levels of

engagement, deeper understanding of content, and greater satisfaction with their grades compared to those exposed primarily to traditional methods.
Qualitative findings further highlighted that students perceive interactive lessons as more enjoyable, motivating, and conducive to collaboration, although challenges such as limited resources and insufficient time were noted.
The study confirms all four hypotheses: (1) student engagement is significantly related to the preferred teaching model; (2) interactive teaching positively influences cognitive and social skills; (3) higher engagement is associated with a more positive classroom atmosphere; and (4) students who prefer interactive teaching report greater satisfaction with their learning outcomes. These findings align with international research on active learning in STEM education and underscore the need for systemic support in Bosnia and Herzegovina, including teacher training and investment in laboratory and digital resources. The study concludes that interactive teaching is not merely a pedagogical innovation but a necessity for preparing students for the demands of the 21st century.

Keywords: *interactive teaching, biology education, student engagement, learning outcomes, motivation, Bosnia and Herzegovina.*

1. Introduction

In recent decades, educational systems worldwide have undergone intensive reforms aimed at improving the quality of teaching and learning. Traditional models, based on frontal lecturing and the reproduction of facts, are increasingly being questioned due to their limited capacity to foster students' critical thinking, creativity, and social skills (Biggs & Tang, 2011). In this context, interactive teaching has emerged as a key pedagogical paradigm that places the student at the center of the educational process, emphasizing active participation, collaboration, and experiential learning (Bonwell & Eison, 1991).

Biology, as a natural science, provides particularly fertile ground for the application of interactive methods. Its very nature involves the exploration of living systems, experimentation, and the integration of theoretical knowledge with practical experiences. However, in many educational contexts, including Bosnia and Herzegovina, biology teaching still predominantly relies on traditional methods such as lecturing and oral examinations, which often result in passive learning and reduced student motivation (Hattie, 2009). This misses the opportunity to engage students at higher cognitive levels, fostering skills of analysis, synthesis, and evaluation that are essential for the modern knowledge society.

Interactive teaching, by contrast, entails the use of methods that actively involve students in the learning process. These include group work, laboratory exercises, educational games, discussions, simulations, and the use of digital technologies. Numerous studies show that

such approaches not only improve academic outcomes but also develop students' social and emotional competences (Prince, 2004; Freeman et al., 2014). Students who participate in interactive activities demonstrate higher levels of motivation, better understanding of the subject matter, and greater readiness to collaborate with peers (Deci & Ryan, 2000).

In the context of Bosnia and Herzegovina, where the educational system is undergoing transition and facing numerous challenges—including a lack of resources, overloaded curricula, and limited opportunities for teachers' professional development—research on the effectiveness of interactive teaching is of particular importance. The introduction and evaluation of these methods can contribute not only to improving the quality of biology teaching but also to the broader development of the educational system toward inclusivity, innovation, and alignment with contemporary pedagogical trends.

The aim of this study is to examine the impact of the interactive model of biology teaching on the educational outcomes of primary school students. Special attention is given to student engagement, the development of cognitive and social skills, perceptions of classroom atmosphere, and students' satisfaction with their own educational achievements. The research was conducted on a sample of sixth- and eighth-grade primary school students in Sarajevo, using a combination of quantitative and qualitative methods. Based on the research objectives, the following hypotheses were formulated:

H1: It is hypothesized that there is a significant relationship between students' level of engagement and their preferred model of instruction.

H2: It is hypothesized that interactive teaching has a positive effect on the development of students' cognitive and social skills.

H3: It is hypothesized that higher levels of student engagement are associated with a more positive perception of the classroom atmosphere.

H4: It is hypothesized that students who prefer interactive teaching report greater satisfaction with their own educational achievements.

These hypotheses serve as the starting point for empirical analysis and enable a systematic examination of the relationship between teaching methods and educational outcomes. Their verification contributes not only to the theoretical understanding of interactive teaching but also to practical implications for improving teaching practices in primary schools. In this way, the study contributes to the academic debate on interactive teaching while also offering practical implications for teachers, schools, and educational institutions. At a time when education is expected to prepare students for the complex challenges of the 21st century, interactive teaching emerges as a necessary and indispensable approach that can ensure a more meaningful and higher-quality educational experience.

