Prototype of Project AI4Math: Interdisciplinary and Innovative Technology for Accelerated Learning of Mathematics

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Abstract: -As the demand for sustainable education increases, teaching and learning strategies also change and evolve. They are becoming more innovative, creative and technology-based. It is mathematics that is one of the most important subjects with horizontal influence on other sectors, which poses the greatest challenges to educators with the question "How to teach students in such a way that they become interested in mathematics?" As an answer to the question, a new product was created. Using a carefully developed methodology and taking into account the needs of students, the post-doctoral research project "Artificial Intelligence (AI) Support for Approach of Accelerated Learning of Mathematics (AI4Math)", through the cooperation of an interdisciplinary team in the fields of information technology, mathematics, mechatronics, sports and artificial intelligence, a prototype was developed for an innovative technology that arouses emotions in students of different ages, creates a competitive spirit and promotes accelerated learning of mathematics.

The AI4Math prototype combines 3 components: 1) a pressure-sensitive floor platform for jumping out the solutions of mathematical expressions, 2) application for calculation of math expressions, evaluation of answers, accumulation and processing of Big Data, 3) an AI solution for emotion control.

The study makes a valuable contribution to researchers, entrepreneurs and the education industry, as it reveals the conditions necessary for modern and sustainable accelerated learning of mathematics. Given that the AI4Math prototype provides an innovative approach to learning mathematics through physical activity, the survey data indicated support and future development prospects for the interdisciplinary technology.

Key-words: AI4Math, technology prototype, accelerated learning of mathematics, interdisciplinary approach.

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1 Introduction

"Support of Artificial Intelligence (AI) for an accelerated approach of learning mathematics (AI4Math)" is an interdisciplinary post-doctoral research project not related to economic activity, where the development of human resources is promoted as a result of the cooperation of specialists from the fields of mathematics, pedagogy and ICT, increasing the diversity, accessibility, motivation, and involvement of mathematics education and relevance to the future needs of STEM industries. This is consistent with Latvia's strategic plans, for example, "Smart Specialization Strategy for Research and Innovation (RIS3)", [1], as a national research and innovation strategy in Latvia highlights as one of the priority areas "Information and communication technologies" and 5th priority: A modern, and corresponding to the future labour market demands, education system that facilitates the transformation of national economy and development of competences required for the implementation of RIS3 priorities, enterprising spirit and creativity at all levels of education.

Today's world is not the world we grew up in, and today's world is certainly not the world our children will live in. The world has undergone dramatic changes, and children of the digital generation must adapt to the demands of future sustainable education. Education is at the heart of the 2030 Agenda for Sustainable Development and essential for the success of all SDGs [2]. Recognizing the important role of education, the 2030 Agenda for Sustainable Development highlights education as a stand-alone

goal (SDG 4) and also includes targets on education under several other SDGs, notably those on health; growth and employment; sustainable consumption and production; and climate change. In fact, education can accelerate progress towards the achievement of all of the SDGs and therefore should be part of the strategies to achieve each of them.

Mathematics is the key to other fields of science. Therefore, the teaching of mathematics plays a particularly important role in the implementation of sustainable education in order to achieve future goals: to make learning of mathematics more meaningful and useful, as well as to support the development of 21st century competencies (critical thinking, creativity, communication and collaboration), [3].

The student survey conducted as part of the research indicates that sustainable education is one that takes into account the interests and needs of students, as well as includes an interdisciplinary approach, adds value to technology and promotes accelerated learning of the curriculum. Therefore, the basic question and challenge of the specific research is "How to teach students in such a way that they become interested in mathematics?" Because interest is what promotes involvement in the learning process and understanding of the subject matter, which in turn improves performance. As an answer to the question, the prototype of the AI4Math project, which is an interdisciplinary and innovative technology for accelerated learning of mathematics, is proposed within the framework of the research. It has been developed by specialists from various fields within one year from July 1, 2021, to June 30, 2022, adapting the functionality to the curriculum of mathematics of general education.

