Attachment 1

MTA-ELTE Digitally Supported Physics Education Research Group

Research plan

1. Introduction

1.1. Objectives and preliminary results

The accelerating development of science and technology, the changing attitudes of students, and the needs of the labor market require the development of physics education at the societal level. This can only be expected from the renewal of contents, methodology and educational tools of school physics teaching.

There are two important pillars of the planned work: science (physics) and content pedagogy. The Eötvös Loránd University have been engaged in the training of physics teachers for about 200 years. This has expanded in the last decade with the a doctoral (PhD) program “Teaching Physics”, which is unique in the country. The former MTA-ELTE Physics Teaching Research Group, which operated successfully between 2016 and 2021, was organized and operated on the basis of the Doctoral School, combining the development of university teacher training with the development of school physics teaching. The successful operation of the research group is shown by the fact that the members of the group wrote 56 English and 62 Hungarian refereed journals and conference articles during the four and a half year period. 22 e-learning materials (8 are in English) and 23 methodological books (6 in English) have also been published. Beside this 16 PhD dissertations were born during the project. The experience has confirmed our conviction that the development of the content-methodology of school physics teaching is really effective, if we involve physics teacher training, in-service teacher training and also PhD training.

The current project is also based on the work of the previous research group, with two important changes:

1) From the research topics, we selected those that may have the greatest impact on the near future of domestic and international physics education, thus yielding well-published results and fitting well into the research activities of the group members. This project focuses on the personal activity of students, their involvement in the learning process, and the systematic integration of modern tools into school work (digital and activity-oriented physics education and learning). We explore the possibilities of using artificial intelligence for teaching physics (teaching physics using elements of artificial intelligence). In addition, due to our situation, we place great emphasis on the development of physics teacher training (development of teacher training using gamification).

2) The leaders of the research are middle-generation researchers / academics whose career and success depend on the quality and quantity of publications. Accordingly, the applicant is Dr. Péter Jenei, who has been continuously involved in methodological developments / research since graduating in 2010 (physics and mathematics teacher). Since 2018, he is the head of physics teacher training at Eötvös Loránd University, the university that train the most physics teachers in Hungary. He also is committed to the development of Hungarian subject pedagogy research to an international level (see attachment 3). In the current project, publication in Q1 journals will be a priority.

1.2. Research topics and presentation of the research group

The work of the research group focuses on 2 major topics:

1) **Digital and Activity-Oriented Physics Education and Learning** Improving physics education or learning? The two without each other are probably problematic, but it's still important where we put the focus. The main actor in physics education is the teacher, who basically already has all the knowledge and necessary competencies. However, in order for students to succeed in physics and related sciences as easily and in large numbers as possible, regardless of gender, we need to develop physics lessons so that our students can be as active participants as possible and learn physics successfully. Our research is designed to go this way: for a "Digital and Activity-Oriented Physics Education and Learning".
2) **Teaching physics using elements of artificial intelligence (machine learning).** In this topic, we create and test software using a large-sample experiment that can offer students individual development paths through machine learning while maximizing the improvement. The innovative idea is that the machine gives practice tasks based on the results of an input competence and a professional test. It analyzes the process and effect of the exercise and refines the practice tasks. For many users, the algorithm sees through the correlations, thereby learning the process of ideal development.

The research team conducts the research on the two topics in close coordination, but the aim and methods of the research are different in each area, so in the next chapter (2. Research topics) we present the introduction of the topics, the goals to be achieved and the research plan separately. Common to the research methods is that each group uses modern research methodological directions Physics Education Research (PER), Model of Educational Reconstruction (MER) and Design Based Research (DBR) - according to their research objectives. It should be note that we do not aim to be exhaustive in explaining the topics. We only refer to the content of the tests, as some of them have not been compiled yet, and those already completed are in Hungarian. Our goal is to be completely transparent about what, when, and for what purpose will we investigate, and what is the significance of the study.

5 full time and 2 part-time ELTE researchers take part in the work of the research group. In addition 21 active school teachers join development and research work (members and responsibilities of the research team are listed in Appendix 4). It is important to emphasize that the listed participants are all current or prospective PhD students, teachers with PhD, and university lecturers. Accordingly, they all have research experience, but additional teachers are expected to join for large-scale teaching experiments.