2. Participants, Materials, and Methods

The study was conducted at the primary school "Grbavica II" in Sarajevo during the 2024/2025 school year. The sample included a total of 102 students, divided into two age groups:

Sixth grade: 52 students (26 girls and 26 boys)

Eighth grade: 50 students (24 girls and 26 boys)

The sample was selected using a convenience sampling method, in cooperation with biology teachers and the school administration. All participants voluntarily took part in the study, with prior parental/guardian consent and school approval. Demographic data (gender, age, academic achievement) were collected for additional analysis but were not used for individual identification of students. This ensured anonymity and ethical protection of participants.

For the purposes of the study, a structured questionnaire was developed based on relevant literature and previous research on interactive teaching (Prince, 2004; Freeman et al., 2014). The questionnaire consisted of three sections:

General information: gender, grade, average grade in biology.

Preferences for teaching methods: questions on the frequency and perception of different methods (lectures, PowerPoint presentations, group work, laboratory exercises, educational games, discussions, fieldwork, digital applications).

Perception of classroom atmosphere and satisfaction: a 5-point Likert scale assessing engagement, motivation, understanding of subject matter, and satisfaction with grades.

The questionnaire was piloted on a smaller group of students (N = 15) to test clarity and reliability. The obtained Cronbach's $\alpha = 0.82$ indicated satisfactory internal consistency of the instrument.

The study employed a quantitative–qualitative design. Quantitative analysis included descriptive statistics (frequencies, percentages, means), chi-square tests to examine associations between variables, Pearson's correlation to assess the relationship between student engagement and perception of classroom atmosphere, and regression analysis to identify predictors of student satisfaction. Qualitative analysis involved processing open-ended questions in the questionnaire, which allowed students to express their views on the advantages and disadvantages of interactive teaching. Responses were analyzed using thematic analysis, through which key categories were identified (e.g., motivation, collaboration, understanding of subject matter).

The research was conducted during regular biology classes. Students completed the questionnaire anonymously, in paper form, under the supervision of the researcher and the teacher. The average completion time was 20 minutes. After data collection, statistical

analysis was performed using SPSS 25.0. Qualitative responses were coded and analyzed manually, applying triangulation principles to increase reliability. The study was carried out in accordance with ethical principles of educational research. Students and parents were informed about the aims and procedures of the study, and participation was voluntary. Anonymity and confidentiality of data were fully ensured.

3. Results

The analysis of the frequency of applying different forms of interactive teaching in biology classes revealed significant differences in the use of individual methods, indicating specific educational practices and possible limitations in their implementation (Fig. 1).

Fieldwork was conducted only once, according to all 102 students. This uniformity points to a very limited application of field activities, despite their potential for developing research skills and linking theory with practice. Possible reasons for such low frequency include logistical, time-related, and organizational constraints. Laboratory exercises showed greater representation: 62 students (eighth grade) participated in two sessions, while 40 students (sixth grade) took part in one laboratory activity. These data confirm that laboratory work plays an important role in interactive biology teaching, particularly in higher grades, where greater independence and experimental work are expected.

The use of mobile applications was not reported by any student, indicating a complete absence of this form of digital interaction. This result may be due to a lack of technical equipment, insufficient digital competence among teachers, or the unavailability of suitable applications aligned with teaching objectives. Educational games were present in teaching but with varying intensity: 71 students reported one session, 21 students two sessions, and 10 students three or more. Although used occasionally, this method was still present in a large portion of teaching, highlighting its potential for motivation and active learning.

PowerPoint presentations were the most frequently used form of interactive teaching, with 68 students reporting three or more sessions and 34 students two sessions. This dominance suggests a broad acceptance of digital presentation approaches, likely due to their accessibility, simplicity, and ability to visually represent content. Video materials were rarely used: only 6 students reported two sessions, 13 students one session, while 83 had no exposure to this method. Such low frequency may indicate technical limitations or insufficient integration of multimedia resources into the teaching process.

