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Active Learning With a STEM Exercise Pool for Schools and Universities

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ABSTRACT

The STEM Exercise Pool is a digital, interactive teaching and learning resource for mathematics education in the first year of STEM and teacher training degree programs, as well as for upper secondary school. Developed by a team of experts from several universities, it comprises nearly one thousand quality-reviewed tasks featuring automatic grading, differentiated feedback, and dynamic visualizations. The pool supports a wide range of instructional scenarios, is available in multiple languages, and can be seamlessly integrated into common learning management systems. Technological innovations such as randomized task parameters, LaTeX and Python support, and a web-based authoring tool for collaborative content creation make it a forward-looking instrument for modern, efficient, and motivating STEM education. An integrated AI tutor for the exercise pool, similar to the one already in use in the bridge course OMB+, is currently under development.

1 | Introduction

Over the past decades, digitalization has become an integral part of teaching and learning at the university level. Modern online learning tools reflect this development and provide opportunities that extend far beyond those of traditional textbooks. They enable a high degree of temporal and spatial flexibility while still maintaining strong interaction and engagement with learners, and thus provide ways to counter the ever-increasing demands on modern STEM teaching: differing prior knowledge across the audience, growing student numbers, and the need for practice-oriented, interactive teaching require new concepts and instructors face the challenge of enabling the most efficient learning processes possible with limited resources.

In this article, we present a digital exercise pool specifically designed for mathematics education in the first year of STEM degree programs at (German) universities as well as for upper secondary education. The focus is on high-quality, interactive exercises with automatic grading and meaningful feedback, which can be used flexibly and adapted in a variety of ways: The material can be adjusted to the individual needs of lecturers and many different instructional scenarios, see section *Instructional Concepts and Use Cases*. Thus, the exercise pool aims to make reliable educational resources accessible and easy to share across institutions. It provides an innovative response to the developments mentioned above by combining high-quality academic content with powerful technology and modern instructional approaches — for future-oriented, effective, and motivating teaching.

An additional challenge in the development of a system such as the one presented here is its relation to AI tools like ChatGPT, Claude, or Google NotebookLM. What is the added value of the exercise pool beyond the tools already available to learners and teachers? We address this question in the section *AI and the Exercise Pool*.

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2 | The STEM Exercise Pool

The STEM Exercise Pool is a digital teaching and learning platform for the first year of STEM studies and upper secondary education, available at https://pool.mumie.net. It was created by experienced university lecturers in close collaboration with the company integral-learning GmbH, which is a spin-off of TU Berlin, RWTH Aachen University, TU Munich, and the University of Potsdam. It grew out of a project funded by the German Federal Ministry of Education and Research (BMBF).

The pool contains nearly one thousand quality-assured exercises for active learning. They can be individually parameterized, automatically graded, and many provide learners with individual feedback to their answers. However, an important aspect of the pool is that it is not merely a repository of isolated exercises. Rather, it provides a structured environment in which exercises can be searched, selected, adapted, combined into worksheets, and reused in different teaching contexts. This distinguishes the pool from a static collection of files: the same basic material can serve different purposes, ranging from unguided self-study to assessed homework, diagnostic tests, or examination preparation. The pool therefore supports the sustainable reuse of teaching resources across courses and institutions.

The organization of the pool by topics, learning objectives, and difficulty levels of the exercises also facilitates curricular alignment. Instructors can select material that fits the progression of their own course and combine basic procedural exercises with more conceptual tasks. This is especially useful in the transition from school to university mathematics, where courses often need to address gaps in prior knowledge while at the same time introducing more abstract forms of mathematical reasoning.

The parameterization of exercises is particularly important for mathematics learning. In many topics, students need repeated practice with the same underlying concept or method, but simple repetition of an identical numerical problem quickly loses its value. Randomized parameters allow the system to generate new instances of a task while preserving its mathematical structure and level of difficulty. This makes it possible to combine repetition with variation: learners can practise until they recognize the method rather than memorizing a specific solution.

Many of the exercises are available not only in German, but also in English, French and Chinese. They offer a wide range of training and testing environments with interactive visualizations of complex mathematical concepts. The exercise pool covers topics from higher mathematics as typically taught in the first and partly second semester of STEM degree programs at universities—particularly calculus, linear algebra and basic statistics. In addition, it also includes topics from business mathematics. Some mathematics problems in the pool can be solved using Python. This allows learners to engage early on with a programming language that is widely used in data science, numerical mathematics, and AI-related applications.

