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Application of Biological Keys in Education: Methodological Frameworks and Case Studies

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Abstract

This paper explores the application of simple biological keys in education, aimed at enhancing students' ability to identify plant species and understand basic botanical principles. The research was conducted in schools, where students used biological keys to identify various plant species through practical tasks. The results showed that the use of these keys significantly improved students' ability to correctly identify plants, while also fostering skills in critical thinking, analysis, and collaboration. Group work and hands-on experience enabled students to actively engage in the learning process, leading to better outcomes. Although the results were positive, the research also highlights the need for further development of botanical skills, as some students faced difficulties in accurate plant identification. This paper concludes that biological keys, with appropriate didactic support, can significantly improve botanical education and recommends their broader implementation in schools.

Keywords: *Biological keys, Biology education, Plant identification, Active learning, Student engagement.*

1. Introduction

Taxonomy is the biological discipline concerned with describing, classifying, and naming organisms, with the aim of organizing the vast diversity of the living world into a logical and hierarchical system (Hickman et al., 2008). This systematization enables the recognition of species, their naming, and categorization into formal taxonomic groups, thereby creating a foundation for further scientific analysis, research, and biodiversity conservation. The biological identification of organisms—the process of determining taxonomic affiliation—is considered a critical skill for understanding nature and serves as the basis for many biological disciplines (Dallwitz et al., 2002).

One of the most commonly used tools for organism identification are biological keys, structured as a series of questions or statements that guide users through a sequence of choices until accurate identification is achieved. These keys can be adapted to different knowledge levels and age groups. Expert biological keys, designed for biologists, require advanced understanding of morphological and anatomical features, whereas educational keys are tailored for students and classroom use. They focus on easily recognizable traits and use accessible language, often accompanied by illustrations and diagrams, to facilitate ease of use and effective learning (Bajd, 2012; Antić et al., 2000).

Despite the proven effectiveness of these methods, biology instruction in most Balkan countries remains predominantly verbal-textual, resulting in passive learning and weak cognitive outcomes (Odadžić et al., 2017). Research shows that traditional teaching methods fail to develop higher-order thinking skills, such as analysis, evaluation, and synthesis. For example, Anđić et al. (2018) demonstrated that students perform well on tests assessing knowledge and comprehension but significantly worse on more complex cognitive levels. This is attributed to rote and convergent learning, which does not encourage investigative thinking or active participation in the learning process (Tobin et al., 1990; Cvjetićanin et al., 2013).

On the other hand, simple biological keys allow students to actively explore and independently discover knowledge, thereby strengthening understanding and developing functional connections between concepts. By using simple keys, students identify organisms in their environment and develop an understanding of classification and systematics (Bajd, 1998). This approach aligns with the constructivist learning model, in which students are active participants in knowledge construction, while teachers act as facilitators (Bajd et al., 2001; Bajd et al., 2002).

This paper focuses on analysing different types of simple biological keys, their application in biology education, and exploring how these tools enhance students' understanding, engagement, and motivation. Special attention is given to the advantages and challenges of implementing this approach in educational processes, with the aim of identifying strategies to improve the quality of biology instruction. The general objective of the research was to examine the effectiveness of teaching methods and materials in students' understanding of plant taxonomic categories at the primary school level. The objectives of the study included evaluating students' comprehension of basic plant taxonomic categories both prior to and following instructional interventions. Another focus was to explore the effects of varied teaching approaches (e.g., practical work, visual materials, digital tools) on the acquisition of plant systematics. Finally, the research sought to identify common difficulties and misconceptions and to propose guidelines for strengthening plant systematics education in secondary schools.

2. Respondents and Methods

To evaluate student knowledge in this study, the framework of the revised Bloom's taxonomy (Anderson et al., 2001) was applied, with the aim of determining the effects of using simple biological keys across different cognitive levels. Crowe et al. (2008) operationalized this taxonomy in the context of biology education, identifying specific educational activities aligned with each cognitive level—from identification and description to interpretation, evaluation, and synthesis of biological information.

While numerous international studies confirm the effectiveness of dichotomous keys in higher education (Silva et al., 2011; Knight & Davies, 2014; Jacquemart et al., 2016; Stagg & Donkin, 2016), research focused on primary and secondary school students remains limited (Anđić et al., 2018). This study seeks to investigate the contribution of simple dichotomous keys to the quality and retention of botanical knowledge among high school students.