Group work was reported by most students, but mainly sporadically: 76 students had one session, and 26 had two sessions. Although this is an active method that fosters collaboration and communication, its irregular application suggests the need for more systematic inclusion in the curriculum. Project-based teaching showed moderate presence: 15 students participated three or more times, 12 twice, 31 once, while 44 students had no

experience with this method. These data indicate selective application of project tasks, likely conditioned by time constraints and teachers' readiness to lead more complex activities.

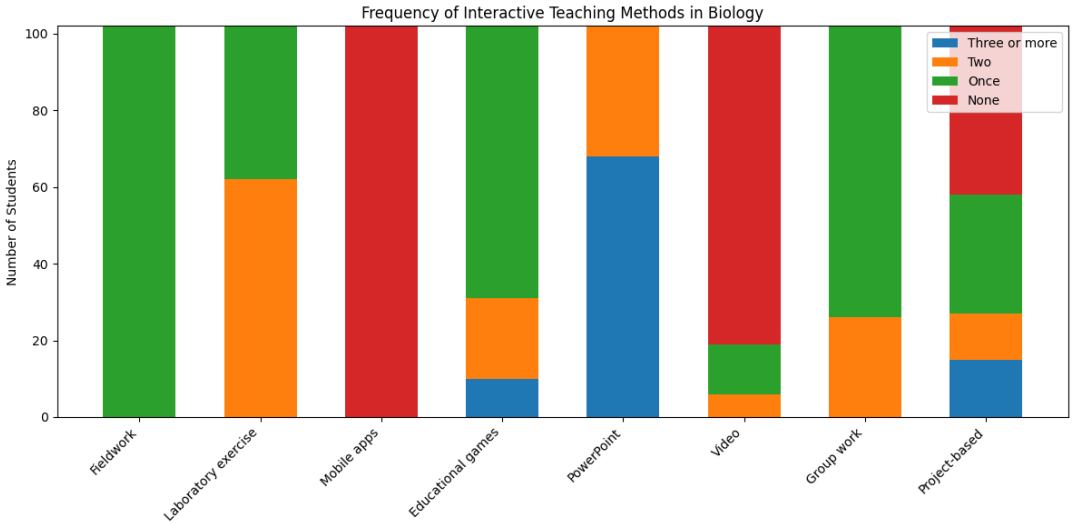

Figure 1. Graphical presentation of Frequency of Interactive Teaching Methods in Biology

These findings indicate a partial implementation of interactive approaches in teaching practice. Although students are aware of the advantages of various forms of active learning, their actual exposure to certain methods—particularly digital and field-based ones—remains limited. This confirms the need for more systematic integration of modern interactive methods into the teaching process.

The analysis of students' attitudes toward increasing interactive activities in biology classes showed strong support for this approach, with nuanced views on its application. In response to the question "Should teachers increase the number of interactive activities in biology classes to better engage students?", the majority (92 out of 102) expressed a positive opinion. Of these, 54 students believed the increase should be comprehensive, while 38 supported a selective increase depending on the teaching content. These results indicate a high level of student awareness regarding teaching methods and their impact on engagement and understanding. Moderate support for selective application (38 students) further emphasizes the need for pedagogical balance. Students recognize that interactive methods are not universally applicable, reflecting maturity in their thinking about the teaching process and highlighting the importance of teachers' professional judgment in method selection.

The reliability of the measurement instruments was confirmed by Cronbach's alpha results. The scale measuring student engagement across different models of interactive teaching (fieldwork, laboratory exercises, projects, group work, educational games, and teacher–

student interaction) showed high reliability, with α = 0.811. The scale assessing cognitive-social learning outcomes, including dimensions of social and creative skills, memory, and understanding of biological concepts, also demonstrated high reliability (α = 0.802), confirming the consistency of student responses in this segment. The scale measuring students' satisfaction with biology (grades, classroom activity, and understanding of subject matter) showed reliability of α = 0.790. These results confirm that the instruments used were valid for further analysis and interpretation within the study.

