IMI MathCode Duel: A Competition-Based Learning Platform for Students

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***Abstract*— This paper presents the web platform IMI MathCode Duel, designed as an interactive environment for primary and secondary school students that encourages learning mathematics and programming through real-time online peer duels. The platform integrates a high-quality task base inspired by the international Mathematical Kangaroo competition and national informatics competitions, enabling customized challenges based on age and knowledge level. The paper outlines the platform's main features: opponent selection, task generation, automatic grading, support for multiple programming languages, as well as an administrative interface for task management and results analysis. It also examines the platform's educational potential in fostering active learning, self-assessment, and the development of analytical and algorithmic thinking. Additionally, the possibilities for system expansion through new functionalities and its application in both curricular and extracurricular contexts are discussed.**

Keywords— gamified learning, mathematical tasks, programming tasks, competitive learning, educational platform

I. INTRODUCTION

Modern technologies have a profound impact on various aspects of life, particularly on education. Today's students grow up in a digital environment, which opens up new opportunities but also poses new challenges for the teaching process. The educational system is expected not only to transfer knowledge but also to provide an environment that is interactive, engaging, and adapted to new generations of learners. Research shows that the introduction of digital tools into teaching has a positive effect on student engagement, understanding of complex concepts, and overall academic achievement—provided that their implementation is methodologically well-planned, technical limitations are addressed, and teachers are adequately trained [1].

In mathematics and programming instruction, traditional approaches are often insufficient in terms of motivating students, especially at younger ages. The standard pace and format of teaching leave little room for active participation, continuous self-assessment, and application of knowledge in real-world contexts [2], [3]. At the same time, teachers face challenges in monitoring individual progress, creating tailored tests, and providing effective feedback [4].

In this context, gamification and competition-based learning are increasingly highlighted as strategies with the potential to enhance the quality of teaching and learning in STEM disciplines. The application of these methods can increase students' intrinsic motivation, reinforce their sense of achievement, and encourage persistence in problem-solving [5], [6]. Empirical studies in mathematics education show that gamified approaches—especially those based on logical reasoning and problem-solving—significantly contribute to the development of analytical thinking and student motivation [7].

These principles underpin the IMI MathCode Duel web platform, available at https://imi.pmf.kg.ac.rs/imi-math-code-duel. The platform was developed at the Department for mathematics and informatics, Faculty of Science, University of Kragujevac, with the aim of enabling primary and high-school students to develop mathematical and algorithmic skills through interactive real-time duels with their peers. A unique combination of mathematics and programming is used to create an environment in which students can measure their knowledge while progressing at their own pace, supported by immediate system feedback.

The mathematics section of the platform is based on a high-quality set of tasks inspired by the international Mathematical Kangaroo competition, adapted to the users' age and knowledge level. On the other hand, the programming section is supported by an integrated code editor that allows students to write solutions in C, C++, and Python, with automatic testing and ranking during duels. The platform aligns with the structure of national informatics competitions for primary and secondary schools. In addition, teachers can use the administrative interface to add tasks, monitor student activity, and export data.

The aim of this paper is to present the key functionalities and educational benefits of the IMI MathCode Duel platform and to discuss its possible applications in both formal and informal education, with particular emphasis on student motivation and competence development.

II. Related Research and Existing Research

A. Overview of Existing Competition-Based Platforms

In the past decade, numerous online platforms have been developed to support competition-based learning in the fields of programming [8], [9], [10] and mathematics [11], [12], [13]. These platforms combine formative assessment with competitive elements, making them suitable for use in both formal education and extracurricular activities.

Codeforces is one of the most prominent examples in the domain of competitive programming. Although initially designed for Olympiads and advanced users, its functionalities have expanded into formal education. In addition to competitions, Codeforces offers virtual contests, automated grading, and training courses, forming a comprehensive educational ecosystem applicable to secondary and higher education programming instruction [8].

CodinGame is a platform that blends programming and gaming. Studies show that its use in university-level programming courses positively impacts student motivation and problem-solving skills. Students rated the platform as both innovative and engaging for learning [9].

For younger learners, CodeCombat has proven particularly well-suited for introducing programming basics. A study conducted in primary schools demonstrated improved understanding of programming concepts and increased enthusiasm among students [10].

