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TEACHING STEM – ASPECTS OF PERSONALIZATION

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ABSTRACT: Contemporary teaching at schools and universities aims to enhance learners' understanding of interrelated science, technology, engineering, and mathematics (STEM) issues by solving real-world problems. To increase the effectiveness of STEM education, personalized teaching methods should be considered and implemented. This research is focused on the classification of modern STEM teaching approaches applied at schools and universities and aims to reveal how they can be personalized. It also provides some practical examples of the personalization of STEM teaching that discusses ways of their possible application worldwide.

Key Words: STEM, Personalization, Teaching approaches, Education.

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1. INTRODUCTION

STEM is a direction in education that combines multiple learning subjects, including Science (such as Physics, Astronomy, Chemistry, Biology), Technology, Engineering, and Mathematics. It aims to reduce the divide between these areas by solving complex real-world problems through modern and innovative methods [1]. New trends in STEM teaching motivate students and prepare them for the professions of the 21st century, providing them with the necessary knowledge and skills. In addition, they feel more confident in improving an extensive array of skills like critical and problem-solving thinking, communication and teamwork, creativity and innovation, flexibility, adaptability, leadership, and so on. [2].

Personalization of STEM education is essential to the effectiveness of the learning process because it allows students to receive the information in their preferred way and at the appropriate speed. The paper briefly reviews the personalized STEM educational methods and the modern tools for implementing STEM personalization. It is structured as follows: The next section describes a classification schema of the STEM-related teaching methods. Then, the challenges of contemporary STEM education are mentioned. The fourth section presents Google trends for "STEM education" and "personalized education". The personalization of STEM teaching methods is also described and good practices in applying methods for personalizing STEM learning are discussed. The paper also presents the SHAPES project, aimed at researching the personalization and optimization of STEM educational methods.

2. STEM-RELATED TEACHING METHODS

The challenges of the contemporary digital society necessitate more STEM-related knowledge, competencies, and skills. Hence, innovative STEM teaching approaches and relevant technology redesign of learning environments must be considered for more effective and efficient student learning [2, 3].

All the approaches for teaching STEM address the challenges of active learning. A classification schema of the STEM-related teaching methods is presented in Figure 1. The classification divides the methods into three groups, considering different teaching strategies for designing instructional practices. The groups of problem-solving, collaborative, and innovative approaches form vertical divisions of STEM-related teaching methods, and two other groups split the methods horizontally depending on the diversity of the approaches. While most methods represent single approaches, multi-approaches include integrated approaches such as flipped classroom (students choose among various ways of representing what they have learned alone), phenomenological approach (teaching interdisciplinary concepts and applications), and practice-based and engineering approaches.

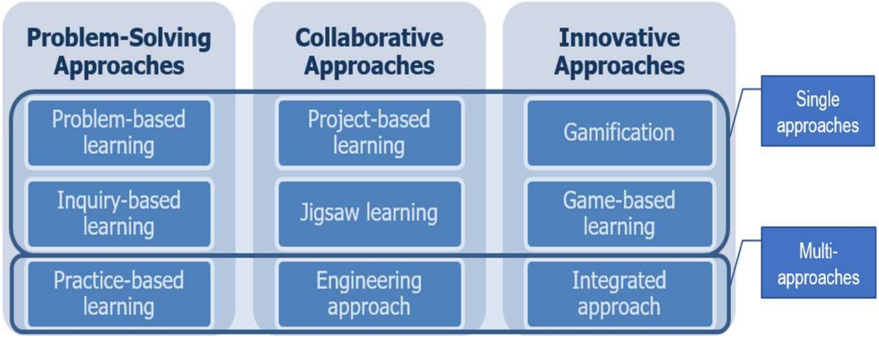

Figure 1. STEM-related teaching methods

3. CHALLENGES OF STEM EDUCATION

Understanding the existing challenges to the personalization process is essential, as such understanding is the first step towards overcoming them. These challenges are related to different aspects of the learning process. Customized learning paths are needed to increase student motivation, allow for efficient performance assessment, and create a personalized learning journey through the curriculum for each student [3]. There is a need for collaboration between different stakeholders in the learning process, such as teachers, researchers, technology developers, and policymakers [4]. In this way, efforts will be distributed among the necessary activities, and the different levels of the courses will be able to be taken into account [5]. Also, ethically and securely use student data when it is necessary to be collected [4]. The need for significant investment in infrastructure and teacher training is often a barrier for many schools. Teachers have to understand the application of new technologies and their limitations [4]. They should eliminate bias and inequities at the development level when implementing fair and inclusive AI tools.

