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Design and Implementation of a Web-Based Platform for Formative Mathematics Practice and Error Analysis

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Abstract: *This paper presents Beyond Right and Wrong, a web-based platform developed to support formative mathematics practice through the analysis of correct and incorrect problem solutions. The platform is based on a task model in which students not only identify the correct solution but also analyze the offered erroneous solutions and recognize the types of errors they contain. In this way, mathematics practice is directed toward understanding solution procedures, typical misconceptions, and the nature of student errors. The paper presents the educational rationale of the platform, the task structure, user roles, and the basic workflow that connects teachers' task preparation, students' analysis, and formative feedback. The system architecture is also described, comprising separate client and server layers, with support for access control, task management, result tracking, and the presentation of mathematical content. The proposed platform may help teachers identify common student difficulties and plan targeted instructional activities, while its practical effectiveness remains to be examined through future classroom implementation. Future work will focus on pilot implementation in a real classroom setting and the evaluation of its usability, acceptance, and educational effects.*

Keywords: *mathematics education; educational technology; web-based learning; error analysis; formative feedback*

1. INTRODUCTION

Digital technologies have become an important part of the educational process, especially in areas where it is necessary to provide interactive learning, continuous progress monitoring, and timely feedback. In mathematics education, their role can be particularly significant, since learning mathematics involves not only acquiring procedures and producing correct results, but also understanding solution procedures, recognizing patterns of thinking, and identifying errors that occur during problem solving.

In the traditional approach to practicing mathematical tasks, attention is often focused on the final answer: students usually receive information about whether their answer is correct or incorrect, while the nature of the error, the reasoning that led to it, and any underlying misconception are not always systematically analyzed. However, errors in mathematical reasoning can have significant educational value. They provide teachers with insight into how students understand a particular concept or procedure, while helping students recognize the difference between formally similar but mathematically different solutions. Therefore, the analysis of erroneous solutions should not be viewed only as a way of identifying deficiencies, but as an integral part of the learning process: when students are asked to compare several offered procedures, identify the correct solution, and explain the nature of errors in erroneous solutions, practice becomes focused on deeper understanding. This approach is particularly important in formative learning, where feedback serves to guide further work, rather than merely to evaluate the achieved result.

Existing digital platforms provide various forms of support for learning mathematics. General learning management systems enable the organization of teaching materials, communication, tests, and monitoring of student activities, while specialized mathematics tools often offer interactive tasks, visualization, and automatic answer checking. Nevertheless, there remains a need for digital environments in which error analysis is systematically integrated into the learning process itself, so that teachers can define characteristic erroneous procedures in advance and students can recognize and understand them during their work.

This paper presents *Beyond Right and Wrong*, a web-based platform intended for formative

mathematics practice through the analysis of different solution procedures. The platform is based on the idea that students should not only identify the correct solution, but also analyze the offered solutions, detect erroneous procedures, and recognize the types of errors they contain. In this way, mathematics practice shifts from simple correctness checking toward understanding procedures, analyzing errors, and developing critical thinking.

The aim of the paper is to present the concept, design, and educational role of a platform that connects mathematics practice, error analysis, and formative feedback. Special emphasis is placed on how the pedagogical idea of learning from errors can be translated into a functional digital environment for teachers and students. The contribution of the paper lies in presenting a platform model that integrates the creation of tasks with correct and erroneous solutions, the recognition of typical errors and misconceptions, structured feedback, and tracking of student progress.

2. RELATED WORK

2.1. Digital Learning Platforms and Mathematics Practice

Digital technologies play a significant role in contemporary mathematics learning, particularly when they support interactive practice, individualized pacing, automatic answer checking, and feedback. Meta-analyses examining the use of educational technologies in mathematics education show that digital tools can have a positive effect on student achievement, especially when they are not used merely as substitutes for traditional teaching materials, but as tools that support active learning, practice, independent work, and progress monitoring [1], [2], [3].

In the context of mathematics education, systems that provide students with structured support during problem solving are particularly important. Intelligent tutoring systems and cognitive tutors have been developed to provide individualized guidance through the learning process, monitor student progress, and offer feedback in response to identified difficulties [4], [5]. Research shows that such systems can be effective in supporting learning but also indicates that their development requires careful modeling of knowledge, student procedures, possible solution strategies, and typical errors [6].