In addition, the PhD program established specifically for this research area may admit 2-4 PhD students each year. It should emphasize that from 2023 January the group will be expanded with another full-time assistant professor, who will help the group to operate excellently.

We know that the planed research is grandiose. We took into account the size of the research team and the budget of the application when choosing the number of research topics. Such a significant professional group cannot and should not be limited to research on one topic. This is also important as there are several doctoral students working on the project who need to be provided with unique research pathways. All of the topics are very topical, and successful research can therefore generate significant professional interest.

1.3. Working method and dissemination

Figure 1 shows the general structure of the research group's working method, the key persons in the steps, and the publication plans.

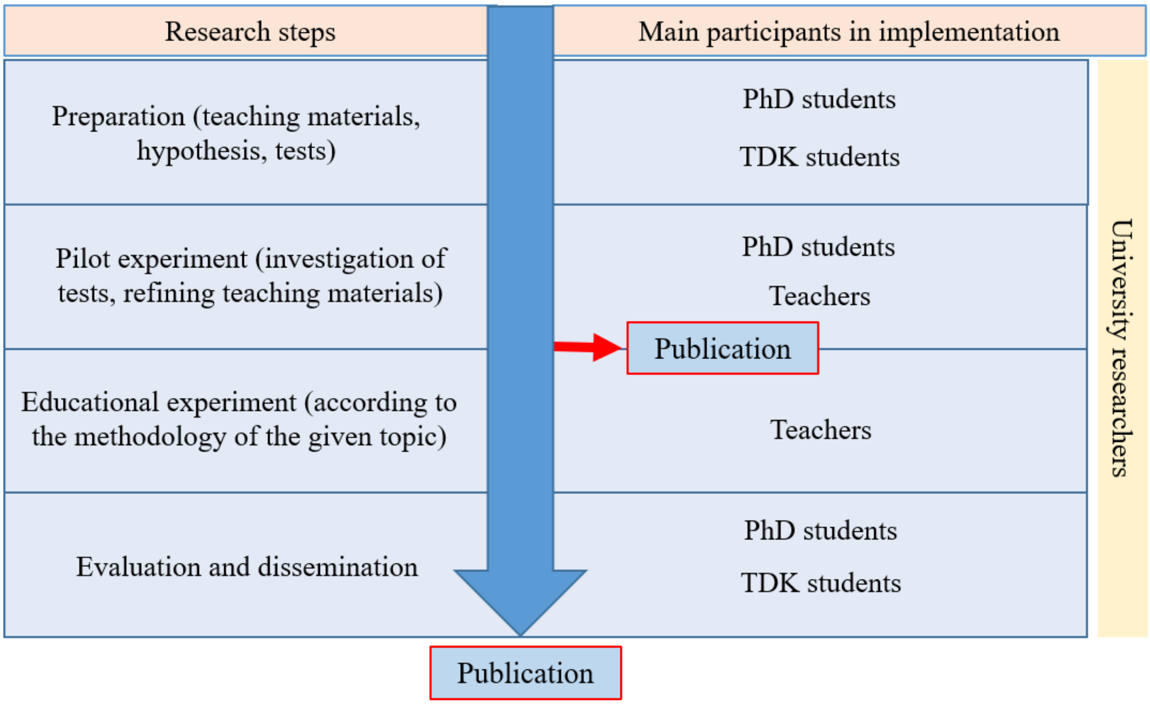

Figure 1. General structure of the group 's research. TDK is a Scientific Students' Associations ("TDK", which stands for 'Tudományos DiákKör' in Hungarian). TDK students mean students who carry out scientific research during their university study.

We build educational experiments in all our research areas, the general stages are the following in our research group:

1. Each topic begins with a careful preparation of teaching materials and tests and a review of the international literature. This is mostly done in close collaboration between PhD students working in the field of research and TDK students.
2. In the next step, the teaching materials and tests are verified by a pilot experiment (with a few group). We examine the reliability, scaling, etc. of the tests. The educational materials then take the final form required to test with larger sample. At this level, preliminary results can be published, of course indicating the limits of the study. The physical education community is often more interested in this than the result of large-scale educational experiments, since we plan to publish these teaching materials in a separate publication in journals for physics and science teachers.
3. The third step is to test the materials on a large sample. This is when physics teachers play the most important role, trying out the materials, writing the tests with the students and giving feedback to other members in the research. We are preparing teachers early in the second step, because in our experience, the teaching materials are still going through a lot of useful changes during the training. It is important to note that most of our PhD students are also active high school teachers, so they can participate in the large sample investigations.