3.1. Students' Preferences and Experiences with Interactive Teaching

Within this part of the study, Hypothesis H1 was tested. The assumption underlying this hypothesis is that students who are more actively involved in the teaching process tend to prefer learning models that encourage their participation, idea exchange, practical tasks, and feedback—characteristics inherent to interactive and student-centered approaches.

To test the hypothesis, a chi-square test of independence (χ^2 test) was applied, which allows for the assessment of whether a statistically significant association exists between two categorical variables: the level of student engagement and their preferred learning model. The learning models included in the analysis were: traditional teaching, a limited combined model (teacher uses presentations), a combined model, and interactive teaching.

The results of the χ^2 test indicate a statistically significant relationship between the analyzed variables. The values of Pearson's chi-square statistic ($\chi^2 = 109.272$, $df = 54$, $p < .001$), as well as the Likelihood Ratio ($\chi^2 = 114.341$, $df = 54$, $p < .001$), confirm that the distribution of student engagement varies significantly depending on the preferred learning model. In addition, the Linear-by-Linear Association ($\chi^2 = 31.416$, $df = 1$, $p < .001$) points to the existence of a linear relationship between the intensity of engagement and preference for more interactive models.

Based on these results, Hypothesis H1 can be confirmed—there is a statistically significant relationship between student engagement and the preferred learning model. Students who demonstrate higher levels of engagement during lessons are more likely to prefer interactive models, further underscoring the importance of active teaching approaches in fostering motivation and student interest.

3.2. The Impact of Student Engagement in Interactive Teaching on Cognitive-Social Learning Outcomes

As part of testing Hypothesis H2, the influence of student engagement on cognitive-social learning outcomes was analyzed. The initial assumption of this part of the study was that active student participation in interactive teaching activities contributes not only to better

understanding of the subject matter but also to the development of key competences. Interactive teaching models—including discussion, group work, experiments, and projects—enable students to integrate knowledge and develop skills through experiential learning.

To test the hypothesis, correlation analysis and multivariate analysis of variance (MANOVA) were applied. The correlation analysis revealed statistically significant positive relationships between student engagement and all analyzed aspects of cognitive-social outcomes (Table 1.). The most pronounced result was observed in group work, which showed an exceptionally high correlation with social skills ($r = 0.866$, $p < .001$), consistent with the nature of this method that fosters collaboration and communication.

Educational games and laboratory exercises demonstrated strong effects across all four categories of abilities—social and creative skills, understanding of biological concepts, and memory—confirming their effectiveness in integrating knowledge and skills. Fieldwork, although rarely applied, showed positive correlations with all analyzed outcomes, particularly with social and cognitive aspects, while teacher–student interaction had a moderate but significant effect, especially on memory and understanding of subject matter.

The MANOVA results further confirmed Hypothesis H2. It was found that the types of teaching activities significantly influenced the development of social skills ($F(72,29) = 6.653$, $p < .001$, $R^2 = .943$), with group work having the strongest effect. For creative skills, laboratory exercises showed a statistically significant contribution ($p = .014$), while for understanding biological concepts and creativity, significant interactions were observed between project-based learning and teacher activity ($p = .013$). These results suggest that the effects of project-based teaching can be further enhanced when accompanied by active teacher evaluation and support.

Table 1. Correlation analysis between student engagement in teaching and cognitive-social learning outcomes

Form of interactive teaching	Social skills	Creative skills	Understanding of biological concepts	Memory
Fieldwork	.458**	.303**	.302*	.209*
Laboratory exercise	.530**	.368**	.221*	.297**
Educational games	.523**	.454**	.435*	.289**
Group work	.866**	.322**	.306*	.204*
Project	.581**	.248*	.128	.054
Teacher–student interaction	.215*	.279**	.267*	.363**

Note: *Correlation is significant at the 0.05 level; **Correlation is significant at the 0.01 level.