Multilingual availability of the content is not only a matter of accessibility but also a pedagogical advantage. Mathematical terminology is often a source of difficulty for students, especially in international programs or in the transition from school to university. Parallel language versions allow learners to compare terminology and formulations across languages, while instructors can use the same mathematical content in different linguistic settings. This increases the reusability of the material and supports internationalization in STEM education.

Several existing online courses, developed, maintained, and used by German as well as international academic institutions, feed their exercises into the pool. These include, for instance, OMB+[1] [1], HM4mint[2] [2] or oHMint[3] [3], providing the pool with a large variety of quality-assured content that has already been used by tens of thousands of students in the past and thus making it a reliable and diverse source for teaching materials from the start.

2.1 | Instructional Concept and Use Cases

Learners in upper secondary school and in the first years of university education often encounter difficulties because they have not yet developed a sufficiently secure understanding of fundamental mathematical concepts and procedures. A substantial part of the exercise pool is therefore designed to consolidate basic concepts through relatively simple applications and to provide systematic practice in standard mathematical procedures. This is a deliberate feature of the pool: procedural fluency and the reliable application of fundamental methods remain important prerequisites for more advanced mathematical reasoning.

At the same time, the pool is not restricted to procedural practice. It also contains conceptual and application-oriented exercises, including multiple-choice and short-answer tasks, that can be used to examine whether students understand definitions, theorems, and the relationships between different representations. Such conceptual checks are important because students may be able to perform a calculation correctly without fully understanding the underlying mathematical structure.

The pool flexibly supports several pedagogical scenarios: traditional exercise formats with or without submission deadlines, flipped classroom models [4], training environments with randomized exercises for repeated practice, automatic assessment, and diagnostic worksheets at the beginning of a course. Such diagnostic worksheets can help instructors identify differences in prior knowledge before central course topics are introduced. This is particularly useful in first-year STEM education, where students often enter with heterogeneous backgrounds from different school systems or preparatory programs. The results of such diagnostic activities can inform the selection of subsequent exercises and help instructors decide whether certain prerequisite topics should be reviewed.

A key pedagogical advantage is that the same exercise can be configured differently depending on the teaching purpose. In a training context, immediate feedback and repeated attempts may be desirable. In an assessment context, the number of attempts, the visibility of hints, or the timing of feedback may be restricted. This configurability allows instructors to distinguish clearly between practice, formative assessment, and summative assessment while still relying on the same underlying pool of exercises.

The exercises can also be used during tutorials or in-class sessions. For example, instructors may select one task as a common starting point, let students work individually or in small groups, and then discuss typical strategies and errors collectively. In this setting, the digital exercise does not replace classroom interaction but provides a shared object around which discussion, explanation, and comparison of solution strategies can be organized.

A further pedagogical use case is the construction of differentiated learning paths. Instructors may provide basic exercises for students who need to consolidate prerequisite knowledge while offering more conceptual or application-oriented tasks to students who are already confident in applying the relevant procedures. Since exercises can be selected according to topic, learning objective, and difficulty, the same pool can support remedial practice, regular coursework, and enrichment activities within the same course.

Exercises can be assembled into individually tailored worksheets with just a few clicks. Instructors may adapt the content and provide it directly through learning management systems such as Moodle, ILIAS, or Stud.IP. This enables flexible integration into existing teaching formats and supports instructional approaches such as the spiral curriculum [5], as well as the application of principles derived from cognitive load theory [6]. Worksheets created from the exercise pool can also be configured for online examinations: working time can be defined, exercises can be individualized, and the order of tasks can be randomized.

Helpful feedback is of particular importance for learning success and has been a central concern of the authors from the beginning of the exercise pool project. Responses to incorrect answers should not merely indicate that an answer is wrong but should support students in identifying the next meaningful step. Many exercises in the pool therefore contain differentiated feedback that is displayed depending on the student's answer. If a submitted answer corresponds to an anticipated error pattern, the system provides error-specific feedback; in other cases, it gives a more general strategic hint.

