THE ROLE OF INNOVATIVE STEM METHODS IN HIGHER EDUCATION FOR BUILDING A SUSTAINABLE FUTURE

Damyana Grancharova
South-West University "Neofit Rilski", Blagoevgrad, Bulgaria, damyanat@yahoo.com

Abstract: This article researches unique approaches and practices introduced in the implementation of university STEM education programs. The improvement of technology focuses on the use of virtual reality (VR), augmented reality (AR), and artificial intelligence (AI), sustainable and practical STEM education and gamification, which are the major topics that are usually included in educational activities. The use of these tools enables students to understand the material better and strengthens their retention of information. Through the article, the deployment of exercises in the curriculum spread through various study domains is shown. It illustrates how the innovative methods and strategies in the curriculum change over time and students become ready for the future by integrating curiosity, novelty, and environment-friendliness.
The article attempts to anticipate the development of STEM education in the years to come by analyzing the trends and innovations that form the pathways of teaching and learning in universities. The list of tools and strategies used by teachers is virtually unlimited with examples such as interactive reality simulation and project-based learning adding to the lessons. They doubly do this by incorporating the scientific drill requirement. Therefore, the educators are using a wide range of tools and methods for connecting the students with a deeper understanding of the STEM concepts. These are exciting times in which knowledge acquisition is being transformed by online platforms and open educational resources, thus, allowing learners from various backgrounds to gain the skills and new information which are essential for them to follow their passion and realize their full potential.
Since the advent of technology, the traditional approach to STEM education that was characterized by lectures, textbooks, and standardized tests is being gradually replaced by a new method that mainly uses innovation to encourage and develop creativity, critical thinking, and collaboration aiming at building sustainable development. If we take the most modern concept of STEM education, we can say that the most successful one is possibly the idea of integration, and that STEM represents the purposeful unification of different disciplines to solve real issues.
The pages which follow discuss these present trends driving the future of STEM education. In these pages, we tried to analyze and present the features and the outcomes of both theory and practice paying respect to corners of knowledge and inspiration for the educators and the stakeholders who have a strong commitment toward nurturing a more innovative and sustainable STEM education.
Keywords: STEM education, curriculum, innovative STEM exercises.

1. INTRODUCTION

In years of technological advances and ever-evolving global challenges, the face of education, especially in the fields of science, technology, engineering and mathematics (STEM), is undergoing a profound transformation. As society navigates the complexities of the digital age, building science literacy has never been more urgent (Grancharova & Raykova, 2021). From artificial intelligence to climate change, STEM disciplines serve as tools to address the complex problems of the 21st century. Gao explains that "another common learning objective of STEM education within the cognitive domain is to help students develop skills that go beyond a single discipline" (Gao, 2013). According to Bybee, as STEM education develops and expands, the use of the acronym is applied in advertisements, classrooms, competitions, conferences, curricula, resources, presentations, workshops, summer activities, videos, and more. However, these examples represent considerable variation in what STEM education can mean and how it can be defined. There is reference to all four disciplines, but sometimes the meaning and emphasis covers only one discipline. In some cases, the four disciplines are considered separate but equal. Other definitions define STEM education as the integration of the four disciplines (Bybee, 2013). At the curricular level, integrated STEM education is described as the integration of science, technology, engineering, and mathematics concepts in ways that reflect the practice of STEM professionals in order to encourage students to pursue STEM careers (Breiner, Harkness, Johnson, & Kohler, 2012). However, this seamless approach is a difficult task for teachers who need support, and the question of what STEM integration looks like in the classroom remains largely unanswered, and existing curricula are not designed to support teachers' integration efforts (Dare, 2018).