2 Literature Review

2.1 Interdisciplinary Approach

An interdisciplinary approach usually promotes knowledge and competences for sustainable development at different stages of education, [4]. Also, in working life, people's ability to cooperate with others is increasingly valued. Cooperation is considered a central factor in the development of prosperity, productivity and innovation, [5]. Close interdisciplinary and cross-industry cooperation can positively influence the professional development of staff, communication strategy and customer research, [6]. Theory suggests that multidisciplinary teams foster innovative thinking, [7] and that entrepreneurial teams composed of members with diverse backgrounds perform better than others, [8]. Start-ups are mostly a team journey where everyone has a “strength”, and it is better if each member has a different “strength”, [9]. In addition, teams solve problems faster if they are more cognitively diverse, so a multidisciplinary team seems more suitable for a start-up team as well, [10]. The interdisciplinary approach has become relevant in modern educational programs, as it is considered an important and challenging future educational solution. Compared to traditional educational approaches, interdisciplinary teaching and learning allows students to combine the learning of different subjects simultaneously to find new and deeper ways of thinking about problems and their solutions. An interdisciplinary approach changes the way students normally learn, allowing them to synthesize multiple perspectives rather than receiving information provided by an instructor according to rigid guidelines. In this approach, teachers collaborate to invent and apply more effective, innovative teaching tools, linking one subject to others. The main goal of the interdisciplinary approach is to develop skills and values, such as critical thinking, the ability to cooperate cooperatively, flexibility, adaptability, solidarity, mainly by providing basic knowledge, its research, classification, selection, evaluation, resolution and observation, [11]. If science is taught with the help of physical activities, then a dynamic and cooperative learning environment is created that promotes positive mutual cooperation, strengthens individual responsibility, promotes interaction and group work, as well as sustainable development competencies: critical thinking, analytics, cooperation and strategic action, [4].

2.2 Innovative Technologies for Education

In the era of globalization, the concepts of "innovation" and "innovative technology" have become an integral part of our lives. Innovative technologies contribute to the development of the

"pedagogical system" of education, [12]. Innovative teaching methods are the goal of many educators. Teaching students in a way that makes them interested in mathematics can sometimes be a big challenge. Research into the cognitive abilities of the brain has shown that certain methods and approaches can improve the learning process. Smartly controlled technology in the classroom: computers, tablets, digital cameras, video conferencing, GPS and other devices can enhance the student's learning experience. The use of innovative technologies in teaching mathematics is associated with the challenges of finding ways and means to activate students' cognitive interest, develop their creative abilities and stimulate mental activity, [13]. When creating the AI4Math prototype, inspiration was taken from the innovative pedagogic methods and technologies collected by The Open University over several years: 1) The "Best learning moments" method promotes deep involvement and immersion in the tasks to be performed, which in turn evokes emotions and creates a sense of pleasure. Best learning moments usually result in a high level of satisfaction and are particularly memorable when technology is applied and students' interests and values are taken into account, [14]; 2) Artificial Intelligence (AI) is already a part of life, which is slowly and quietly entering classrooms as well. It still has huge potential for improvements in education, and the topic of AI in education is too important to be left only to entrepreneurs and engineers. It is very important for educators and researchers to collaborate and help understand the possibilities of AI support for the improvement of the learning process, [15]; 3) "Playful Learning" is a method that stimulates creativity, imagination and a sense of happiness. Playful learning focuses more on the process than the results, so it develops an experimental mindset that allows for failures and mistakes. Play is an active process of exploration, as opposed to focusing on memorization and results. Well-designed educational applications are usually interactive and flexible, with built-in elements of motivation [16].

2.3 Accelerated Learning of Mathematics

Recent neuroscience researches suggest that children of the digital generation have developed "hyperlinked minds". Their brains process information parallelly or simultaneously. New scanning technologies have shown that the brain is highly adaptive and developable throughout life, that we can change the capacity of memory, the processing power of neurons, and actually regenerate neurons. This process is called "neuroplasticity", [17]. Today's children are simultaneously exposed to many digital devices, as a result of which digital "bombardment" creates a new culture in children's brains. Digital children process information differently than we do, where visual perception is especially important. If people remember only 10 percent of the information after 72 hours, adding a visual image to the text can increase recall to 65 percent. This is because the brain processes images 60,000 times faster than text, [17]. The digital generation wants 1) to learn "in the moment" and not for every occasion, 2) to receive fast and understandable feedback, which is usually given by computer games, 3) learning to be active, creative and fun, 4) spatial and problem tasks similar to strategic computer games [17].