4. Evaluation is performed using statistical methods according to the number and the distribution of the sample. The stations of the dissemination are shown in Figure 2.

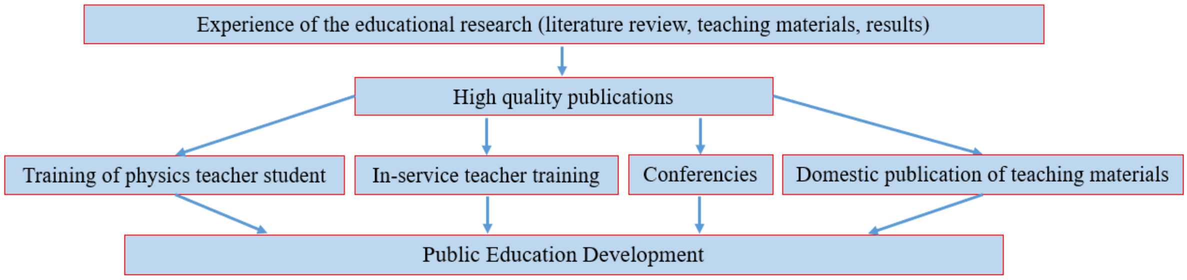

Figure 2. Dissemination plan of the research group

It is important to note that we seek after Q1 quality publications. It is the basis for other activities aimed at the development of public education. Beside this we consider it important that all our results appear in teacher training, in-service training materials for physics teachers and in the Hungarian literature. It is also important to attend larger education conferences at home and abroad.

The researcher of the university necessarily oversee all areas and steps and actively contribute to their implementation.

2. Research topics

2.1. Digital and Activity-Oriented Physics Education and Learning

2.1.1. Introduction

The primary goal of physics education is to emphasize the applicability of physics knowledge in addition to the scientific approach: the development of scientific skills and competences [1]. The content regulators of the teaching work – national core curriculum and curricula of physics teaching – formulate the need for competence development, both in the field of professional and soft skills, as well as for student-centered, activity-oriented science education. Our conception of knowledge is changed due to the scientific, economic and technological development. In the 21st century education, not only the quantity of knowledge, but also its quality is important. The available knowledge is constantly expanding at a rapid pace; thus, the education should put emphasis on the development of those skills, which allow the proper use and application of knowledge, and the insight into the contexts [2]. This also changes the role of teachers. In many cases, the teacher appears in the class as a "tutor" [3], who coordinates the work processes and gives students the opportunity to get completely involved in their own learning processes – working independently or in groups of a few pupils. In an activity-based lesson, students are actively involved in building their own knowledge with appropriate teacher coordination, even in an informal environment - e.g., at home. Physics is an empirical subject; knowledge is determined by previous knowledge, observation and experiences. The aim of activity-oriented physics classes is to deepen and strengthen the previously acquired knowledge through activity-based practice, thus supporting skills development, too [4]. As a teacher, it is worthwhile to plan our lessons along operators (competence elements) that ensure the availability, understanding, practice, and application of knowledge – guide students from the basics to more abstract problems [5-6].

It is important to note that, as a result of current physics teaching practices, girls are significantly under-represented in physics-related higher education courses [7-8]. Unfortunately, this phenomenon is already emerged in the secondary school education, too [9], including the case of traditional participation rates (e.g., in Physics Olympiad [10]). However, girls' participation rates in activity-oriented competitions, which build on research, e.g., IYPT (International Young Physicists' Tournament [11]), ICYS (International Conference of Young Scientists [12]), Jugend forscht [13], the participation rate of girls is significantly higher. This experience also shows that in many cases girls' interest and success in physics depend significantly on the methods of teaching and strategies used - thus it seems worthwhile to carry out targeted – country-specific – research and development in Hungary to support girls progress in physics [14]. As the literature shows, activity-oriented tasks not only support active student participation at school, but also those tasks that require longer, more persistent work can increase girls' interest and may lead to their more success.

The primary goal of our research is to increase the number of those students - special emphasis on girls -, who are interested in and dedicated to science subjects, with the support of the methods we have develop and test. To achieve this goal, we focus on developing those skills and competences that are necessary for the careers of engineering, research and development by targeting the natural interests and active participation of students.