In addition to research-based tutoring systems, various digital platforms for organizing instruction and supporting mathematics practice are widely used in educational settings. General learning management systems, such as Moodle and Google Classroom, support the distribution of teaching materials, communication, assignment of activities, and monitoring of student work. On the other hand, platforms and tools such as Khan Academy, GeoGebra, Photomath, and similar digital environments provide different forms of support for mathematics learning, ranging from video explanations and automatically checked tasks to dynamic visualization, interactive exploration, and step-by-step solution support. GeoGebra stands out as an example of a dynamic mathematics environment that connects modeling, visualization, and interactive work with mathematical content [7].

Although these environments have significant educational value, their primary focus is most often on organizing instructional activities, explaining content, visualizing concepts, providing practice opportunities, or checking answer correctness. Less attention is devoted to the systematic inclusion of teacher-defined erroneous solutions and the explicit analysis of typical student errors as part of mathematics practice itself. In such systems, an error is most often registered as an incorrect answer, while its nature, cause, and connection with the student's understanding are not always analyzed systematically enough.

For this reason, there is a need for platforms that do not offer only a set of tasks or automatic answer checking, but also enable teachers to include different solution procedures, characteristic erroneous solutions, and typical errors in the task design itself. Such an approach is particularly important in mathematics, where an incorrect answer is often not random, but results from a misapplied rule, incomplete conceptual understanding, or a procedural misconception. In this respect, the digital platform presented in this paper builds on existing directions in educational technology, while focusing on a specific need: the structured analysis of correct and erroneous solutions as part of mathematics practice.

2.2. Error Analysis and Formative Feedback in Mathematics Learning

Errors in mathematics learning can have an important diagnostic and educational function. They not only indicate that a student has failed to obtain the correct result, but can also reveal how the student understands a mathematical concept, which procedures are being applied, and where the reasoning deviates from a correct procedure. For this reason, in contemporary approaches to learning, errors are increasingly viewed as a potential source of learning, rather than merely as elements to be eliminated.

A particularly important line of research concerns the use of erroneous examples. In such activities, students analyze not only correct procedures but also erroneous ones; they are expected to detect, explain, and correct errors in the offered solutions. Adams and colleagues showed that working with

erroneous examples in a web-based tutoring system can improve mathematics learning, as it encourages students to think about the reasons why a particular procedure is incorrect [8]. A similar approach appears in studies on decimal learning, where erroneous examples have been shown to have delayed positive effects on learning, particularly when students have the opportunity to understand and explain the nature of the error [9].

Error analysis is especially important in areas in which students often develop stable misconceptions. In a study on fraction arithmetic, Di Lonardo Burr and colleagues examined the role of computer tutors in addressing misconceptions, emphasizing that digital support can be useful when it does not merely inform students that an answer is incorrect, but guides them toward understanding why a particular line of reasoning is wrong [10]. Further recent research shows that learning from errors can be supported through adaptive computer-based systems, in which the transition between independent problem solving and explicit instruction is based on students' procedures and errors [11].

Formative feedback is a key element of this approach. Unlike feedback reduced to a correct/incorrect indication, formative feedback should help students understand their answers and guide the next steps in learning. Hattie and Timperley emphasize that feedback has the greatest value when it helps students understand where they currently are, what the learning goal is, and what they need to do to make progress [12]. Shute stresses that formative feedback should be supportive, specific, and directed toward improving learning, rather than merely evaluating performance [13]. In digital environments for mathematics learning, this type of feedback may include an explanation of the correct solution, an indication of the error type, a comparison of different procedures, and a recommendation for further work [14].

In relation to existing research, the platform presented in this paper connects two important directions: digital mathematics practice and learning through error analysis. Its specificity lies in the fact that the teacher defines in advance not only the correct solution, but also erroneous solutions and the error types they contain. In this way, the error becomes part of the task structure and planned instructional activity, rather than merely a consequence of unsuccessful problem solving. Students are guided to compare different procedures, identify the correct solution, and understand the nature of errors in the remaining answers, thereby connecting practice with the development of analytical thinking and a deeper understanding of mathematical concepts.

3. PLATFORM CONCEPT AND DESIGN

Building on the educational approach described above, the platform was designed around a task model in which correct and erroneous solutions are structured in advance as elements of student analysis. This model makes it possible to combine, within a single activity, the selection of the correct procedure, the recognition of errors, and the provision of feedback.

The central element of the platform is the mathematical task (Figure 1). Each task includes a problem statement, one correct solution, several erroneous solutions, explanations, and error types associated with the erroneous procedures. This structure allows the task to be used not only for knowledge assessment, but also for guiding students toward the comparison of different procedures. Students are expected to identify which procedure is mathematically correct, but also to understand why the remaining solutions are incorrect.