Until recently, such feedback could only be implemented in the exercise pool in a rule-based way. For each exercise, authors had to anticipate typical errors and construct a decision tree connecting these errors with suitable feedback messages. Although this approach can be very effective, its systematic implementation is extremely labor-intensive. For a large and diverse pool, the complete realization of such a feedback system is therefore limited by the enormous authoring effort required. A qualitative improvement of this situation is now becoming possible through the use of automatic tutoring systems that act in a Socratic manner, such as the AI tutor already available in the bridge course OMB+ (see next section).

An example of implemented feedback is shown in Figure 1 (right), where the student is encouraged to exploit the particular structure of the matrix when computing its determinant. In this example, the feedback should be understood as a strategic hint rather than as a reliable diagnosis of the specific error that produced the incorrect numerical answer. More complex exercises may provide genuinely error-sensitive feedback when their authors have anticipated typical incorrect answers, when the task collects intermediate results that make particular errors identifiable, or when an AI-based tutor can use the structured exercise context to guide the learner through the relevant reasoning steps.

This form of repeated practice may also support self-regulated learning. Students can decide when to repeat an exercise, compare several variants of the same task type, and monitor whether their performance improves over time. The immediate availability of new instances lowers the threshold for additional practice and gives learners greater control over the pace and intensity of their learning process.

Concerning the future development of the exercise pool, we regard a stronger focus on systematic alignment with competence-oriented learning objectives as a particularly important aspect. One planned extension is to use an AI tutor to suggest to the students competence-oriented tasks related to the exercise they are currently working on. Such a task may, for example, ask them to explain a solution strategy, compare different representations, interpret a result, justify the choice of a method, or transfer the underlying concept to a new context. In this way, procedural practice can be complemented by activities addressing reasoning, problem-solving, interpretation, and transfer.

Because the pool addresses both upper secondary education and the initial phase of university mathematics, it also supports the transition between these educational stages. Its exercises can be used to revisit school topics in a university context, gradually introduce more formal notation, and connect familiar procedures with the more abstract expectations of higher mathematics. This makes the pool suitable not only for regular courses but also for bridge courses and preparatory programs.

2.2 | AI and the Exercise Pool

Many students use AI tools for learning and for solving homework problems. Teachers use AI tools to generate and correct exercises. So, what is the added value of the exercise pool?

In contrast to the output of general large language models, the exercises in the pool are quality-assured by experienced teachers; notation and style can be adapted to the course, answers are automatically graded, and the grades can be synchronized, for example, with the Moodle grade book. In many cases the grading includes differentiated feedback.

However, AI offers excellent complementary possibilities, in particular if AI tools are deeply integrated in the course material and are to a very high degree free from hallucination and computational errors. Both hallucination and computational errors are of particular importance in mathematics learning and teaching since both erode trust in the system and reduce acceptance by users.

The exercise pool can therefore serve as a grounding layer for AI-based support. Instead of asking an open language model to solve an arbitrary mathematical problem, an AI tutor can

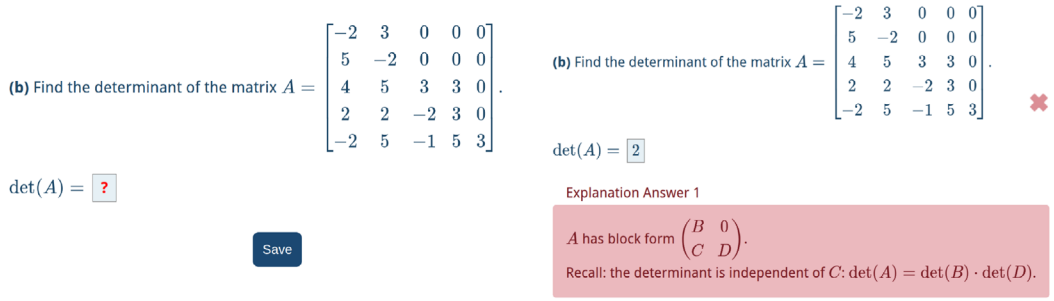


FIGURE 1 | Example of an exercise that can be repeatedly solved with randomized parameters (left) and feedback providing a strategic hint after an incorrect answer (right).