2.1.2. Objectives and procedures

During the research process, we investigate the opportunities of activity-based teaching of primary and secondary school students, as well as the emergence of practice orientation in the field of gifted education, its impact on the acquisition of long-term knowledge, as well as its role in competence development.

Our goal is to develop methods, techniques and tasks that allow students to get acquainted with the various possibilities of physics and give them the opportunity to get actively involved in classroom and professional physics activities, e.g., research project or measurements.

Use of Arduino-controlled sensors in physics classes and physics clubs

Based on our hypothesis, physics classes supported by Arduino contribute to the development of the professional and soft skills of students.

We conduct research to develop and test classroom and more advanced – for extracurricular activities – measurement tasks with mobile devices, mainly with the application of Arduino [15] and Arduino-controlled sensors. One of the advantages of these is that we can obtain tools at a relatively low cost, these sensors give teachers the opportunity to assemble a number of different experimental setups for the physics lessons, thus contributing to the development of the physics laboratory. We write worksheets – with description, questions and tasks – for each measurement we develop in order to support the classroom work. With methodological comments and suggestions, we publish these materials.

Several Hungarian and international articles deal with the educational possibilities of Arduino and other microcontrollers [16-19], but only some of them investigate its impact on competence development. In our educational experiment, we investigate the role of student measurements supported by Arduino in the development of competences, as well as its impact on the acquisition of long-term knowledge.

Activity-oriented physics projects - girls in focus

Based on our hypothesis, activity-based, practice-oriented physics projects contribute to the acquisition of solid, applicable physics knowledge, to the recording and deepening of the previously acquired knowledge, as well as to the improvement of girls' attitude towards physics and engineering.

The primary goal of activity-centered physics education and learning is to increase students' motivational level and encourage them to participate actively in physics classes. For example the development of demonstration experiments using the Sokoloff method [20], the Interactive Lecture Demonstration (ILD) allows students to take part actively in the physics lesson, even in lectures, and develops both professional and soft skills of students, as the problem (a series of tasks based on the demonstration experiment) requires the cooperation of pupils. The method can enhance the standard of physics lectures by conducting lecture demonstrations in an interactive way and engaging the participants of the lecture in the work processes – in the learning processes. Demonstration is shown to students, who make predictions about the outcome of the phenomenon. Then they have the opportunity to work in small groups and discuss their opinion. After the discussion the students observe the results of the experiment and compare them with their predicted results. At the end of the process, they are able to explain the whole phenomenon. The application of ILD can enhance effective learning in a way it changes students' belief when they are confronted by differences between predictions and observations. During our research, we develop worksheets based on Sokoloff's method, and we test its effectiveness in an experimental group – comparing to control group.

In order to optimize the learning process outside the classroom and to make students more active, it is worth examining the role of learning diaries [21-22] in the physics education in physical learning [21-22] and adapting them to Hungarian goals, opportunities and challenges. This method seems to be particularly useful in giving girls a sense of success, as due to their psychological and cognitive development they seem to be better suited to persistent, regular and punctual work [9], which is necessary for later research/ engineering work.

At a deeper level of activity-based physics education and learning, research-based methods appear [23-24] The IYPT method [25], which supports preparations for the International Young Physicists' Tournament, gives the opportunity to students to carry out research, while gaining a high level of physics and acquiring skills such as literature review, designing and conducting experiments, etc. Moreover, during the learning process, students become familiar with various measurement possibilities, even modern, digital ones, that enable them to work efficiently. By applying the method in classrooms, teachers can involve more students in research-based activities. According to our teaching experience, physics competitions based on research projects are more popular among girls than traditional competitions built on counting tasks. Our goal is to properly transform the physics class processes using the strategies and structures of the mentioned competitions – we develop, apply, test and share methods that can be attractive for girls as well. We create a collection of projects that includes previous IYPT, Jugend forscht, Kömal [26] measurement problems, organized according to topics and grades. We encourage our students to conduct these research projects (supported by research diaries) – even in homework (or in a digital "work from home" environment). As confirmed by the COVID-19 pandemic, there is a need for ideas that contribute to effective physics education – and gift education – outside the classroom. The application of project tasks in an out-of-classroom work schedule makes it possible to acquire solid, applicable knowledge. We choose experiments and measurements whose activity-based solution contributes to the deepening of previously acquired knowledge. We support the measurements with worksheets containing guided questions, which we also make available to colleagues.