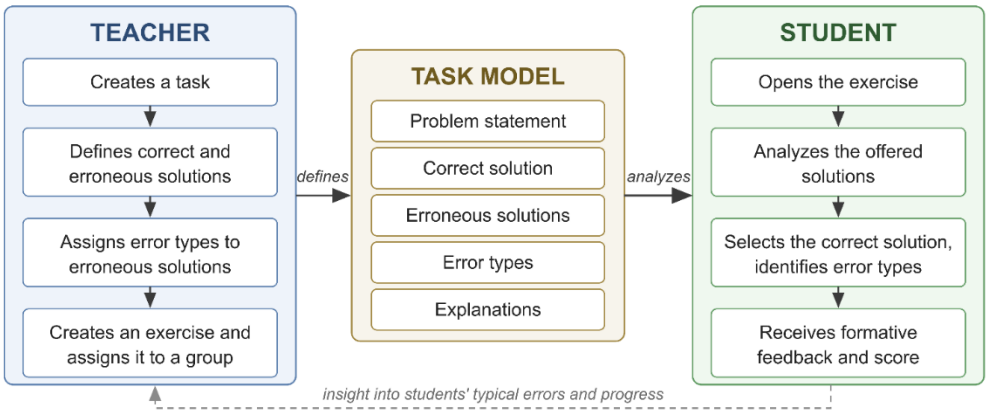


Figure 1. *Conceptual model of the platform workflow*

The platform includes three basic user roles: teacher, student, and administrator. The teacher designs instructional activities by creating areas, entering tasks, defining offered solutions, and linking erroneous procedures to the corresponding error types. The teacher then creates an exercise

from the selected tasks and assigns it to a specific group of students. In this way, the teacher prepares in advance not only the content for practice, but also the framework for analyzing student errors.

The student accesses the assigned exercise and examines the offered solutions for each task. The student's work does not end with selecting the correct answer. In addition, the student is expected to identify the errors present in the erroneous solutions. This workflow requires more careful reading of the offered procedures and encourages the student to distinguish correct reasoning from a misapplied rule, an incomplete procedure, or another type of misconception.

The administrator has a supporting but important role in maintaining the basic structure of the system. The administrator manages users, subjects, and access rights. In this way, responsibilities are clearly separated: the administrator provides the organizational framework of the platform, the teacher prepares instructional activities, and the student participates in the process of solving tasks and analyzing different solutions.

A particular value of this design lies in the way erroneous solutions are treated (Figure 2). In traditional multiple-choice tasks, incorrect answers often serve as distractors. In this platform, they have an additional educational function, because they are linked to specific error types and misconceptions. For example, an erroneous solution may result from a computational error, a misapplied rule, a misunderstanding of a concept, or a skipped step in the procedure. Thus, an error is not viewed only as an incorrect outcome, but as an indicator of a way of thinking that the student should recognize and understand.

Feedback is designed in accordance with the task structure. After completing an exercise, students receive insight into the correct solution, explanations, and their success in recognizing error types. In this way, feedback does not remain limited to the overall score, but shows students in which parts of the analysis they were successful and where they had difficulties. At the same time, this model can be useful for teachers, as it indicates the errors that students find most difficult to recognize.

The platform design enables teachers to adapt instructional activities to problems that actually occur in the classroom. If students often make mistakes in applying a particular rule or misunderstand a particular concept, the teacher can include such an error in the task as one of the offered erroneous solutions. In this way, the platform can be used not only for additional practice, but also for the targeted clarification of characteristic misconceptions.