In the field of competitive mathematics, Mathletics provides interactive and competitive activities for elementary school students. Research indicates that Mathletics represents a complex educational environment that intertwines functionality, pedagogical values, and parental expectations. Its use is not purely educational but also a form of play with multiple interpretations, requiring critical pedagogical guidance to ensure its role in learning is constructive [11].

Finally, tools such as Kahoot! and Quizizz, which rely on digital quiz formats, are widely used for student engagement and knowledge checks. Meta-analyses of multiple studies confirm that Kahoot! has a significant positive effect on student motivation and engagement across various educational contexts [12], while comparative studies show that both Quizizz and Kahoot! enhance feedback quality and student participation [13].

B. Gamification and Competition-Based Learning in Education

Gamification and competition-based learning are pedagogical strategies that merge game mechanics and competitive elements with formal educational objectives. These strategies are increasingly applied in STEM education, where they have proven effective in boosting motivation, fostering analytical thinking, and promoting active student participation.

A study involving a university-level calculus course showed that implementing a leaderboard and point system as part of a gamification strategy significantly improved student performance. However, the approach had no notable effect on students' intrinsic motivation, highlighting the need for careful design of gamified components [14].

Another study analyzed different types of competition in online learning environments and found that real-time direct competitions had a more positive impact on learning outcomes than indirect ones such as leaderboards. Students' self-confidence and stress resilience were identified as mediating factors in learning effectiveness [15].

Gamification has also been studied in the context of gender differences. In one study focused on programming learning platforms, although overall student performance improved, female students often perceived gamification elements as less motivating, suggesting the importance of inclusive design that accommodates diverse learner profiles [16].

In primary education, gamified approaches to teaching programming proved particularly effective in motivating students, especially when the design included timely feedback and peer or teacher support [17].

In mathematics instruction, gamification led to significant improvement in student achievement and more favorable perceptions of the subject, confirming the effectiveness of such approaches even in long-term curricular implementations [18].

C. Positioning IMI MathCode Duel Among Existing Platforms

Unlike most existing platforms that focus exclusively on either programming or mathematics, IMI MathCode Duel offers a unique integration of both disciplines. Its dual structure enables the simultaneous development of algorithmic thinking and logical-mathematical reasoning, with each user engaging in tasks tailored to their age and proficiency level.

As mentioned earlier, the mathematical component of the platform stands out through a task base inspired by the international Mathematical Kangaroo competition, ensuring high content quality and suitability for formal education. On the other hand, the programming component features a built-in code editor supporting C, C++, and Python, allowing students to solve problems in real time and receive immediate feedback through automated testing.

What distinguishes IMI MathCode Duel is its interactive real-time duel format, combining the motivational impact of competition with the formative value of feedback. This combination makes the platform adaptable for both formal and informal educational contexts, enabling students to progress at their own pace while providing teachers with tools for monitoring, analysis, and instructional support. In this way, IMI MathCode Duel bridges the gap between purely competitive educational platforms and those intended solely for practice, integrating the strengths of both approaches.

III. Description of the IMI MathCode Duel Platform

A. System Architecture and Implementation

The IMI MathCode Duel platform is developed as a web application based on a client–server architecture, enabling students to solve mathematics and programming tasks in real time through a competitive format. The system consists of two primary components: the client-side interface

implemented using the Angular framework and the server-side logic developed in the Laravel PHP framework.

The backend is responsible for processing user requests, managing tasks and users, executing code submissions, and storing results. Visual Studio Code was used as the development environment, and Laravel's built-in tools such as Artisan and Sanctum were employed for component generation and API authentication. Object-relational mapping is achieved through Laravel's Eloquent ORM, allowing seamless integration with both relational (MySQL) and document-based (MongoDB) databases.

The frontend application is developed in Angular using TypeScript. The user interface provides access to duels, tasks, and performance data and is optimized for interactive use by students. Mathematical expressions are rendered using the MathJax library, which supports LaTeX syntax and eliminates the need for formula images or static HTML formatting.

Communication between the client and server is established through RESTful API requests, primarily using GET and POST methods. The server responds with data formatted in JSON, which is parsed and rendered on the client side. This structure ensures efficient data exchange and enables the execution of core functionalities from any remote location.

To support real-time interactions during duels, the Laravel WebSockets package is used, enabling bidirectional communication without relying on external services. This allows functionalities such as challenge requests, acceptance notifications, duel initialization, and result broadcasting to occur instantly and reliably.