2.1.3. Methods

Research strategy, data collection and sample selection

Our group performs its targeted research tasks in accordance with the principles of design-based research (DBR) – design-based research [27] within the framework of lessons. The investigation will be carried out in several phases for the four academic years from September 1, 2022 to August 31, 2026. In the first year, the educational materials (worksheets, methods, strategies, tests) are developed, and then in the first research phase of our work, we test our methods on a small sample (in some classes) with an experimental and a control group. We conduct research among students studying in the Hungarian (H) and German (D) education system based on different curricula, thus the investigated age groups may differ in the two systems. In the third year, we enhance the number of classes participating in the experiment after the necessary modifications and improvements have been made based on experience and results of the first research phase – we conduct research mainly involving high school teachers from the research group. Details of the plans are shown in *Table 1 and 2*.

Table 1. Research plans for digital and activity-oriented physics education and learning.

Project	Test grade	Topic	Duration (per topic)	Measurements
Use of Arduino-controlled sensors in physics classes and clubs	7^{th} (H).-8^{th} (D)	Kinematics	6 lessons	pre-, post- and follow-up measurements for professional knowledge development (development of competencies), attitude test
Use of Arduino-controlled sensors in physics classes and clubs	9^{th} (D).-10^{th} (H)	Electricity Magnetism	6 lessons	pre-, post- and follow-up measurements for professional knowledge development (development of competencies), attitude test
Learning diary	7^{th} (D)-8^{th} (H) 9^{th} (D)-10^{th} (D)	Optics, Electricity Kinematics, Dynamics	2 semesters (longitudinal study), year-round project	pre-, post- and follow-up measurements for professional knowledge development (development of competencies), attitude test
Learning diary (“work from home” research project)	7^{th} (D)-8^{th} (H) 9^{th} (H)-10^{th} (D)	Optics, Electricity Kinematics, Dynamics	2 semesters (longitudinal study), year-round project	pre-, post- and follow-up measurements for professional knowledge development (development of competencies), attitude test

Table 2. Work plan for “*Digital and Activity-Oriented Physics Education and Learning*” topic

Tasks and subtasks	Year 1	Year 2	Year 3	Year 4
1. **Use of Arduino-controlled sensors in physics classes and clubs**				
1.1 Development of traditional classroom experiments and measurements with Arduino				
1.1.1. Application in different classes, examination of the possibility of differentiation				
1.2 Development of measurements with Arduino-controlled sensors for physics clubs – development of teaching materials				
1.3 Testing of the developed methods on a small sample				
1.4. Development based on former results, testing on a large sample				
1.5 Communication of results (publications, presentations)				
2. Activity-based physics projects - girls in focus				
2.2 Learning about research-based competitions: methods and strategies				
2.3 Collection and development of project activities according to topics and grades – learning about learning diaries				

2.4 Development of a strategy for the application of project tasks in physics education (emphasis on girl-oriented methods)				
2.5 Testing of developed methods on a small sample				
2.6 Development based on former results, testing on a large sample				
2.7 Communication of results (publications, presentations)				

2.1.3. Data analysis methods

The effectiveness of the tasks is reflected both in the impact on the acquisition of long-term knowledge and the development of competences, as well as in the motivating role. For the data analysis, we investigate the effectiveness of our methods by comparing the students' performance on pre-test, post-test and the follow-up (end of unit test) test. At the beginning and at the end of different units our students take a test in order to investigate their progress and the effectiveness of the applied methods. In the first phase of our study, we compare the results of the two independent samples - the experimental and the control group - on the pre-test, and then investigate the possible significant differences in the case of each task type of the post-test. When measuring the role of competence development, competences are assigned to each task of test, the development of these is measured and the two samples are compared to each other. We also look at how students have improved compared to themselves during the research period, and what role the method plays in acquiring long-term knowledge. We use statistical tests to evaluate the data. The investigation of the motivating role of the different techniques are carried out by evaluating questionnaires and responses to the attitude test. The impact of applied activity-oriented tasks and strategies on girls' attitudes to physics is analyzed with an ANCOVA test. Our results are published in Hungarian and international journals and presented at conferences.