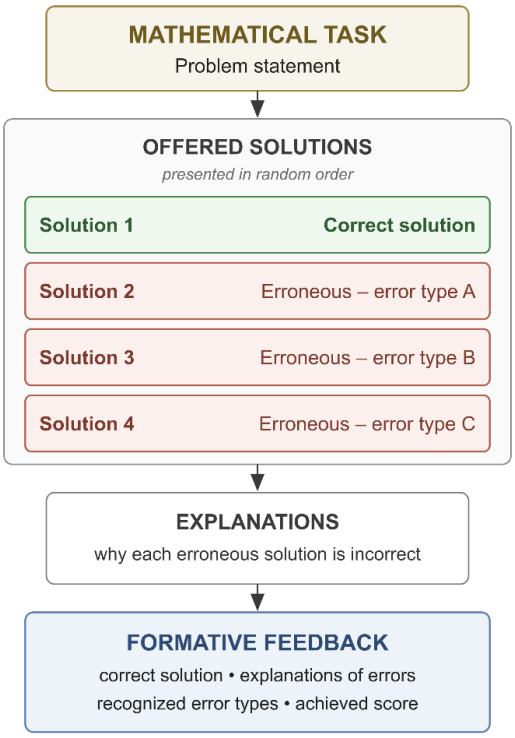


Figure 2. *Structure of a task based on correct and erroneous solutions*

This concept connects three elements: teacher design of tasks, student analysis of offered solutions, and feedback based on recognized errors. Therefore, the platform does not function only as a space for solving tasks, but as a digital environment in which mathematics practice is directed toward understanding procedures, comparing solutions, and analyzing errors.

4. SYSTEM ARCHITECTURE AND IMPLEMENTATION

The platform is implemented as a web application with separate client and server layers. This architecture enables a clear separation of the user interface, application logic, and data, which facilitates system maintenance, functional extension, and adaptation to different user roles. The client application was developed as an Angular single-page application, while the server side was implemented using the Laravel framework and a MySQL database. NgRx is used for client-side state management, JWT for authentication, Eloquent ORM for data access, and MathJax for rendering LaTeX-based mathematical expressions. The client application provides the user interface and handles user interaction, while the server-side application manages business logic, authentication, authorization, and database operations. Communication between the two layers is handled through a REST API, with data exchanged in JSON format.

The platform architecture can be represented through three interconnected layers: the user interface, application logic, and the database. The user interface includes different views intended for teachers, students, and administrators; the application layer processes requests, access rights, tasks, exercises, and results; and the database stores users, instructional content, offered solutions, error types, and work results. An overview of these layers and their interconnections is shown in Figure 3.

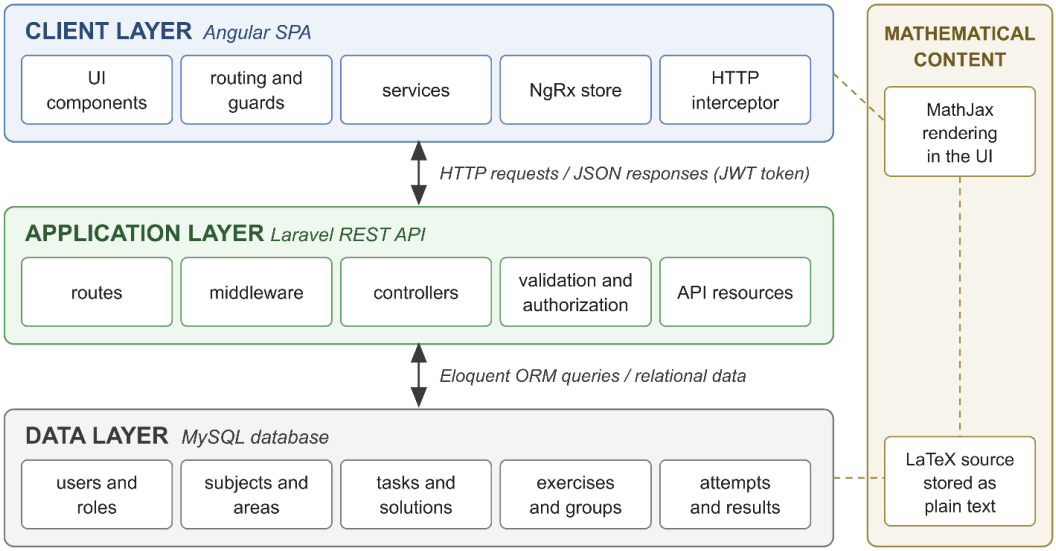


Figure 3. *System architecture of the platform*

On the client side, the system is organized into functional units that correspond to the main parts of the platform: users, tasks, groups, exercises, and results. This organization allows each unit to be developed and maintained independently, while common elements, such as authentication, navigation, and communication with the server, are used at the level of the entire application. Access to individual functionalities depends on the user role, so students, teachers, and administrators have different workflows and different sets of available options.

The server side of the application provides request processing and storage of the data required for the platform to function. The data model includes users and their roles, subjects and areas, tasks, offered solutions, error types, student groups, exercises, and work results. These entities are interconnected so as to support the basic educational workflow of the platform: the teacher prepares tasks and exercises and assigns them to groups, the student completes the exercise, and the system stores the results and enables the display of feedback. In this way, the data model is not merely a technical structure for storing information, but follows the educational workflow on which the platform is based.