The concept of accelerated learning (AL) does not have a clear and unified definition yet. The concept of AL is continuously debated by researchers and educational professionals in various fields. And some important components have also been discussed in the literature. In the beginning, AL was defined as "faster acquisition of skills and knowledge", [18]. Other definitions also focus on the time factor, for example, "any learning system that tries to optimize the time spent learning to the content learned", [19]. On the other hand, researchers, [20], [21] have pointed out that AL is an approach that is used to improve students' learning abilities, so that students can learn faster and more efficiently, and the learning atmosphere is created as a fun and active interaction between students and teachers. The beginnings of the involvement of "the whole body, mind and human experience" in the learning process were proposed by Meier, [22]. The Center for Accelerated Learning (Alcenter) has stated that AL is the most advanced of methods today, forming a complete system to accelerate the learning process based on the latest brain research. AL is the way we learn using all of our human gifts: physical, creative, musical, artistic, etc. AL is an

activity-based and student-oriented process that has the following basic principles, [22], [23]: 1) learning covers the entire human mind and body with all senses and emotions, 2) learning is the creation of new knowledge and skills, not consumption, 3) learning is cooperation, 4) learning takes place on many levels at the same time, 5) learning takes place by practicing, 6) positive emotions significantly improve learning, 7) visual images help to perceive and retain information more easily.

According to Dave Meyer's view, the AL approach helps students to develop a positive attitude directly towards mathematics, [24]. The National Institute for Excellence in Teaching (NIET) emphasizes that accelerated learning of mathematics is usually associated with special programs for gifted children or, on the contrary, for students with more special needs. It is often controversial but understanding it in general promotes greater involvement of teachers in planning and regular evaluation of the learning process. Students thrive in an environment where their needs are taken into account and their readiness levels are determined, [25]. Accelerated learning of mathematics is a curriculum-based system that includes several principles: delivering content appropriate to skill level, setting personalized goals, providing sufficient practice time, and providing direct and immediate feedback, [26].

3 Methodology

For the qualitative development of the AI4Math prototype, a methodology model was created (Fig. 1), it includes elements of divergent and convergent thinking. Divergent thinking refers to reaching a solution to a problem in which several possible solutions are proposed and the correct or optimal one is chosen, [27]. Convergent thinking, on the other hand, refers to the application of rules or procedures to obtain one correct solution to a problem [27]. Also, the model includes problem space and solution space. Legner et al., [28], found that the accumulation of knowledge about a certain field usually occurs gradually as a result of various situations and knowledge maturation (solution space) and in response to changing data sets (problem space).

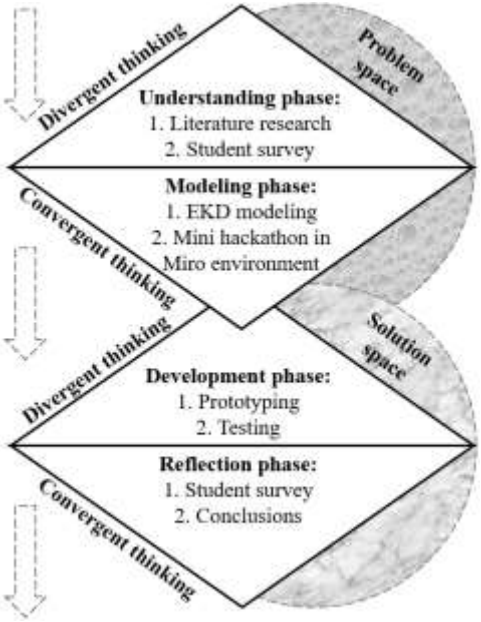

Fig. 1: The methodology model of research

According to the model, the study consisted of four stages of development: 1) Understanding phase (literature research and student survey); 2) Modeling phase (EKD modeling and mini hackathon in Miro environment); 3) Development phase (technology prototyping and testing) and 4) Reflection phase (student survey and conclusions).

3.1 Understanding Phase 1

First, the most current literature in the field of education related to interdisciplinary approaches, innovative technologies and accelerated learning of mathematics was collected and analysed. (see "Literature review" section).