Based on the conducted analyses, it can be concluded that the most significant forms of interactive teaching that positively influence students' cognitive-social outcomes are group work and laboratory tasks. The obtained results confirm Hypothesis H2 and highlight the importance of active teaching approaches in developing students' educational competences.

3.3. Students' Attitudes and Satisfaction

As part of testing Hypothesis H3, the relationship between student engagement and their perception of classroom climate was analyzed. The assumption of the hypothesis was that active student involvement in the learning process positively influences the emotional experience of the learning environment.

For the analysis, correlation analysis and multiple regression analysis were applied, including an ANOVA test. Classroom climate was operationalized through elements of motivation, enjoyment, peer collaboration, and the quality of communication with the teacher.

The correlation analysis (Table 2.) showed that student engagement in different forms of interactive teaching significantly and positively correlates with their perception of classroom atmosphere. The strongest associations were recorded for laboratory exercises ($r = 0.609$, $p < .001$) and educational games ($r = 0.606$, $p < .001$), indicating that these methods have the greatest motivational and emotional impact. Group work also showed a strong correlation ($r = 0.486$, $p < .001$), while projects ($r = 0.286$, $p = .002$) and teacher–student interaction ($r = 0.267$, $p = .007$) were significant but with weaker effects. All results were statistically significant at the $p < .01$ level, confirming that the observed associations are stable and likely present in the population.

Table 2. Correlation analysis between student engagement in teaching and perception of classroom atmosphere

Form of interactive teaching	Classroom atmosphere
Laboratory exercise	.609** (p < .001)
Educational games	.606** (p < .001)
Group work	.486** (p < .001)
Project based learning	.286** (p = .002)
Teacher–student interaction	.267** (p = .007)

Note: Correlation is significant at the 0.01 level (2-tailed).

Regression analysis provided a more precise understanding of the contribution of individual forms of engagement to the perception of classroom climate. The obtained model was statistically significant and explained 50.4% of the variance in classroom atmosphere ($R^2 = 0.504$, $R = 0.710$), confirming Hypothesis H3. The ANOVA test results ($F(5,96) = 19.492$, $p < .001$) showed that the set of predictors significantly explained variability in classroom climate perception.

The coefficient analysis (Table 3.) revealed that laboratory exercises (β = 0.390, p = .001) made the greatest contribution to a positive perception of classroom climate, making them the strongest predictor of a motivating classroom. Educational games (β = 0.281, p = .005) and group work (β = 0.278, p = .010) also significantly contributed to a positive climate. Interestingly, projects showed a negative association (β = -0.224, p = .036), which may indicate that students perceive them as demanding or stressful. Teacher–student interaction, although positive, did not reach statistical significance (p = .182).

Table 3. ANOVA results – coefficients for testing H3

Predictor	β (Standardized)	t	p
Laboratory exercise	.390	3.710	.001
Educational games	.281	2.895	.005
Group work	.278	2.630	.010
Project based learning	-.224	-2.127	.036
Teacher–student interaction	.103	1.346	.182

Dependent variable: Classroom atmosphere (ATM).

Based on these results, it can be concluded that student engagement in interactive forms of teaching significantly affects their perception of classroom climate. Laboratory exercises, educational games, and group work stand out as key factors in creating a motivating and stimulating environment. These findings confirm Hypothesis H3 and emphasize the importance of planning teaching activities that not only increase student engagement but also contribute to the formation of a positive emotional classroom environment.

As part of testing Hypothesis H4, the relationship between students' perception of the usefulness of interactive teaching and their subjective satisfaction with achievements was analyzed.

To test the hypothesis, Pearson's correlation analysis was applied (Fig. 2). The results showed a statistically significant positive relationship between students' attitudes toward interactive teaching and all analyzed aspects of satisfaction. The strongest correlation was observed between attitudes toward interactive teaching and satisfaction with classroom activity (r = 0.600, p < .001), indicating that students who perceive interactive teaching as useful also report greater engagement and satisfaction with their participation in classroom activities.