4. TRENDS OF STEM PERSONALIZATION

Personalized learning is tailored to and continuously modified to an individual learner's conditions, abilities, preferences, background knowledge, interests, and goals and is adaptable to the learner's evolving skills and knowledge [6]. It provides a solution to tailoring the learning according to individuals' needs and prior experience to allow them to reach their maximum potential through customized instruction. Generally, personalized education relies on progressively student-driven models, where students deeply engage in meaningful, authentic, and rigorous challenges to demonstrate desired outcomes [7].

Though STEM education has been a buzzword for the last two decades, it is not yet well recognized and fully implemented worldwide. Figure 2 represents Google trends for the terms "STEM education" and "personalized education", for the last 15 years.

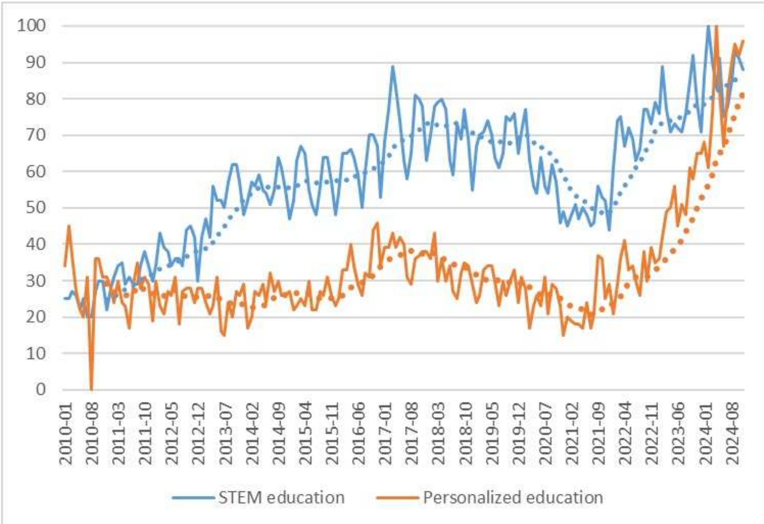

Figure 2. Google trends for "STEM education" and "personalized education"

The numbers show search interest relative to the point of maximum value on the chart worldwide for a half-year interval. 100 means the maximum popularity of the term, and 0 means there is not enough data for it. The 12-month moving averages for both lines are given in dotted curves. It is interesting to note that both the lines had a local maximum in 2017 that was surpassed in 2023. The lines reveal a local minimum for 2021-2022 due to the COVID-19 crisis, which has been overcome during the last two years.

5. PERSONALIZED STEM TEACHING

According to Bray and McClaskey [8], there are three main approaches to the personalization of learning: (1) individualized training – usually assists learners with special educational needs; (2) differentiated (group) learning – learners are divided into groups considering their knowledge and skills background or interests to offer a specially designed curriculum; (3) personalized learning – focused on the particular learner's needs, knowledge level, interests, and preferences, where learners have an active role in setting learning goals and choosing the preferable way of learning. There may be several concepts underlying the personalization of learning: *Learner modeling* [9] – the teaching process is personalized based on the learner's characteristics (separately or combined), being static (e.g., age, gender, cultural and social specifics; needs, knowledge level, interests, and preferences; learning or playing styles [10], etc.) or dynamic (e.g., learning behavior, outcomes, and performance; motivation and engagement; goals and requirements [11]). *Educational goals' setting* – defining expected learning outcomes (mandatory or optional); the teaching process is personalized according to the educational goals set by the teacher or by the academic institutions [11]. *Learning process feedback* provided to the teacher – the teaching process is personalized by processing feedback from the learner (in real-time or post-mortem, e.g., with machine learning approaches), parents, society, etc.