3.2 Understanding Phase 2

To achieve the goal of the study, a survey was conducted for the target group to ascertain the conditions that, according to the students, can accelerate the learning of mathematics. An online survey was used instead of a paper survey, as the data was collected in the fall of 2021 – a period when Latvian schools were closed under the influence of the Covid-19 pandemic, forcing a complete transition from face-to-face learning to online learning. The online survey lasted one month in total and a total of 225 responses were received

from students at different Latvian schools and ages. The demographic profile of respondents was 62% girls and 38% boys. In the survey, the question "Could the learning of mathematics be accelerated by the following approach?" students could mark the answers 'yes', 'partly' or 'no' next to the statements (Fig. 2):

	Yes ☺	Partly 😐	No ☹
Use of technology	71%	26%	3%
Collaboration with peers	40%	49%	11%
A creative approach	37%	50%	13%
Interdisciplinarity	27%	42%	31%
Visualization and colorfulness	63%	31%	6%
Fast feedback	68%	26%	6%
Errors and its corrections	73%	22%	4%
Regularity	44%	43%	12%
Extracurricular activities	33%	50%	17%

Fig. 2: Survey of Latvian students "What can accelerate the learning of mathematics?"

3.3 Modeling Phase 1

For modelling the Enterprise Knowledge Development (EKD) method developed at the Royal Institute of Technology (KTH) in Sweden was used, [29]. The EKD modelling method is one of the most recognized methods of company modelling and strategic analysis. It has proven its effectiveness in both the private and public sectors. The EKD method helps to clearly formulate and discuss various issues related to solving difficult-to-structure problems. It allows the creation of models that determine the further development of the organization or project, thereby contributing to its restructuring and implementation of changes, [30]. The EKD method also contributes to the implementation of the developed models since the interested parties in the development are involved in the EKD modelling workshop. A modelling workshop usually consists of activities such as generating ideas, evaluating and structuring ideas, and making concrete decisions to achieve the set goals. The "visible" result of such a seminar is a model that documents the developed problem solutions and the adopted decisions, [31]. Specifically, during project research, two work seminars were held in the fall of 2021, where cooperation partners met to create an EKD model for the development of an AI4Math prototype. The created EKD model (Fig. 3) consists of six basic parts:

1) target groups (Students aged 3 to 18 years, Schools (public and private), Math teachers, Families where students grow up, Libraries, Interest education groups, Educational game companies);
2) problem solution and purpose (Arouse emotions, Emotion creates interest, and interest creates understanding, Add value to technology, A creative approach to learning mathematics, Promote motivation, Accelerated learning, Learning with joy and movement);
3) cooperation partners and design ideas (Vidzeme University of Applied Sciences, Valmiera Business Incubator, Company "Asya.AI", Riga Technical University, Schools, University of Malta);
4) communication and collaboration tools (Whats App, Miro, e-mail, Trello, MS Teams, Zoom, Weekly meetings, Power Point, Google docs, Scientific papers);
5) benefits for customers (Emotions, Physical activities, An interdisciplinary approach, Innovative technology, Math App, Fast feedback, Collaboration with peers, AI support);
6) value proposition (Health (physical), Health (mental), Growth opportunities, Balance, Motivation, Time, Feedback, Mathematical competence, Cahoot, Know-how, Technologies).