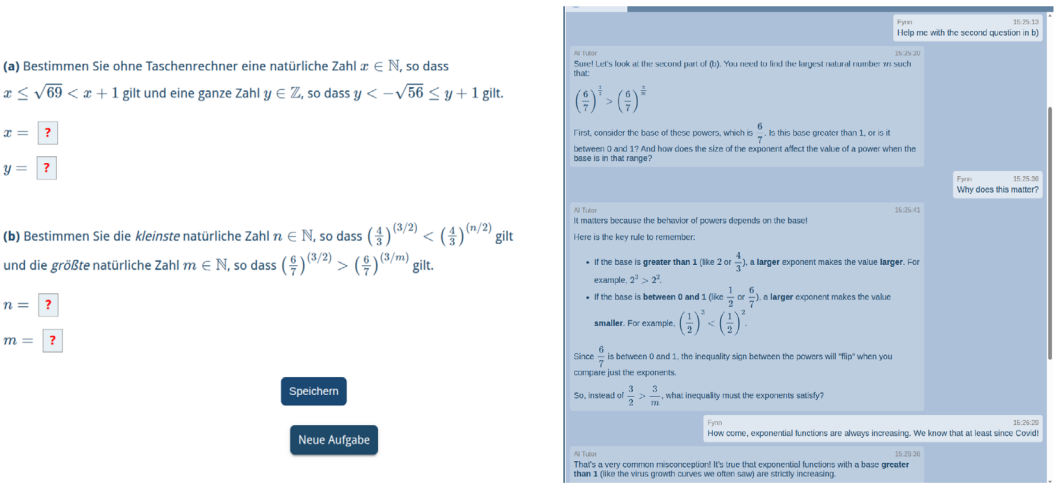


FIGURE 2 | Example of a socratic dialogue with the AI tutor.

operate in the context of a specific, quality-assured exercise whose task statement, parameters, expected solution path, and feedback structure are already known. This makes it possible to restrict the dialogue to the relevant mathematical context and significantly reduce the risk that the AI system introduces unrelated methods, unsuitable notation, or incorrect assumptions.

An example in which these conditions are met is the AI tutor, which has recently been integrated into the bridge course OMB+ [1]. There, students are assisted by the tutor while working on individualized problems. If they tell the AI tutor, for example, "help me with the second question in problem b)" see Figure 2, they will get help in the form of a Socratic dialogue. The AI tutor will not tell them the solution directly, but leads students on a solution path through questions and answers.

This distinction between producing a solution and supporting the solution process is crucial. In a learning context, the fastest answer is not necessarily the most helpful one. If a student receives a complete solution too early, the opportunity to identify relevant concepts, choose an appropriate method, and carry out the argument independently may be lost. A useful AI tutor should therefore support productive struggle: it should help students overcome obstacles while preserving their responsibility for the essential mathematical steps.

For use in regular teaching, an important additional feature would be configurability by instructors. Depending on the course setting, teachers may want to allow only general hints, permit step-by-step support, or restrict AI assistance during assessed work. Such configurability would make it possible to align AI support with the instructional purpose of a worksheet and with local examination rules.

We conclude this section with a few remarks on the technology behind the AI Tutor. Its architecture is based on an agentic AI framework in which several open-source Large Language Models (LLMs) work together with deterministic code—used to verify mathematical computations—to provide accurate answers to students' questions and guide them step by step towards the solution. As new models emerge rapidly, the underlying LLMs can be replaced easily through a configuration file. At present, the system primarily relies on models from the GLM and Llama families. All models and the supporting code are hosted on European servers and comply with the requirements of the DSGVO.

2.3 | Relation to Previous Research

The pedagogical and technical design of the STEM Exercise Pool is guided by established findings from educational research

rather than by technological considerations alone. Interactive exercises with immediate feedback support active engagement of learners, an approach that has repeatedly been shown to improve learning outcomes in STEM education compared with passive instruction [7]. The possibility of solving multiple randomized instances of the same exercise is closely related to the principle of deliberate practice, enabling learners to consolidate procedural skills while avoiding simple memorization of fixed solutions [8].

The differentiated feedback implemented in the exercise pool follows principles of formative assessment. Effective feedback should not merely indicate whether an answer is correct, but should help learners identify appropriate next steps in the learning process [9]. The opportunity to repeat exercises, monitor progress, and work independently also supports self-regulated learning, which has consistently been identified as an important predictor of academic success [10].