2.1.4. Rationale of the research

In Physics education, a change of attitude towards innovative teaching methods is necessary in order to be effective even under the changed conditions – decreasing hours, the needs of our Generation Z students [28], changing knowledge concepts and changing expectations – and provide students with the same quality of education. The shortage of human resources in the fields of technology and science in Europe has now become one of the main obstacles to the economic development – which is also largely due to the fact that the number of girls is significantly underrepresented in these fields. Due to the low number of lessons and the decreasing popularity of science subjects, it is a great challenge for teachers to choose appropriate methods. In order for education to adapt to changing needs and abilities, methodological preparedness beyond traditional education and the need for continuous professional development are needed. Activity-oriented physics education and learning enhances student activity, shows the applicability of physics and the versatility of the subject, thus allowing teachers to reach as many students as possible. It is also important to highlight that the applicability of digital tools in education is expected. In order to integrate the use of these tools effectively, efficiently and time-efficiently into our classrooms, it is necessary to rethink and develop the techniques used earlier.

2.1.5. Brief introduction of the leader of the topic

The leader of the research topic, Dr. Mihály Hömöstrei (graduated as a teacher of mathematics and physics at Eötvös Loránd University in 2006, Ph.D. Teaching Education Research, Eötvös Loránd University 2017), knows as a practicing physics teacher the possibilities, frameworks and limitations of teaching physics to students at primary and secondary schools. He has a great overview of the different levels of physics education due to his diverse work. He works with students from 7th grade, he gives professional support to secondary school students who take part in international physics competitions (IYPT, Jugend forscht), and he gives methodology lectures to physics teacher trainees. In the course of his methodological research, the investigation of the appropriate cognitive and motivational levels of the given topic and their conscious consideration have always been given a prominent role. His research results so far show that activity-oriented educational units can be considered as another useful area of research in order to improve today’s educational environment and learning outcomes. He is member of the International Organizing Committee of the IYPT since 2013, member of the Physics Matura Exam Committee since 2014, member of the OKTV Committee of Physics since 2021, his educational work was awarded with MOL Mester-M Prize in 2010 and with Ericsson Prize in 2020.

2.2. Teaching physics using elements of artificial intelligence (machine learning).

2.2.1. Introduction

Teachers are often hopeless to see what prior knowledge and competencies the student is coming from and thus what the ideal developmental task is in the given lesson. In this research topic, our goal is to create a computer program that can learn what practice task a student should solve for the most optimal development based on his/her knowledge and competencies.

It is an accepted fact that information and communication technology (ICT) has significantly changed both education systems and learning processes. Using online tutorials provides us with a huge amount of data. The classification of data is made possible by the use of elements of machine learning, and with this, predictive analytical tools, which have great importance today, are also available in the learning process. [29]

It is also well known that students can access high-quality online courses without space and time constraints. Therefore, in selecting the appropriate courses, in addition to the professional aspects, the perception and examination of the students' behavior is an important task. Machine learning techniques can certainly provide a way to make course recommendations more effective through students ’use preferences. [30]

In the field of education, in addition to the evaluation of learning process, the examination of the effectiveness of teaching plays important role. New methods are also emerging in several areas that effectively complement traditional, consistent, pre-built methods, using machine learning methods as well in teaching assessment. [31]

Research is also motivated by the growing lack of teachers in physics education. If the process continues, then unfortunately the teachers will not be able to fully control the educational process, thus optimizing the development and the practice tasks for the student. It is important to note that our aim is not to replace the teacher. We are convinced that the personality of the teacher plays a crucial role in education, which cannot be replaced by a machine in the foreseeable future. The project aims to create software to help students learn independently.

2.2.2. Schematic of the algorithm

The essence of the planned algorithm is shown in Figure 4. Before completing a given specific test (mechanics, thermodynamics, etc.), we assess students’ general competencies (mathematics, reading literacy, science, etc.), as finding the optimal pathways for development is highly dependent on these abilities. Students then complete a subject related, specific test (eg. kinematics), the computer evaluates it, and sends feedback to the student about the result. Based on the result, it identifies the typical misconceptions and errors and then releases a version of the practice tasks to correct them. The system monitors the solution of practice tasks and - again - provides feedback to the student. The student then repeats the test. Based on the results, the machine analyzes the progress. The machine monitoring the input parameters (competencies), the specific test results, the solution of the practice tasks and the development data. Based on many fills, this results a huge data set. Artificial intelligence sees through the correlations and refines the practice process based on it, allowing students to develop personalized optimization. The cycle can, of course, be repeated. It is important to note that the tasks of competency measurement and specific-tests are constantly mixed by the computer in order to determine the optimal path from the largest possible combination of parameters. Accordingly, a huge question bank needs to be created initially.