The entire communication cycle, from client-side request to data visualization, is illustrated in Fig. 1.

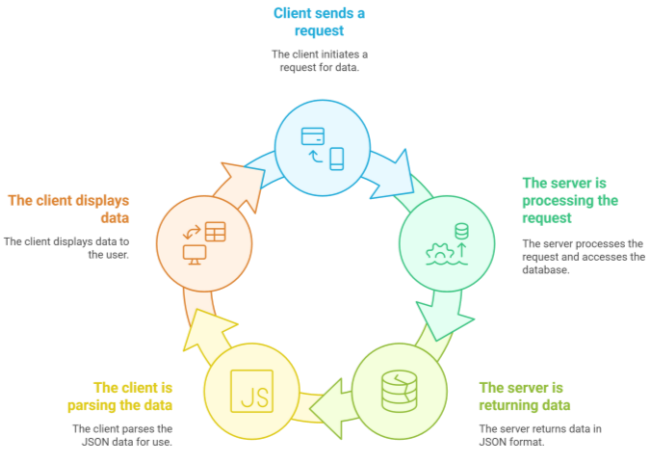

Fig. 1. Client–server communication cycle within the IMI MathCode Duel platform..

This architecture ensures scalability and extensibility of the platform, which is essential in educational contexts involving a large number of users and requiring real-time responsiveness.

B. Key Functionalities and User Roles

IMI MathCode Duel is a web-based platform that combines competition and education in the fields of mathematics and programming. Through interactive real-time duels, users are given the opportunity to test their knowledge, develop problem-solving skills, and track their individual progress.

The platform supports two primary subject areas:

- Mathematics, with tasks inspired by the international Mathematical Kangaroo competition, classified by age and difficulty level;
- Programming, via an integrated editor supporting C, C++, and Python languages, with automatic testing and evaluation of solutions, also aligned with Serbian national informatics competition categories.

The application features two user types: administrators and students/competitors. Administrators have access to a control panel for adding new tasks in mathematics and programming, managing users, filtering data by various criteria, and exporting results in CSV format. These administrative functionalities are implemented as separate components and are available only to authorized users.

Students participate in duels where tasks are simultaneously presented to both parties. The winner is determined first by accuracy and then by the time required to complete the task.

On the left side of the home page (Fig. 2), all registered users are listed, with a color indicator next to each name signaling their availability - green for online users and red for offline. Only currently active users can be challenged to a duel. The list is sorted to prioritize users who are online, listed as friends, and of the same age group as the logged-in user.

On the right side, there is a search field where users can find others by entering a nickname. The search results allow users to send friend requests and view more detailed information about a user, such as name, school, and city. Below the search bar, a list of received friend requests is shown, with options to accept or decline.

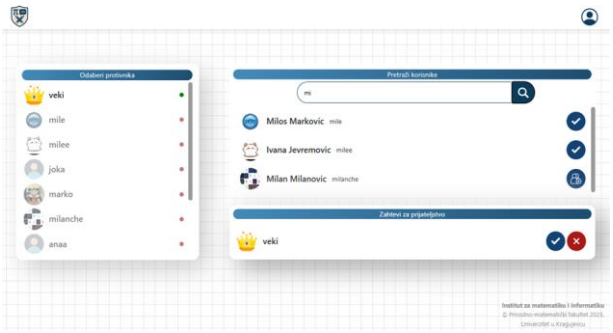

Fig. 2. Interface of the IMI MathCode Duel platform – opponent selection, user search, and friend request overview.

When the user clicks on the desired opponent, a window appears in which they need to select the category (mathematics or informatics) and the grade level (Fig. 3).

Fig. 3. Selection of duel parameters: opponent, subject, and grade level. The user chooses whom to compete against, in which subject area (mathematics or informatics), and at what difficulty level (based on grade). The system automatically adjusts the tasks according to the selected criteria.

When the opponent accepts the challenge, they are redirected to the game interface. In the case of mathematics, the game consists of nine questions: the first three are of the lowest difficulty, followed by three of medium difficulty, and finally three of the highest difficulty, in accordance with the structure of the Mathematical Kangaroo competition. The user selects one of the five multiple-choice answers (only one of which is correct) that they believe is correct (Fig. 4). Competitors have thirty minutes to complete all nine questions, but they can submit their answers earlier if they finish in less time. If the chosen subject is informatics, competitors also have thirty minutes to submit their solution. They receive one task to solve using one of the three available programming languages: C, C++, or Python. A single test case is provided, including input and the expected output for that input (Fig. 5).