The planned integration of an AI tutor builds upon several decades of research on intelligent tutoring systems. One of the pioneers in this research area was Erica Melis [11] at the DFKI in Saarbrücken. Meta-analyses have shown that tutoring systems providing individualized guidance and scaffolded problem solving can substantially improve learning outcomes, particularly in mathematics and STEM education [12, 13]. More recent research on generative AI demonstrates that large language models can become effective learning companions when they are embedded in a pedagogically designed environment with appropriate instructional guardrails. Conversely, unrestricted conversational AI may improve homework performance while impairing conceptual learning [14]. These findings support the central design principle of the present work: combining quality-assured mathematical exercises, automatic assessment, and context-aware AI tutoring within a structured learning environment rather than relying on general-purpose AI systems alone.

2.4 | Technological Innovations

The technical implementation of the exercise pool provides numerous innovative features: exercises can be generated with new parameters each time they are accessed, ensuring that repeated practice always provides fresh learning stimuli. Automatic grading with individualized feedback saves time and promotes autonomy in the learning process. The exercise pool also supports Python-based tasks and LaTeX integration. Interactive 2D and 3D visualizations can be created and embedded without significant prior programming knowledge.

Automatic grading in mathematics requires careful handling of equivalent representations. A correct answer may be written in several algebraically equivalent forms, and numerical answers may require tolerances or exact formats depending on the task. The grading logic must therefore distinguish between mathematical equivalence, acceptable simplification, and typical incorrect answers. This is particularly important when feedback is intended to respond not only to correctness, but also to the kind of error made by the learner. For the validation of answers we use a combination of rule-based checks and symbolic transformations, as well as numerical checks of formulas.

The generation of randomized parameters requires more than replacing fixed numbers by arbitrary values. Parameter ranges must be chosen so that each generated instance remains mathematically meaningful, solvable, and comparable in difficulty. For example, denominators must not vanish, systems of equations must have the intended type of solution, and graphical objects must remain visible within a useful range. Authors design the tasks individually such that these criteria are met and during quality review special attention is devoted to checking them. The technical framework of the exercise pool therefore combines randomization with mathematical constraints and rigorous validation mechanisms.

A further technical advantage is the separation between the central exercise pool and the local learning management system. Institutions can integrate selected exercises into their existing digital infrastructure without having to replace established platforms such as Moodle, ILIAS, or Stud.IP. This reduces the technical threshold for adoption and makes the pool usable across institutions with different local systems. At the same time, updates and improvements to the exercises can be maintained centrally while teaching activities remain embedded in the familiar course environment of the respective institution.

Whether it is for examinations or regular exercises, all communication between the platform and the local learning management system is carried out in accordance with the European General Data Protection Regulation (GDPR/DSGVO). In particular, all information is encrypted and no real names or matriculation numbers are communicated.

The interface of the exercise pool is available in German, English, French, and Chinese. Its database can be searched using keywords as well as filtered by language, type (exercise vs. worksheet), topic, learning objective, and difficulty of the desired exercise, see Figure 3. Search results are displayed as a list that can be sorted by parameters such as title, date or difficulty of the exercises. These may then be previewed, opened in the authoring tool, or imported directly into local learning management systems.

Since exercises may be reused and adapted in many contexts, maintainability is an important technical requirement. Changes to source files, parameters, feedback rules, or visualizations must remain traceable, especially when exercises are used in several courses or institutions. To this end, the pool relies on a technical infrastructure for previewing, testing, and reviewing modified content, which is essential for keeping the pool reliable as it grows.

2.5 | Adaptation and Quality Assurance

Throughout this paper, the term *quality* refers to mathematical correctness, the correctness and precision of the accompanying text, and pedagogical suitability. For tasks in the exercise pool, the latter is ensured by the long-standing teaching experience of the authors in mathematics education for STEM students, prospective mathematics teachers, and upper secondary school students.