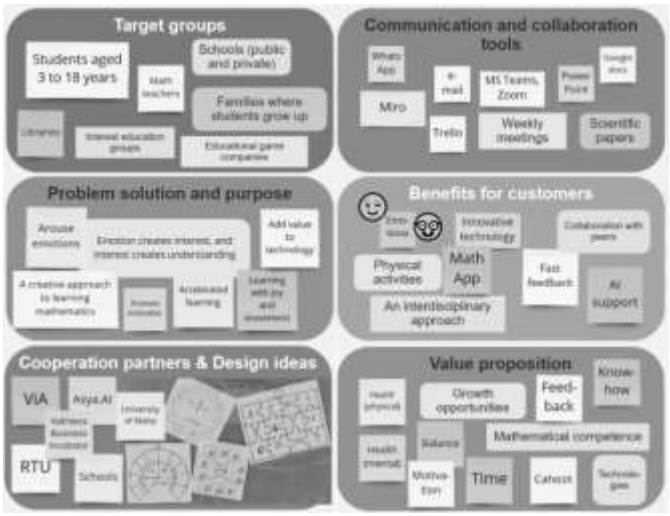

Fig. 3: EKD model of AI4Math prototype

3.4 Modeling Phase 2

In order to involve the minds and abilities of students in the research project, the hackathon method was used. According to an informative source, [32], the idea and practice of hackathons in the world started way back in 1999 in Canada, when the developers of the OpenBSD programming company got together to avoid legal problems caused by US cryptographic software export regulations. That's how the term started, because the word hackathon is a combination of the words "hack" and "marathon", where "hack" is used for research planning, not malicious hacking of a computer program. A hackathon or technology marathon is an event aimed at creating new teams and creating new technological solutions. Initially, everyone who has a business idea presents it to the other participants. Participants then choose which idea to develop further to build a real product prototype from scratch, [33]. Specifically, in the course of project research, in November 2021, a hackathon of 30 students of the Faculty of Engineering of Vidzeme University was held in the online ZOOM environment in order to create five ideas for a possible AI4Math prototype using the MIRO tool (Fig. 4).

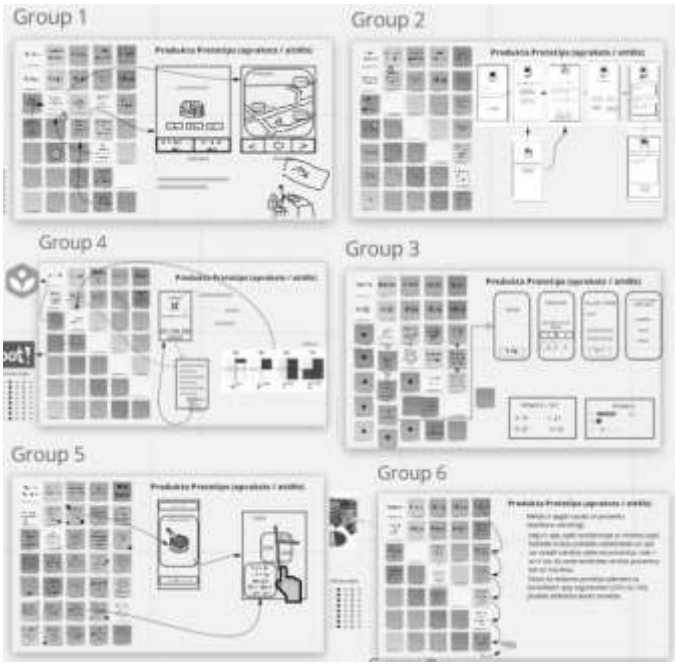

Fig. 4: Hackathon in Miro environment for AI4Math prototype idea generation

4 Results

4.1 Development Phase 1

Taking into account all the conditions described above, an interdisciplinary technology prototype was created as part of the research project with the following goals: 1) to make learning mathematics in schools more exciting and fun, 2) to encourage students to move and be more physically active, 3) to promote students' emotional well-being and energize brain activity. The AI4Math prototype combines 3 components: 1) a pressure-sensitive platform for jumping out the solutions of mathematical expressions, 2) an application for calculation, evaluation, accumulation and processing of Big Data, 3) AI solutions for emotion control. Through the cooperation of three students of the Vidzeme University Faculty of Engineering, each of the three components of the prototype, which can be seen in the picture (Fig. 5), was developed as part of a separate bachelor's thesis: “Developing a prototype input device for learning of mathematics”, [34], “Development a prototype of mobile application for learning mathematics with artificial intelligence support”, [35] and “Artificial Emotion Intelligence to Increase Mathematical Competence”, [36].