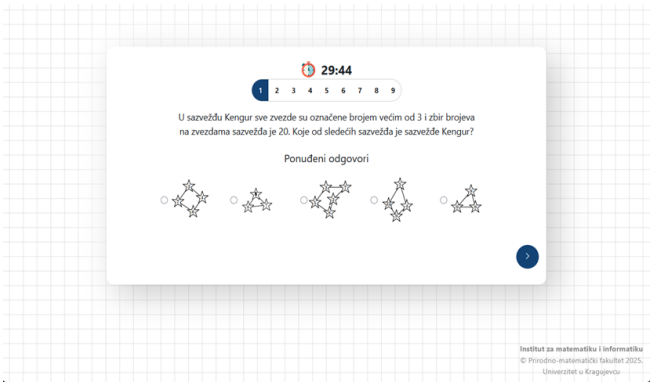

Fig. 4. Example of a mathematics task within the IMI MathCode Duel platform.

Fig. 5. Example of a programming task within the IMI MathCode Duel platform.

After both participants submit their answers, they receive a notification with the result of the duel. The winner is the user with more correct answers (mathematics) or the correct answer (informatics). If both participants have the same number of correct answers, the winner is the one who completed the duel in a shorter amount of time.

C. Task Creation and Result Analysis

The IMI MathCode Duel platform allows administrators to create custom tasks in the fields of mathematics and programming, tailored to different age groups and difficulty levels.

Mathematics tasks are formulated as text-based questions with multiple-choice answers. The content entry supports LaTeX syntax, enabling precise formatting of formulas and mathematical symbols. In addition to text, users can also insert illustrative images. When creating a task, the correct answer, number of points, and target student category (e.g., grade or knowledge level) are defined.

For informatics tasks, the creation process is similar, but instead of multiple-choice options, a number of test cases are defined, along with input and expected output data for each case. This structure enables automatic testing of the programs submitted by students during duels.

Administrators/teachers are also provided with tools for data analysis. They have access to a list containing student information such as first and last name, school, location, grade, math and informatics grades, number of wins and losses, and total number of duel participations (Fig. 6).

The system enables data filtering by all listed criteria, allowing teachers to accurately monitor progress, identify the most successful students, and recognize those who may need additional support. Furthermore, all filtered data can be exported in CSV format, enabling further statistical processing or integration into existing record-keeping systems. This functionality is especially useful for tracking individual student development and making data-driven pedagogical decisions.

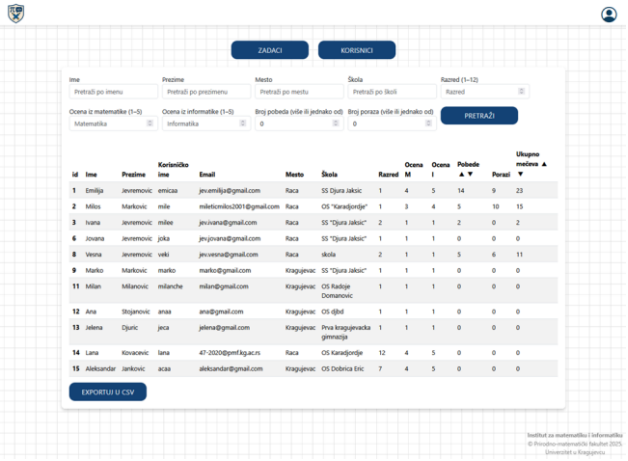

Fig. 6. Student performance analysis and data export.

IV. Educational Significance and Development Potential of the Platform

A. Encouraging Active Learning and Self-Assessment

IMI MathCode Duel promotes an active student role in the learning process through real-time problem-solving and immediate feedback. This dynamic allows for instant knowledge assessment and encourages student engagement, experimentation, and error correction. The platform structure also fosters independent discovery of solutions and the development of problem-solving strategies. The scoring and result comparison mechanisms motivate students toward continuous improvement, while repeated problem-solving contributes to knowledge reinforcement and increased self-confidence.