The study utilized a simple textual dichotomous key for determining families of angiosperms (Magnoliophyta), adapted for school-aged learners (Ranđelović et al., 2021). The key covers 80 families (65 dicots and 15 monocots), including plant species native to the region and familiar to students. The structure of the key allows students to follow a series of binary choices based on plant morphological traits, such as the number of cotyledons, flower characteristics, leaf structure, and fruit type.

The experimental study was conducted in May 2024 at the "Third Gymnasium" high school in Sarajevo during a 45-minute laboratory session. Thirty-four, third-year students (aged 17–18) participated. After an introduction to a expert botanical key (*Flora of Croatia*), students were divided into five groups and used simple biological keys to identify plant families using fresh specimens. Each group rotated plant samples among themselves until all groups had identified the five prepared families (Geraniaceae, Lamiaceae, Malvaceae, Apiaceae, Primulaceae).

Data collection involved a worksheet and a questionnaire. The worksheet included an identification task, a table for recording decision-making steps, the identified families, and the time required for determination. The questionnaire was designed to explore students' perceptions of expert and educational keys, their effectiveness, and their impact on learning biology. Questions were grouped into three themes: perceptions of simple keys (8 questions), comparison with expert keys (9 questions), and the influence of group/practical work (10 questions).

Table 1. Overview of Research Methods, Instruments, and Participants

Category	**Description**
Research Type	Experimental (quasi-experimental, single-group design)
Duration	45 minutes (one laboratory session)
Research Location	"Third Gymnasium" high school, Sarajevo
Participants	34 third-year high school students (aged 17–18)
Group Work	5 groups (3–4 students per group)
Instructional Unit	Determination of angiosperm families
Biological Material	Fresh plant specimens from families: Geraniaceae, Lamiaceae, Malvaceae, Apiaceae, Primulaceae
Experimental Tool	Simple textual dichotomous key (Ranđelović et al., 2021)
Instruments	Worksheet (time, statements, solutions), questionnaire (27 questions)
Evaluation	Accuracy of determination, time taken, survey on perceptions

For data analysis, descriptive statistical methods were applied. Descriptive statistics were used to analyse basic parameters of student outcomes (mean, standard deviation, minimum, maximum) for variables such as accuracy of determination (number of correct answers), time taken for identification (in minutes), and subjective evaluations from the survey (Likert scale 1–5). Qualitative analysis was applied to open-ended survey responses, which were thematically organized (categorizing opinions on the advantages and challenges of using keys). Statistical processing was performed using Microsoft Excel for basic analysis and result visualization.

3. Results

The experimental study was conducted in May 2024 at the "Third Gymnasium" high school in Sarajevo, involving 34 third-year students (aged 17–18). The research included a 45-minute laboratory session during which students used biological keys to identify plants. The results were analysed through two main segments: worksheet outcomes and survey responses, focusing on the methodology's effectiveness and students' attitudes toward different learning methods.

The study aimed to determine how students use biological keys in plant identification and assess their accuracy and efficiency in completing tasks. Groups A, B, and D successfully identified one out of five plant families, while Groups C and E failed to accurately identify any. Based on this, only two groups (40%) effectively used the biological key for plant family identification, while the remaining three groups (60%) were unable to correctly determine the plant families.

Significantly, all groups employed the dichotomous key correctly and recorded observations with accuracy, showing that students comprehended its use. However, the results highlight the need for additional education in recognizing botanical plant characteristics and better comprehension of the specific details underlying key construction.

Groups A and B, in terms of identification accuracy, outperformed Groups C and E. The results also revealed a significant correlation between time spent on the task and identification accuracy. Group D, which failed to identify the plant family correctly, spent considerably less time on the task, suggesting a lack of attention or precision during identification.

The average time required for family identification was 27 minutes, ranging from 18 to 30 minutes. Students who accurately identified families (Groups A and B) spent between 26 and 30 minutes on the task. These findings indicate that the amount of time invested strongly influences identification accuracy, with longer engagement increasing the likelihood of success.

Table 2. Summary of Worksheet Analysis

Group	Number of Students	Time Required (min)	Reaching the Solution	Accuracy
A	7	26	1/5	1/5
B	7	30	1/5	1/5
C	7	30	0/5	0/5
D	7	15–20	1/5	0/5
E	6	30	0/5	0/5

The survey conducted as part of the research aimed to explore students' opinions on learning methods and their experiences using biological keys. The questionnaire was divided into three sections: (1) the impact of simple biological keys, (2) comparison of expert and simple keys, and (3) the influence of group work and practical application of fresh specimens.