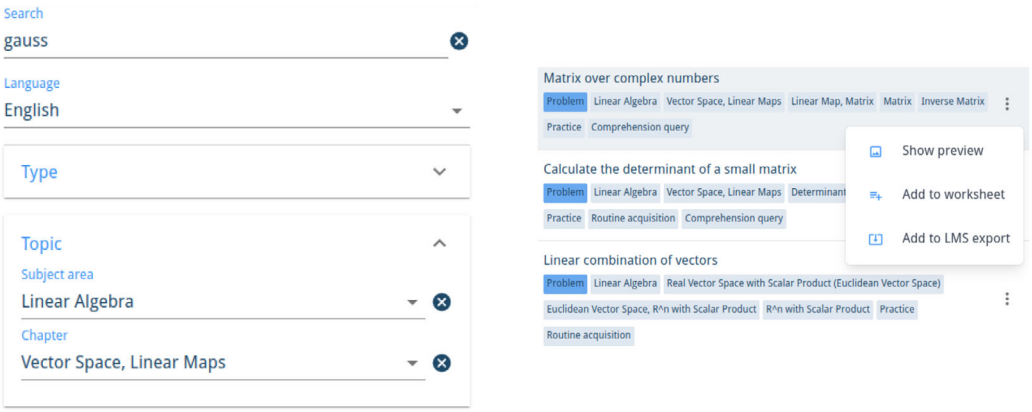


FIGURE 3 | Search and filter the pool (by keyword, language, subject area,…) to preview and select exercises or worksheets to import into a local learning management system.

All learning content in the pool can be created or adapted using a convenient web-based authoring tool, where exercises may also be edited collaboratively. The authoring tool explicitly supports quality management by providing a work flow that allows users to directly assign newly developed (or significantly modified) files to other authors for review and approval. This makes is it easy to distribute responsibilities and track activity through the course of any project that introduces new exercises to the pool. The workflow is similar to the standard workflow in software development: for example, a newly developed exercise is sent to another author for review. They either approve it or ask the first author to modify or correct it. Only after this review cycle has been completed successfully is the exercise added to the pool.

A central challenge for a shared exercise pool is to balance local flexibility with common quality standards. Instructors need the freedom to adapt notation, terminology, examples, or the level of detail to their own courses without risking to compromise the quality of the exercises for others. In the pool, this problem is addressed as follows. A problem edited by an instructor becomes their own version, which they can use in their own course. It does not automatically become part of the general set of problems in the pool – an edited version must go through a review process before it may be added to the pool.

This precautionary measure ensures that the material remains mathematically correct, technically functional, and pedagogically coherent. The authoring and review workflow is therefore not merely an administrative feature, but an essential mechanism for preserving the quality and reliability of the pool as it grows.

The syntax for the source code is based on LaTeX, an example is shown in Figure 4. It is displayed in the left half of the window and can be written using any text editor. A preview of the compiled code is shown and can be tested on the right. A user can individually modify any exercise in the pool: add or delete subtasks, change input parameters, adapt terminology and notation,… As explained above, the modified exercise is then saved in the database, but is accessible only for the person who made the change in order to prevent excessive accumulation of similar (and unreviewed) files throughout the pool.

2.6 | Benefits for Instructors and Learners

For instructors, using the exercise pool means enormous time savings while maintaining high exercise quality. For learners, it creates a motivating, interactive learning environment with direct feedback. The pool promotes self-directed learning, provides clear content orientation through a large number of exercises in many variations, and engages learners through dynamic visualizations, where they can modify parameters and immediately observe the resulting changes in the graph of a function, for instance. This is particularly relevant in large first-year courses, where the number of students often makes individual correction and feedback difficult. The pool helps to scale practice opportunities without reducing all learners to the same fixed set of tasks: randomized parameters, differentiated feedback, and individually configured worksheets allow for combining large-scale teaching with a certain degree of individualization.

For teaching teams, the pool can improve course organization. Exercises, worksheets, feedback settings, and assessment formats can be prepared in a structured way and reused in later semesters. This supports continuity across changing teaching teams and reduces the risk that valuable material disappears when individual lecturers or tutors leave a course.

Another benefit for instructors is the possibility of sharing and comparing teaching material across institutions. A well-structured pool makes successful exercises visible beyond the local course in which they were created. This reduces duplication of work and encourages a more collaborative culture of teaching development in mathematics and STEM education.