Personalized learning is customized for the needs of each learner. It may include personalization of curriculum, learning paths and resources, teaching methods and scenarios, learning pace, feedback, assessment, stimuli, etc. The implementation of personalized approaches during the teaching process may be of three types: (a) static – represents pre-set personalization done by fixed rules; (b) dynamic – applies on-the-fly adjustment and tuning of the personalization method based on learner feedback and performance; (c) hybrid approaches – combine features of both static and dynamic approaches.

The paper introduces the concept of personalized STEM education, namely the personalization of the modern STEM-related teaching methods shown in Figure 1. The implementation of personalized approaches for STEM education should be (1) Student-centric: (a) identifying and revealing the individual potential of every learner effectively; (b) fostering critical thinking; (c) developing skills and competencies; (2) Applicable for all the STEM teaching approaches; (3) Integrating novel and flexible STEM learning environments; (4) Engaging learners with real-world problems – involving students in practical tasks and experiments; (5) Fostering creativity and innovative spirit; (6) Allowing easy evaluation of its benefits; (7) Open for application of artificial intelligence tools.

6. DISCUSSION

Personalizing learning allows students to learn according to their learning style, personal pace, or preferred sequence of topics in the learning material. This approach places the student at the center of the learning process, i.e., the learning is student-centered. Teachers and university lecturers apply various methods for personalizing

STEM learning and below are briefly highlighted some good practices in this direction.

The PERCEPOLIS project [5] experiments by creating a community of STEM teachers and students across multiple campuses. They have a shared cyberinfrastructure that facilitates collaborative teaching and encourages customization of STEM courses and curricula. Each course consists of a set number of required and elective topics. The primary goal is to develop many educational resources and create and maintain a broad networked curriculum. The proposed personalization allows for sharing and access to various educational resources, which can be intended for teachers or students. This personalization ensures that students receive as many learning artifacts as their teacher deems appropriate. Intelligent software agents assist teachers by considering their teaching style and set of critical topics and recommending appropriate resources. Similarly, students receive recommendations based on features like academic profile, learning style, and interests.

The learning content in STEM education is often complex and requires intelligent learning systems with AI algorithms that offer good personalization. These systems can detect gaps in students' knowledge and recommend appropriate learning resources to fill them. By implementing this type of feedback, the learning is adapted to the style and speed of students' learning.

Different types of simulations of the phenomena studied in STEM subjects can facilitate abstract concepts understanding so that students can remember them for a longer time. Virtual and augmented reality suits these cases, and experiments can be carried out safely in the classrooms. Students' knowledge and skills vary significantly, and in many cases, traditional assessments and standardized tests do not assess them objectively enough. In this regard, research [12] suggests that applying tools that use artificial intelligence and machine learning can improve the assessment of student abilities and the development of learning. These assessment and feedback methods in education can assess more skill nuances and help students discover and work on their weaknesses.

Collaboration at all levels is critical to successfully integrating new technologies in STEM education. Collaboration between stakeholders and among teachers of different STEM subjects contributes to developing interdisciplinary lessons and new educational applications. Partnership between teachers and researchers is recommended to contribute to the development of innovative and effective tools for learning purposes.

7. CONCLUSION

STEM education has been expanding recently and is the main focus of research and policymakers in many countries. Although it has been proven to benefit students, there is still a lack of understanding of what instructional design should be for STEM education to maximize its impact. Even though personalized teaching approaches are confirmed to be efficient, they are not often used in STEM education. Thus, the current paper contributes to understanding personalization in the context of STEM education.

This topic has shown a steady increase in interest over the last decade. The essential issue related to it is the research of relevant instructional approaches concerning implementing STEM in classroom practices. To address this, the authors launched the SHAPES project (http://shapesproject.eu/), which explores innovative teaching methods applicable to STEM education. As a future work, it will propose approaches to the personalization and optimization of these teaching methods, considering teachers' opinions and preferences gained through structured interviews with experts and online surveys.

STEM education is still in the development stage in Bulgaria. Currently, a National STEM center that aims to support the building and development of a STEM environment in every Bulgarian school has started constructing modern technology-enhanced classrooms and laboratories for all STEM subjects.

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