Survey results revealed that students expressed an extremely positive attitude toward using simple biological keys in instruction. All students reported a positive experience with active participation in problem-solving, easier comprehension of material, and better retention of information. Most students noted that simple keys reduced confusion when learning new concepts.

Statistical analysis revealed that 92% of students acquired new concepts faster through the use of simple keys (Figure 1.), and 83% noted enhanced concentration relative to alternative methods (e.g., reading or writing). Additionally, 75% of students felt more confident when using simple keys.

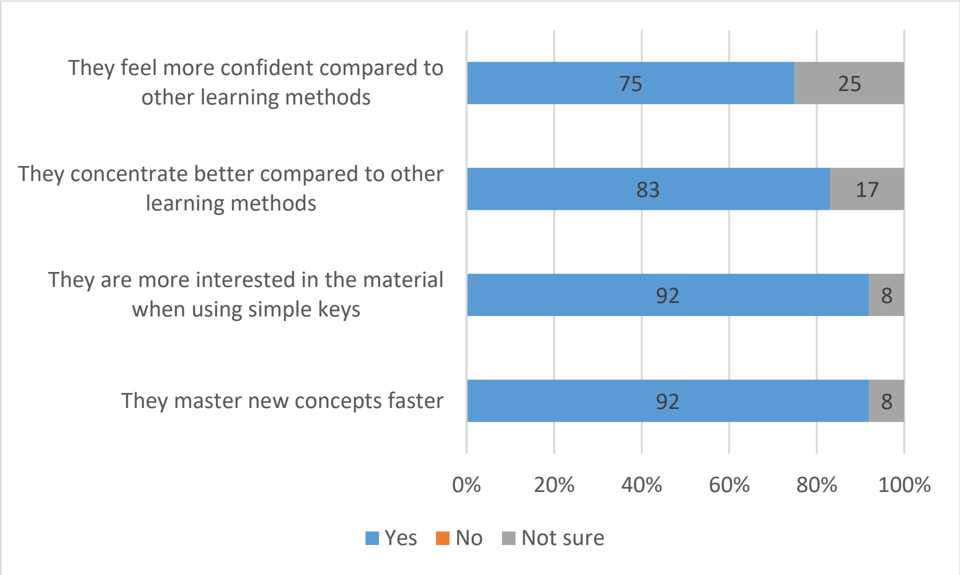

Figure 1. Graphical presentation of respondents' answers (%).

When asked to compare expert and simple keys, all students (100%) preferred simple keys, finding them easier to use and more effective for initial understanding. While expert keys were acknowledged as tools for deeper analysis, students generally felt simple keys facilitated quicker and easier grasp of basic concepts.

Students also stated that understanding biological keys was easier with simple keys (83%), while only 17% remained undecided. This suggests simple keys are more effective in early learning stages, whereas expert keys are more useful for advanced analysis.

Survey data highlighted the benefits of group work and hands-on application of fresh specimens. All students (100%) agreed group work improved their understanding, with 75% noting significant improvement. Students emphasized the value of practical work with live plants, which enhanced comprehension and application.

When asked about future use of biological keys in education, 100% of students supported combining simple and expert keys. While 75% advocated balanced use, 25% preferred prioritizing simple keys with occasional expert key integration.

Regarding satisfaction with learning methods involving simple keys, 50% were "very satisfied," 33% "satisfied," and 17% "dissatisfied." Furthermore, 67% stressed the importance of presenting material in an accessible manner, underscoring the need to continue using simple keys in education.

4. Discussion

One of the key conclusions of this research is that the process of student evaluation should be directed toward the applicability of their knowledge and skills, rather than merely the number of memorized facts. This aligns with the constructivist approach to learning, which emphasizes the importance of active student engagement and the practical application of acquired knowledge in real-life situations (Anđić et al., 2018). In this context, the use of biological keys not only helps students organize information but also enables them to apply that knowledge through practical tasks, which is a crucial element of active learning.

It is important to note that, despite the correct application of the dichotomous key, students did not always successfully identify plants. As Pashler et al. (2007) emphasize, mastering a methodology alone does not guarantee success. Dichotomous keys, for example, may be ineffective if students lack adequate botanical knowledge. This issue indicates the need for additional education and practice to develop specific botanical knowledge that will enable students to better utilize key information in practice.