When the exercises are used in courses such as the preparatory bridge course OMB+ [1] or the mathematics course for engineers HM4MINT [2], the learning process is supported by a help center with tutors as well as an AI-based tutor, available around the clock. In our view, such a scenario is the best use of the exercise pool: the teaching resources in the pool serve as a complementary part in a blended learning or inverse classroom course combined with an AI tutor. Such a combination of automatic feedback, human tutoring, and AI-based support creates a layered support structure. Routine feedback can be provided immediately by the

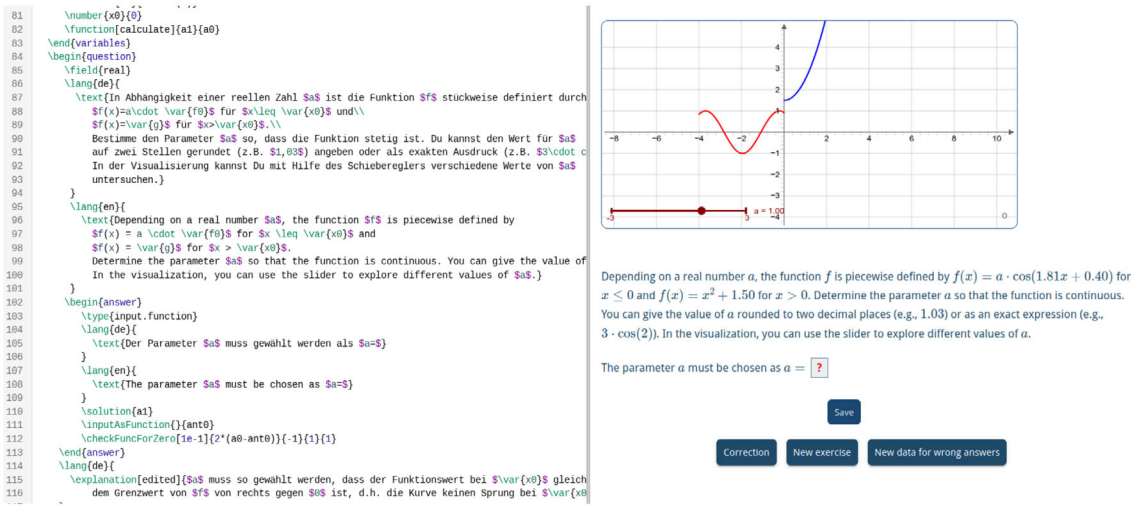


FIGURE 4 | Develop and modify exercises through the online authoring tool: simultaneous display of LaTeX-based code (left) and preview (right). In the task shown here, the slider varying the parameter a can be used by students to verify their calculations by visually confirming that the desired function is continuous.

system; more individual or conceptual questions can be addressed by tutors; and the AI tutor can offer low-threshold guidance outside regular support hours. Such a layered model is especially promising because it does not rely on a single form of support, but combines automated, human, and conversational assistance.

3 | Vision and Outlook

The STEM Exercise Pool aims to fundamentally improve mathematics education in schools and universities. Its goal is to motivate the broad middle range of students through modern methods of active learning. The pool focuses on interactivity, multilingualism, and technological innovation with the primary intention of recognizing, activating and sustainably fostering the potential of individual learners.

The pool is open to all educational institutions and is currently used primarily by universities and universities of applied science. Interested instructors can sign up free of charge and immediately try out its features before integrating it into their teaching. The help center provides comprehensive support for the OMB+ [1] and HM4MINT [2] courses.

A central direction for further development is the integration of an AI tutor into the exercise pool itself—not intending to replace structured exercises, human tutors, or teachers, but to provide additional low-threshold support within a quality-assured mathematical environment. Future versions should make such a tutor increasingly context-aware, so that it can refer to the current task, the student's input, the intended solution path, and the available feedback while still avoiding premature disclosure of complete solutions.

At the same time, the use of AI in mathematics education requires careful safeguards. Responses should remain aligned with the reviewed exercise content, and mathematical statements produced by the tutor should be checked against the structured information available in the system wherever possible. This is particularly important because computational errors or misleading explanations can quickly undermine trust in a learning environment. The exercise pool can provide an appropriate framework for such controlled AI support.

Another important perspective is the continued development of both the content and the usability of the pool. While the current focus is on calculus, linear algebra, business mathematics, stochastics, and related first-year topics, further content can strengthen the connection to applications in engineering, data science, the natural sciences, economics, and teacher education. In particular, Python-based and modeling-oriented exercises offer opportunities to connect mathematical foundations with computational and applied STEM contexts.