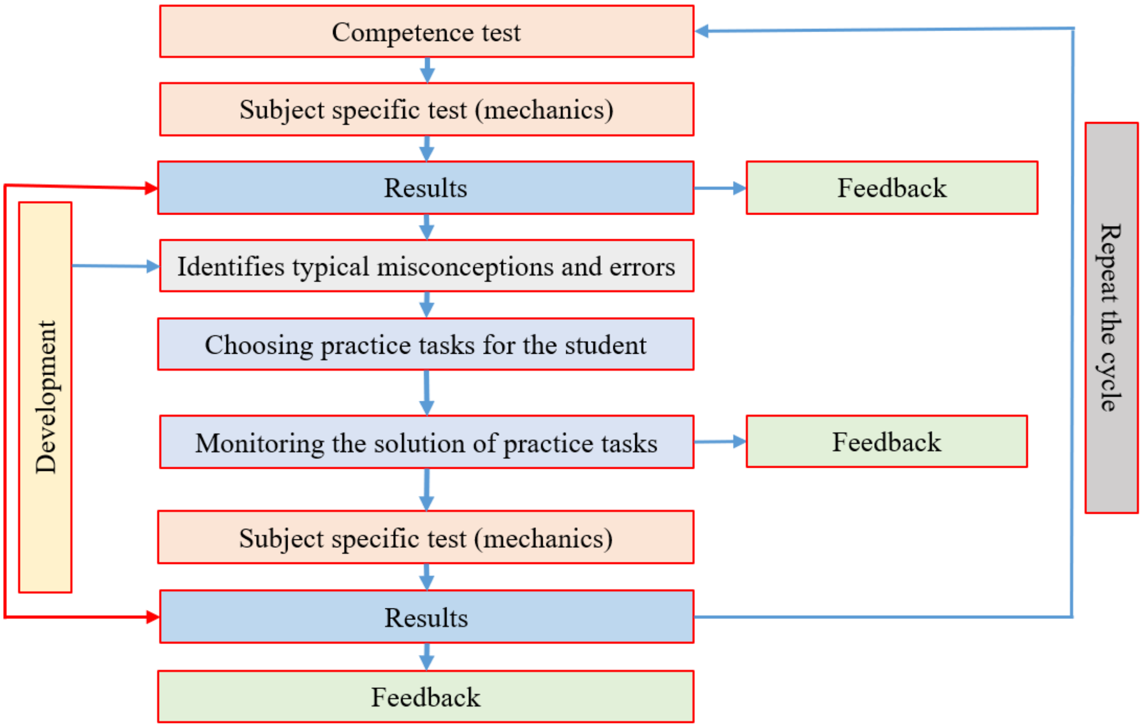

Figure 4. Schematic structure of the planned algorithm

2.2.3. Tests and educational experiment

The planned algorithm will be tested in the field of mechanics. We chose this area because

- i) it is an important, critical chapter in physics education in primary and secondary schools, in which many new concepts are introduced,
- ii) there is an extensive literature in this chapter on the identification and treatment of characteristic misconceptions,
- iii) The members of the group have a lot of previous experience, material and tests on this topic.

There are numerous examples of competency tests in the domestic and international literature. In this work, it is important to select the most appropriate list of questions for the algorithm. The series of questions examines not only competencies very closely related to mathematics and physics, but also, for example, to reading literacy and learning strategies. The experimental group of the educational experiment will be high school students from the 9th to the 12th grade, as well as the first year physics teacher and physics BSc students at ELTE (for classes in 2024 and 2025). Pilot tests will start in the second year of the project, large-sample experiment planned for the third year, with a total of more than 1,000 experimental users expected, what would be sufficient to find key correlations.