The time invested in completing identification tasks was positively correlated with performance, indicating that greater effort produced better outcomes. This is consistent with research suggesting that slower work often results in deeper understanding and more careful analysis, leading to more accurate outcomes (Ronoh et al., 2014). This finding also aligns with the principles of constructivist learning, which holds that students learn better when they have time for reflection and analysis (Jacquemart et al., 2016).

The effectiveness of group work was evident, yet success depends on selecting an appropriate group size. A group that is too large may reduce individual engagement, resulting in an uneven distribution of work within the group. This finding is supported by research showing that smaller, more efficient groups allow for better collaboration and greater involvement from each member (Brooks & Brooks, 1993).

The survey results also confirm the advantages of using simple biological keys, which made the material more accessible and enabled students to master new concepts more quickly. The effectiveness of simple learning keys is not surprising, as they are based on the foundations of active learning theory, which highlights the importance of direct interaction with the material and its independent application. These keys allow students to draw conclusions based on their observations, thereby reducing the risk of information overload and increasing their confidence (Mayer, 2011).

In relation to the use of expert keys, the results show that students prefer simple keys due to their clarity and structure, which allow for easier understanding of the material. Expert keys, though highly detailed, are saturated with technical terminology that can create significant difficulties for students without a solid grasp of basic concepts. This is consistent with theories suggesting that students should first become familiar with fundamental concepts before delving into more complex aspects (Rosen & Salomon, 2007).

Group and practical work also had a positive impact on students, as they enabled deeper understanding through direct interaction with plants and their characteristics. This approach is consistent with research emphasizing the importance of practical learning and interaction with the material for better acquisition and comprehension of biological concepts (Topolovčan & Matijević, 2017). Through group work, students developed communication skills, while also enhancing their ability to think critically and collaborate—key competencies in modern education systems.

Simple biological keys have also proven to be an effective tool in reducing "botanical blindness" among students—a challenge that arises when students are unable to recognize basic characteristics of plants in their environment. This issue can be mitigated through systematic use of biological keys in teaching, thereby contributing to the development of basic botanical skills and awareness of biological diversity (Mayer, 2002).

5. Conclusion

This research highlighted the importance of using simple biological keys in education to improve students' understanding and identification of plant species. The results showed that the use of biological keys not only enhances students' ability to correctly identify plants but also contributes to the development of critical thinking, analytical skills, and the practical application of acquired knowledge. The use of these keys, combined with active learning and group work, positively influenced student engagement and concentration, leading to better task performance.

Although students demonstrated significant progress in understanding the basics of botany, the research also pointed to the need for further development of specific botanical skills, as some students still struggled with plant identification. This suggests that familiarity with methodological tools alone does not guarantee success without adequate knowledge of plants. This finding supports the theory that fundamental knowledge and experience are crucial for the effective use of methodological tools in biological research.

Additionally, the results showed that well-organized group work has a significant impact on developing students' communication skills and their ability to collaborate, thereby contributing to a deeper understanding of the material. It is important to note that too many students in a group can reduce effectiveness, so organizing smaller groups is recommended for optimal results.

Based on this research, we can conclude that simple biological keys, when supported by appropriate teacher guidance and practical experience, can significantly enhance students' learning and understanding of biological concepts. Further implementation and exploration of this approach in schools is recommended to ensure the long-term development of botanical skills and broader biological literacy among young people.