B. Use in Teaching and Extracurricular Activities

IMI MathCode Duel can be successfully integrated into the teaching process as well as extracurricular activities. In formal education, the platform serves as a supplement to lessons, allowing students to interactively practice material, participate in competitions, and develop algorithmic and mathematical skills. Although there is no direct support for organizing sessions or groups by class, students can independently join and challenge peers to duels, which teachers can encourage as part of in-class activities.

In extracurricular settings, the platform has proven to be highly suitable for organizing school and interschool tournaments, competition preparations, or as a tool for individual advancement of students who show particular interest in mathematics and programming.

C. Competency Development and Expansion Opportunities

The IMI MathCode Duel platform contributes to the development of various student competencies, particularly in the domains of analytical thinking, algorithmic reasoning, mathematical logic, and digital literacy. Through duels, participants continuously make decisions, evaluate solution strategies, and manage time, which supports metacognitive skills and promotes independent work.

In programming duels, students go through the entire problem-solving cycle - from task requirement analysis to implementation and testing. This process encourages structured and algorithmic thinking, which is a fundamental element of modern computer literacy.

To enhance the platform's functionality and effectiveness as an educational tool, new components and usage scenarios can be developed. Potential extensions include introducing detailed statistics (accuracy percentage, average solving time, top-performing subject), as well as progress visualization in the form of charts. Such information would help students better understand their own progress and identify areas for improvement.

Additionally, the introduction of a leaderboard system by class or level could promote social motivation and healthy competition among students. For programming tasks, extended result analysis, showing execution time and the number of passed test cases, could improve insight into solution quality.

Finally, opportunities for collaboration and experience sharing could be expanded by implementing a chat or forum feature, thereby further opening the platform to support peer learning and informal education.

In the future, we also plan to explore the integration of AI systems for content personalization. Such integration could enable dynamic adjustment of task difficulty based on individual student performance, as well as generate tailored feedback and recommendations. This would significantly enhance the adaptability of the platform to different learning styles and paces, thereby improving overall user experience and educational impact.

Given that the platform was developed at the very end of the 2024/2025 school year, a period typically marked by increased school activities, especially those related to assessment, we have not yet had the opportunity to widely introduce the IMI MathCode Duel platform to primary and secondary school students. There are plans to promote the platform at the beginning of the next school year, primarily by introducing it to mathematics and informatics teachers through professional development seminars, as well as through existing professional collaborations with colleagues working in schools across the Republic of Serbia. Following this, we also plan to analyze the use of the IMI MathCode Duel platform in the context of examining the positive impact of peer-based duels, exploring students' attitudes and opinions regarding this method of learning and practice, as well as identifying potential limitations and challenges. A structured evaluation plan has already been developed. It includes teacher training workshops, user testing in selected schools, and surveys targeting both students and teachers. Metrics such as user engagement, task completion accuracy, and user satisfaction will be analyzed to assess the platform's impact.

V. Conclusion

IMI MathCode Duel is an innovative digital environment that combines mathematics and programming through a real-time duel format. Its dual structure—on one side inspired by tasks from the international Mathematical Kangaroo competition and on the other based on informatics competition problems solved in multiple programming languages—enables comprehensive development of STEM-

related competencies, adapted to students' age and knowledge level.

Through an analysis of key functionalities and usage examples, the platform has been shown to promote active learning, self-assessment, and the development of analytical and algorithmic thinking. The ability to compare results and receive real-time feedback makes the platform suitable for both formal and informal education.

In addition to existing features, this paper identifies directions for further improvement—such as detailed statistics, ranking systems, and user communication support—which can enhance student engagement and the platform's scalability.

With continued development and teacher support, IMI MathCode Duel has the potential to become a valuable resource for classroom instruction, student competition preparation as well as for contributing to the broader digital transformation in education.

Given that related literature highlights that gamification and competition-based learning lead to increased student motivation, and considering that the goals of mathematics and informatics competitions often emphasize the popularization of these disciplines, we expect that peer competition within the IMI MathCode Duel platform will positively influence students' interest in exploring these subjects more deeply. This constitutes the focus of our future research.

ACKNOWLEDGMENT

This work was supported by the Serbian Ministry of Education, Science and Technological Development (Agreement No. 451-03-137/2025-03/ 200122).

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