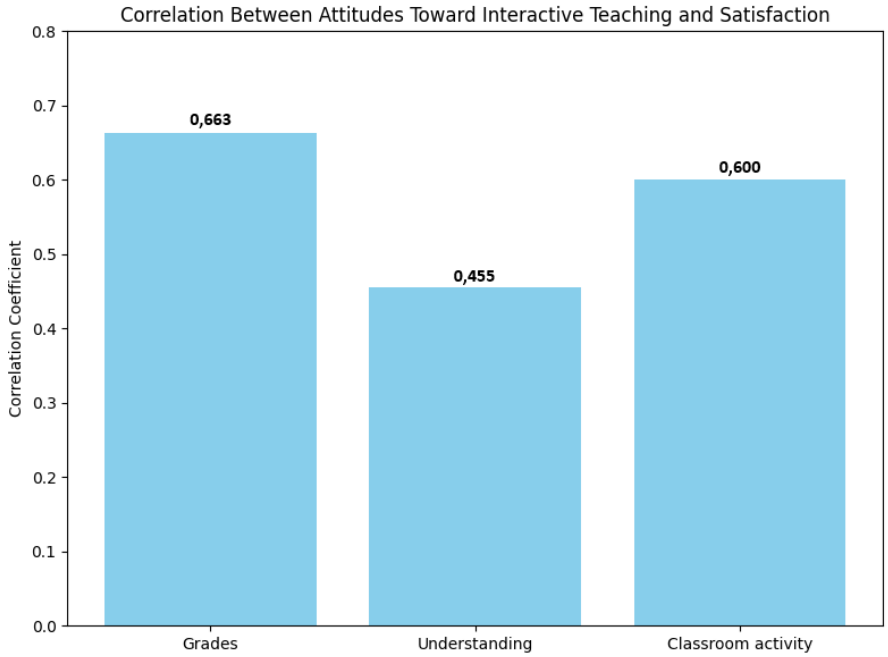

Figure 2. Correlation analysis between attitudes toward interactive teaching and students' satisfaction levels. (Note: Correlation is significant at the 0.01 level (2-tailed)).

A significant correlation was also recorded between attitudes toward interactive teaching and satisfaction with grades ($r = 0.663$, $p < .001$), suggesting that students who positively value interactive methods also report higher satisfaction with their academic success. In addition, the correlation with satisfaction regarding understanding of subject matter was $r = 0.455$ ($p < .001$), confirming that interactive teaching contributes to the perception of better comprehension of biological concepts.

All correlations were statistically significant at the $p < 0.01$ level, confirming that the observed associations are not random but likely present in the population. The obtained results confirm Hypothesis H4 and indicate that the perception of the usefulness of interactive teaching is an important predictor of students' subjective satisfaction with their achievements, including grades, understanding of subject matter, and classroom activity.

4. Disscusion

The results of the study confirm that the interactive teaching model has a significant and positive impact on various aspects of the learning process, including cognitive outcomes, motivation, student engagement, and satisfaction with instruction. These findings are consistent with contemporary pedagogical theories that advocate active learning as the

foundation for developing deeper understanding and long-term knowledge retention (Bihorac et al., 2019; Pribićević, 2017).

Empirical data obtained in this study show that student engagement during interactive teaching positively correlates with self-reported understanding of biological concepts and memory retention. These findings support the thesis that active participation in the learning process enables students to better connect theoretical concepts with practical experience, thereby transforming knowledge from reproductive to functional (Popović, 2007). In line with the constructivist approach, the student is viewed as an active constructor of knowledge, while the teacher assumes the role of facilitator (Pribićević, 2017). The observed effects of interactive teaching are particularly reflected in cognitive outcomes, where students reported improved ability to understand, analyze, and apply acquired knowledge. This result confirms previous research emphasizing that interactive approaches—such as project-based learning, laboratory experiments, and group work—stimulate higher levels of cognitive engagement compared to traditional frontal methods (Bihorac et al., 2019).