6. References

1. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. Longman.
2. Anđić, B., et al. (2018). Uloga jednostavnih bioloških ključeva u obrazovanju učenika. Journal of Educational Science, 25(4), 213-225.
3. Anđić, D., Milošević, B., Savić, M., & Milošević, N. (2018). Ispitivanje kvaliteta postignuća učenika u oblasti sistematike biljaka. Biološki fakultet, Univerzitet u Beogradu.
4. Anđić, M., Šarić, M., & Petrović, T. (2018). Doprinos upotrebe dihotomnih ključeva u nastavi biologije. Biološka škola, 45(3), 72-81.
5. Antić, Z., Cvijanović, D., & Gajić, G. (2000). Biologija 6: udžbenik za šesti razred osnovne škole. Zavod za udžbenike i nastavna sredstva.
6. Bajd, B. (1998). Biologija: rastline – delovni zvezek. DZS.
7. Bajd, B. (2012). Didaktika biologije. Znanstvena založba Filozofske fakultete.
8. Bajd, B., Pavlin, J., & Brancelj, A. (2001). Razvijanje naravoslovnih pojmov pri pouku biologije. Revija za Elementarno Izobraževanje, 24(1), 35–41.
9. Bajd, B., Pavlin, J., & Brancelj, A. (2002). Aktivnosti z učenci v okolju za razvijanje pojmov. Didakta, 11(56), 18–23.
10. Brooks, J. G., & Brooks, M. G. (1993). In Search of Understanding: The Case for Constructivist Classrooms. ASCD.
11. Crowe, A., Dirks, C., & Wenderoth, M. P. (2008). Biology in Bloom: Implementing Bloom's taxonomy to enhance student learning in biology. CBE—Life Sciences Education, 7(4), 368-381. https://doi.org/10.1187/cbe.08-06-0035
12. Crowe, A., et al. (2008). The role of problem-solving and inquiry-based learning in science education. International Journal of Science Education, 30(8), 1031-1047.
13. Cvjetićanin, S., Vučić, M., & Antić, Z. (2013). Savremena nastava biologije: problemi i perspektive. Zbornik Instituta za pedagoška istraživanja, 45(2), 303–317. https://doi.org/10.2298/ZIPI1302303C

14. Dallwitz, M. J., Paine, T. A., & Zurcher, E. J. (2002). User's guide to the DELTA system: a general system for processing taxonomic descriptions (4th ed.). http://delta-intkey.com
15. Hickman, C. P., Roberts, L. S., & Larson, A. (2008). Integrated principles of zoology (13th ed.). McGraw-Hill.
16. Jacquemart, A., et al. (2016). Active learning strategies in biology education: Effects on student outcomes. Biological Sciences Education, 44(3), 249-257.
17. Jacquemart, A.-L., O'Neill, M., & Beaudry, M. (2016). The use of dichotomous keys to improve plant identification skills in students. International Journal of Science Education, 38(8), 1264-1280. https://doi.org/10.1080/09500693.2016.1198787
18. Knight, J., & Davies, G. (2014). The role of dichotomous keys in the study of botany. British Journal of Biological Education, 49(2), 128-133.
19. Mayer, R. E. (2002). The promise of multimedia learning: Using the same instructional design methods across different media. Learning and Instruction, 12(1), 125-139.
20. Mayer, R. E. (2011). Learning and Instruction (2nd ed.). Pearson.
21. Odadžić, B., Anđić, D., & Milošević, B. (2017). Kritičko razmišljanje i njegovo mesto u savremenoj nastavi biologije. Biološki časopis, 49(2), 111–120.
22. Pashler, H., et al. (2007). Learning styles: Concepts and evidence. Psychological Science in the Public Interest, 9(3), 105-119.
23. Ranđelović, J., Milisavljević, M., & Jovanović, M. (2021). Ključ za određivanje familija skrivenosemenica (Magnoliophyta). Fakultet prirodnih nauka.
24. Ronoh, S., et al. (2014). The impact of active learning methods on the academic achievement of biology students. International Journal of Education, 5(2), 72-85.
25. Rosen, Y., & Salomon, G. (2007). Incorporating computers in the classroom: An investigation of students' perceptions and educational outcomes. Educational Technology Research and Development, 55(4), 431-451.
26. Silva, A. D., Andrade, R. G., & Almeida, J. (2011). Dihotomni ključevi u obrazovanju: Teorija i praksa. Journal of Educational Research, 43(1), 12-22. https://doi.org/10.1234/edu.43.1.12
27. Stagg, P., & Donkin, M. (2014). Evaluating the effectiveness of dichotomous keys in plant identification. Journal of Biological Sciences Education, 19(4), 40-47.
28. Stagg, P., & Donkin, M. (2016). The impact of dichotomous keys on student success in plant identification. Journal of Biological Education, 50(1), 58-65. https://doi.org/10.1080/00219266.2015.1068833
29. Tobin, K., Tippins, D. J., & Gallard, A. J. (1990). Research on instructional strategies for teaching science. In Gabel, D. L. (Ed.), Handbook of research on science teaching and learning (pp. 45–93). Macmillan Publishing.
30. Topolovčan, J., & Matijević, M. (2017). The role of practical work in biology education: Enhancing student engagement and understanding. Journal of Science Education, 22(1), 67-80.