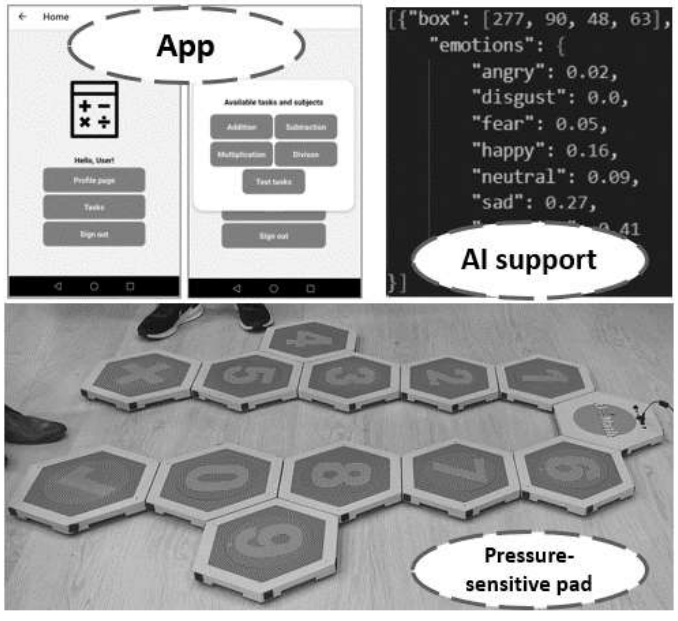

Fig. 5: AI4Math prototype for accelerated math learning

4.2 Development Phase 2

Prototype testing was done for each component separately within each bachelor's thesis. The testing of the application was carried out step-by-step, both during the development of the modules and after the completion of the development of the mobile app prototype. Testing was done on a Huawei P10 mobile device with Android 9 version of the operating system using the Expo service. Testing was done by running manual tests that were designed according to the functionality provided by each module. The performed tests were created according to scenarios, how the user could intuitively handle the mobile app, without receiving any instructions about the functionalities of the mobile app. Errors encountered during testing were captured and fixed until the next phase of testing, which usually occurred at the end of the development of the current module. At the end of the functionality development of each new module, new tests were developed and tested. Along with the execution of the new tests, the tests of the previously developed functionality were also executed to make sure that the new functionality did not "break" any of the previously implemented functionality. During testing, both the user interface and various input data fields were tested to avoid incorrect information being entered by the user.

The purpose of testing AI support was to test the functionality of the server and the behavior of the AI solution prototype, and the testing used WinSCP and Putty software, Swagger UI documentation, FastAPI web framework, UUID identifier and GET method.

In turn, the entire AI4Math prototype was put together and tested several times in the prototyping laboratory of the Riga Technical University at Cēsis Study and Science Centre together with two researchers, two scientific consultants and 11 students of different ages. As a result, improvements were made according to the noted shortcomings and the suggestions of the students.

4.3 Reflection Phase 1

In order to ascertain the usefulness of the prototype, focus group interviews with students were held during the testing sessions. All interviewed students (100%) stated that after the events of the COVID-19 pandemic, health has become one of their main values. For this reason, physical activity should also become an integral part of life. Considering that the AI4Math prototype provides an innovative approach to learning mathematics through physical activities, all students (100%) indicated support and a future development perspective for the interdisciplinary technology.

5 Conclusion

Research and AI4Math prototype test results indicate that sustainable education is one that takes into account students' interests and needs, and 1) includes an interdisciplinary approach, 2) adds value to technology, and 3) promotes accelerated learning, 4) teaches “in the moment ” not for every case, 5) provides quick and understandable feedback, 6) ensures that learning is active, creative and fun, 7) evokes emotions and creates a sense of pleasure, 8) promotes deep involvement and immersion in the tasks to be performed, 9) allows failures and mistakes, 10) develops experimental thinking and 11) promotes motivation.

The study makes a valuable contribution to researchers, entrepreneurs and the education industry, as it reveals the conditions necessary for modern and sustainable accelerated mathematics learning. While more and more new AI solutions are emerging in manufacturing, in school education AI solutions are still at an early stage of development. Mathematics is one of the most grateful subjects where AI solutions can be successfully used to promote collaboration and individual approach, to speed up task correction and feedback, to generate more and different tasks, to relieve teachers' time and to respond to students' emotions. As a result, teachers, researchers and IT industry specialists are invited to cooperate in order to create more and more new interdisciplinary and innovative technologies for accelerated learning of mathematics, as well as to develop a new research direction "accelerated learning", which has so far been very little studied and described in scientific research.

This study also has limiting factors, as the target audience survey was conducted during the Covid-19 pandemic in a remote format and within the framework of only one country (Latvia). Therefore,

the research should be continued even after the pandemic and from the perspective of other countries.

Considering that the AI4Math prototype created within the project provides an innovative approach to learning mathematics through physical activities, the survey data indicated support and a future development perspective for the interdisciplinary technology. Future tests of the prototype are planned in schools, science centres and libraries to collect data and further its development at the level of the application, the AI algorithms and a pressure-sensitive floor platform. We are already working on attracting additional funding to develop the AI4Math prototype to the production level.

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