The results also show that students participating in interactive teaching express higher levels of motivation and satisfaction with the learning process. Most respondents described interactive methods as “interesting,” “motivating,” and conducive to a positive classroom atmosphere. These findings align with claims that interactive teaching fosters the development of a positive emotional environment, which in turn stimulates intrinsic motivation for learning (Pribićević, 2017). Particularly noteworthy is that students who actively participated in interactive forms of teaching reported greater satisfaction with their grades and personal achievement, indicating a link between perceived instructional effectiveness and the affective experience of academic success. This result supports Hypothesis H4 and is consistent with literature emphasizing the importance of students’ affective experience as a prerequisite for successful learning (Popović, 2007).

The results clearly indicate that laboratory exercises, project activities, and group work are the forms of teaching that generate the highest levels of student engagement. In contrast, teaching forms such as the use of mobile applications and fieldwork were less represented, even though students recognized their potential. These data highlight the need for didactic diversification and greater integration of digital technologies into biology teaching. Modern educational systems, according to international studies (TIMSS, PISA), emphasize that active and inquiry-based methods are key to achieving better results in science education (Džumhur, 2019). Therefore, educational policies should support curricular reforms and professional development of teachers that enable the systematic application of interactive approaches.

Compared to the traditional model, which is predominantly oriented toward frontal teaching and knowledge reproduction, the interactive model demonstrates superiority in terms of

active student participation, the development of critical thinking, and the connection of theory with practice. Traditional teaching often fails to meet the needs of modern generations of students, who are characterized by digital literacy, rapid information exchange, and the need for autonomy in learning (Popović, 2007). This study confirms that the shift from a traditional to an interactive paradigm is necessary to improve the quality of science teaching in primary schools. Increasing student engagement, understanding, and motivation through interactive methods points to a higher level of didactic efficiency of this approach.

Although the study provides significant insights into the effects of interactive teaching, certain limitations must be considered. The sample was purposive and included students from a single school, which may limit the generalizability of the results. Furthermore, the study relied on student self-assessment, which may involve subjective biases. Additional research with larger and more diverse samples, as well as a combination of objective measurement instruments (e.g., knowledge tests) and qualitative methods (interviews, focus groups), could contribute to a deeper understanding of the impact of interactive teaching.

This study confirms the importance of interactive didactic approaches in the context of primary education. The results point to the need for modernization of teaching methods and the empowerment of teachers to apply innovative instructional strategies. Establishing a balance between traditional and interactive methods, with greater emphasis on the student's active role, can significantly improve educational outcomes in biology teaching.

The findings confirm the initial assumption that the interactive teaching model represents a more effective approach to education compared to traditional methods, as it fosters active learning, deeper understanding, greater engagement, and student satisfaction. Interactive teaching is not merely a methodological innovation but a paradigm shift in which the student is regarded as the central actor in the educational process. Considering global trends and the results of international studies (TIMSS, PISA), it is recommended that interactive approaches be systematically integrated into curricula and that teachers receive additional training for their implementation through professional development and digital education. This would create the conditions for developing 21st-century student competences in line with the demands of contemporary education.

5. Conclusion

The results of this study clearly confirm that interactive biology teaching has a strong and multidimensional impact on the educational outcomes of primary school students. Analysis of both quantitative and qualitative data demonstrated that methods such as group work, laboratory exercises, and educational games not only increase student engagement and

motivation but also contribute to the development of cognitive, social, and creative skills. Students who are actively involved in the learning process report higher levels of satisfaction with their own achievements and perceive the classroom atmosphere more positively.

In the local context of Bosnia and Herzegovina, where the educational system still largely relies on traditional methods, these findings carry particular significance. They highlight the need for systematic investments in laboratory equipment, digital tools, and continuous teacher training in order to enable broader implementation of interactive teaching.

In conclusion, interactive biology teaching should not be viewed merely as a pedagogical innovation but as a necessity in contemporary education. Its implementation can significantly improve the quality of instruction, increase student motivation and satisfaction, and contribute to the development of competences essential for life and work in the 21st century.

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