Table 4. Work plan for "*Teaching physics using elements of artificial intelligence (machine learning)*" topic

1. year
Compilation of competency test. Analysis of domestic and international surveys in terms of algorithm optimization. Creating a question bank.
Creation of the mechanics test, division into items, identifying possible sources of error and misconceptions per item. Creating practice tasks to correct errors and misconceptions.
i) Collecting data based on the compiled tests. [32] ii) Performing samples and evaluations after pre-processing and transformation of the data. iii) Preparing models that can be utilized in the learning/teaching algorithm and the corresponding teaching materials, based on the samples and correlations.
2. year
Analysis of tests and the algorithm with small-sample (pilot) experiment. It is important to check the reliability and difficulty of tests and surveys at each feedback stage.
3. year
Large sample experiment. Because of the greater control, the software is tested primarily with the group's active high school teachers. The undergraduate students will be involved in testing at the end of the first semester. It is important to note that the software continuously analyzes the results, if statistical methods show the possibility of cheating, the algorithm will not take the results into account.
4. year
Evaluation of results, publication
Development and publication of software based on user experience

2.2.4. Brief introduction of the leader of the topic

The development process is led by Dr. Tamás Orosz Gábor, associate professor at the Faculty of Informatics of Eötvös Loránd University. Tamás Orosz Gábor graduated as a physicist in 1996 at the Attila József University. He obtained his Ph.D. degree at the Institute of Technical Physics and Materials Science of the Hungarian Academy of Sciences (HAS) in 2004. He has been a member of the public committee of the HAS since 2016. He obtained his habilitation degree in the field of computer science in 2020 at the Doctoral School of Applied Informatics and Applied Mathematics of the University of Óbuda, and later, in 2021 at the Eötvös Loránd University. From 2014 to 2021, in addition to university physics courses, he developed a curriculum for catch-up courses, and was responsible for theoretical and practical courses. He has been a member of the American Association of Physics Teachers, (AAPT) since 2016. Dr. Orosz has given 4 presentations at the annual national conference of the AAPT so far. Since 2015, he has been leading the Székesfehérvár branch of the Physics Olympic Olympics. At the AAPT Summer National Conference in 2016, he was invited to use this online learning environment as an instructor at MIT's Adaptive Physics course in his own courses, including the Student Olympics. He participated in the Physics Education Program of the Doctoral School of Physics of Eötvös Loránd University. Since 2020, he has been the subject author of the Doctoral Program in Physics with the announced topic: Adaptive preparation for advanced physics graduation by incorporating elements of machine learning. From 2021 he was the supervisor of the Doctoral School of Materials Science and Materials Technology of the University of Óbuda.

3. Summary and expected impacts

Our research team is represented in all fields of physics education, from primary school education through talent development to PhD training of physics teachers. Eötvös Loránd University plays a key role in physics teacher training, given that more than half of physics teachers study / have studied here. Improving their training will crucially determine the quality of physics education in the long run. In their later work, students will be taught effectively in the ways they have encountered (experienced as a student) during their training, so it is worthwhile to apply and continuously develop the most modern forms at the university. The results of our planned research group could have a great impact on the development of the field of physics teaching. In addition, many of the expected outcomes are independent of the discipline (gamification methodology, learning diary, artificial intelligence), so our results will not only be interesting for the physics teacher community.

The personal requirement for successful research is provided by the lecturer staff of the PhD Program of physics teachers and the constantly expanding staff of PhD students. In addition, we place special emphasis on good relationships with school physics teachers and provide opportunities for researcher teachers to join.

Successful research is also supported by synergies between topics. The mechanics test developed in research on the methodology of gamified teacher education can be used in the study of machine learning. Projects developed in activity-oriented learning can be incorporated into the methodology of gamified physic education, and countless other points of connection show the very conscious structure of the research plan.

Although the most important goal of our research is to publish in high-level journals, we also keep in mind the support of the development of public education in Hungary. The teaching materials (tasks and methods developed, tested and developed during the research process, worksheets, task collections, digital study materials) prepared as a result of our research are published and distributed at home in many forums (eg. conferences, in-service training, etc). Our goal is to use our research results to support the work of practicing teacher colleagues in the following areas:

1) Researching teaching materials and good practices which support an effective, empirically constructed, enjoyable learning process (other than frontal) realized because of the active participation of students.
2) We create software that uses the elements of artificial intelligence to help students learn independently at home and prepare for graduation.

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