However, a growing number of exercises also creates challenges for users. Even with filters for language, topic, learning objective, and difficulty, instructors may still be confronted with many potentially suitable tasks. Selecting the most appropriate exercise or worksheet can therefore require considerable time, especially when several resources address similar content but differ in notation, level of abstraction, type of feedback, or intended teaching scenario. Consequently, the further development of the pool should not focus on quantitative growth alone, but also on improved navigation, curation, and decision support. Here, an AI support for lecturers might be helpful.

In summary, the STEM Exercise Pool combines quality-assured content, flexible adaptation by instructors, randomized and automatically graded exercises, differentiated feedback, multilingual access, integration into local learning management systems, and emerging AI-based support. Its particular strength lies in bringing these elements together in a coherent infrastructure for self-study, tutorials, homework, assessment, bridge courses, and blended learning scenarios.

The pool therefore offers more than additional digital material. It provides a model for organizing mathematical practice, feedback, institutional cooperation, and AI-supported learning in a reliable

and pedagogically meaningful way. In this sense, it can contribute to a more active, accessible, and sustainable mathematics education at the interface between school and university.

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Conflicts of Interest

The authors declares no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

Endnotes

[1] https://ombplus.de

[2] https://hm4mint.nrw

[3] https://www.ohmint.de/ohmint/link/OHMintHOOU

References

1. S. O. Krumke, K. Roegner, L. Schüler, R. Seiler, and R. L. Stens, "Der Online-Mathematik-Brückenkurs OMB – Eine Chance zur Lösung der Probleme an der Schnittstelle Schule/Hochschule," *Mitteilungen der DMV* 20, no. 2 (2012): 115–120.

2. M. Hensgens, "HM4MINT – Höhere Mathematik für MINT-Studiengänge," Proceedings 16, *Workshop Mathematik in ingenieurwissenschaftlichen Studiengängen* (Hochschule Wismar / Gottlob-Frege-Zentrum, 2020), 54–55.

3. H. Barbas, I. Gasser, F. Konieczny, A. Lohse, and R. Seiler, "oHMint: Online Higher Mathematics for MINT Students – An Online Mathematics Course and Learning Platform," in *Proceedings of the 46th SEFI Annual Conference* (SEFI, 2018), 573–580.

4. C. Spannagel and J. Spannagel, "Designing In-Class Activities in the Inverted Classroom Model," in *The Inverted Classroom Model*, ed. J. Handke, N. Kiesler, and L. Wiemeyer, 1. Aufl, (Oldenbourg Wissenschaftsverlag, 2013), 113–119.

5. J. Bruner, *The Process of Education* (Harvard University Press, 1960).

6. T. de Jong, "Cognitive Load Theory, Educational Research, and Instructional Design: Some Food for Thought," *Instructional Science* 38 (2010): 105–134.

7. S. Freeman, S. L. Eddy, M. McDonough, et al., "Active Learning Increases Student Performance in Science, Engineering, and Mathematics," *Proceedings of the National Academy of Sciences* 111, no. 23 (2014): 8410–8415.

8. K. A. Ericsson, *Deliberate Practice and Acquisition of Expert Performance* (Academic Press, 2008).

9. J. Hattie and H. Timperley, "The Power of Feedback," *Review of Educational Research* 77, no. 1 (2007): 81–112.

10. B. J. Zimmerman, "Becoming a Self-Regulated Learner: An Overview," *Theory Into Practice* 41, no. 2 (2002): 64–70.

11. B. M. McLaren, S. Sosnovsky, and V. Aleven, "Preface – Emerging Technologies and Landmark Systems for Learning Mathematics and Science: Dedicated to the Memory of Erica Melis – Part 1," *International Journal of Artificial Intelligence in Education* 24, no. 3 (2014): 211–215.

12. K. VanLehn, "The Relative Effectiveness of Human Tutoring, Intelligent Tutoring Systems, and Other Tutoring Systems," *Educational Psychologist* 46, no. 4 (2011): 197–221.

13. J. A. Kulik and C.-L. C. Fletcher, "Effectiveness of Intelligent Tutoring Systems: A Meta-Analytic Review," *Review of Educational Research* 86, no. 1 (2016): 42–78.

14. H. Bastani, O. Bastani, A. Sungu, H. Ge, Ö. Kabakci, and R. Mariman, "Generative AI Can Harm Learning," *Proceedings of the National Academy of Sciences (PNAS)* 122 (2025): e2422633122.