Special attention is given to the presentation of mathematical content. Since tasks and solutions may contain formulas, the system supports the input of mathematical expressions in LaTeX format. Such notation is stored as textual data and then rendered in the user interface in a clear and readable form. This is important for the usability of the platform in mathematics education, as it enables the precise presentation of formulas in problem statements, offered solutions, explanations, and feedback.

Security and access control are implemented through authentication and role-based authorization. This ensures that teachers can access functions for creating and organizing instructional activities, students can access functions for solving assigned exercises, and administrators can access functions for managing the basic elements of the system. This division is important not only from a technical perspective, but also from an educational perspective, as it preserves a clear distinction between the preparation of instructional content, student work, and system administration.

This architecture enables the platform to be further developed without changing its basic model. In the future, the existing structure may be extended with more advanced analytics of student errors, adaptive task recommendation, expansion to other areas of mathematics, or integration with existing educational systems.

5. EDUCATIONAL POTENTIAL AND FUTURE WORK

The educational potential of the platform lies in the possibility of organizing mathematics practice as a process of analysis rather than merely as a means of checking answer correctness. During their work, students are guided to examine several offered solutions, distinguish between correct and

erroneous procedures, and relate errors to specific ways of thinking. Such an approach may contribute to the development of more careful mathematical reasoning, since students are not merely informed which answer is correct but are also encouraged to understand why the remaining procedures are incorrect.

From the teacher's perspective, the platform can be useful for formative monitoring of student work. The error types that students recognize or fail to recognize can provide teachers with additional insight into which concepts, rules, or procedures are problematic. Based on this, teachers can adapt further work, revisit certain areas, or create new exercises focused on specific misconceptions. In this way, the platform serves not only as a tool for individual practice, but also as support for teachers in planning subsequent instructional activities.

A particular advantage of this approach is the possibility of targeted use of typical student errors. In teaching practice, certain errors occur repeatedly, especially in areas that require the understanding of rules, symbolic notation, or multi-step procedures. When such errors are included in a task in advance, students have the opportunity to analyze them in a controlled environment, without perceiving the error solely as a sign of failure. In this way, the error becomes part of the instructional material and a means for developing deeper understanding.

A current limitation of this work is that the platform is presented through its concept, design, and implementation, while its educational effects have not yet been empirically examined in a real classroom setting. Therefore, the next step should involve a pilot implementation of the platform in teaching and learning settings. Such a study would enable the evaluation of system usability, the quality of feedback, user acceptance of the proposed approach, and its possible impact on the understanding of mathematical concepts and the recognition of errors.

Further development of the platform may proceed in several directions. One direction concerns the expansion of the task repository and the systematization of error types across mathematical areas. A second direction involves the development of more advanced analytics, through which teachers could obtain an overview of the most frequent errors at the level of an individual student, a group, or an instructional area. A third direction may include adaptive task recommendation, so that after making certain errors, students receive additional tasks focused on the same or related concepts. In later stages of development, integration with existing learning management systems may also be considered, as well as the use of artificial intelligence methods for analyzing freely entered student solutions.

In this way, the platform may evolve from a tool for structured practice into a broader digital environment for formative mathematics learning, in which data on student errors are used to better understand the learning process and to plan instructional support.

6. CONCLUSION

This paper presented *Beyond Right and Wrong*, a web-based platform developed to support formative mathematics practice through the analysis of correct and erroneous problem solutions. The platform is based on the idea that mathematics practice should not be limited to selecting the correct answer, but should enable students to examine different procedures, recognize typical errors, and understand their nature.

The contribution of the paper lies in presenting a platform that integrates the educational concept of learning from errors, a task model based on offered solutions, and a technical architecture adapted to working with mathematical content. The platform enables teachers to design tasks and typical errors in advance, while providing students with a structured environment for solution analysis and feedback. In this way, the digital environment is intended to support not only knowledge assessment, but also the development of understanding, analytical thinking, and targeted instructional intervention.

Although the paper presents the concept and implementation of the platform, the next step is its application in a real classroom setting. Future research should include the evaluation of usability, acceptance by teachers and students, and the educational effects of the platform on error recognition and the understanding of mathematical concepts. Further development may include expanding the task repository, more detailed analytics of student responses, and adaptive support for learning.

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