2. INTEGRATING STEM TECHNOLOGIES

Virtual reality (VR) as well as augmented reality technology (AR) are dragging the STEM education field to the new era when such technologies make activities immersive, interactive and that can bring many new experiences that

people were not able to do before. Thus, they convert abstract thoughts into concrete understanding and in such a way make the process of learning much more captivating and effective. Students will be able to virtually dissect the human body, create chemical experiments, and take virtual field trips, all from their classrooms.
Vats, suggests that VR and AR technology boosts student motivation and learning is very encouraging. Particularly, the study conducted by Vats showed that using VR and AR technologies in the classroom led to a 35% improvement in student engagement and 28% higher retention rates among students (Vats & Joshi, 2024). VR additionally might replicate the real-life practice, particularly herein that of medical education (Rosengrant, 2023).
AR, is the technique of overlaying digital info on the physical world, thus, the learning process is enriched. It is relevant to use such technology in different subjects i.e., in the case of biology, whether students work with 3D single cells or whole systems, they can see and interact with the models in 3D, thus, the concepts of biology will be much easier to comprehend. Furthermore, AR applications have also been made to assist the hearing-impaired learners, thus, education becomes more accessible (Kurni et al., 2023).
Sustainable STEM education is so important in the modern learning process, where the environmental concepts like ethical oversight and student responsibility are the main focus. STEM projects with "Green technologies and sustainable development" of attention on the natural environment as well as ecological problems which are used for engaging students in the directions of learning about the environment and solving the issues.
Sustainability, with form of education, is integrated into STEM. Educational Project based learning is where students, who are engaged with real-world environmental issues, learn themselves about sustainability. They can comes up with innovative renewable energy solutions developing of environmental protection strategies. When sustainably is incorporated to STEM education, educators are able to teach kids the essential role of eco-friendly development in the environment and further prepare the kids to be responsible global citizens and innovative problem solvers (Gavari-Starkie et al., 2022).
Project-based learning (PBL) is a type of supervision that takes place in the real world by engaging students in projects that require critical thinking, collaboration, and problem-solving. A major reason for the increasing adoption of this approach is that it allows the students to see STEM concepts as useful and applies them to relevant tasks. The use of Hands - on learning experiences serves the purpose of not undermining students' comprehension of STEM concepts while at the same time encouraging basic 21st century skills such as creativity, collaboration and communication.
Virtual laboratories enable scholars to perform various scientific experiments and understand various concepts of science without being constrained by the physical space of a laboratory A virtual laboratory helps the student in appreciation of practical skills by enacting real laboratory environments (May et al., 2023).
Gamification incorporates game design elements into educational activities to make learning more engaging. Using points, rewards and leaderboards, teachers can motivate students to actively participate in lessons and improve their problem-solving skills. Research shows that gamification can trigger the release of dopamine in the brain, creating pleasurable learning that increases motivation and engagement. Additionally, gamification also fosters a competitive atmosphere and motivates students to realistically anticipate the arduous tasks, and improvement process (Jaramillo-Mediavilla et al., 2024).
Ortiz Rojas, Chiluiza, & Valcke, stated, "Preparing young people for scientific and technological advancements associated with the contemporary society is very important". Within this frame of reference, the implementation of gamification in the field of STEM can become a way to harness students' interests in the areas of further undergraduate and graduate education (Ortiz Rojas, Chiluiza, & Valcke, 2016).

3. EXPERIMENTAL PART: DISTRIBUTION OF EXERCISES FROM THE CURRICULUM BY STEM FIELDS

We thought it would be useful to analyze the impact of different innovative STEM methods included in the university curriculum on student learning and engagement. The purpose of this article is to present research data and determine how the specific distribution of exercises across STEM disciplines will help identify effective approaches and identify challenges in implementing these methods.
The curriculum is structured in two main modules: "Methods of teaching STEM in natural sciences" and "Innovative techniques in green STEM education". The goal of the program is to prepare students with fundamental pedagogical knowledge while using modern teaching tools. It consists of 45 study hours, of which 30 hours are lectures and 15 hours are exercises and seminars, and carries 3 ECTS credits.
Module A_1, which is named "Methods of teaching in STEM innovative technologies", is planned to make students of the field of STEM technologies feel easy to effective teaching methodologies designed for the natural sciences.
Module A_2, which is named "Modern Techniques in STEM Technology Education", thus introduces students to modern techniques and methodologies essential to STEM Technology Education.

Students are urged to elevate their mastery of information literacy and science-related knowledge and hence to understand the integration and sustainability of STEM technologies in the education. Consequently, the course supports teamwork and communication, which are fundamental for the successful implementation of the teaching tools that are innovative in science.

This systematic review aims to characterize the different aspects describing the listed STEM methods, attempting to answer the following *research questions*:

- What is the distribution of the curriculum exercises in the different STEM fields?
- What is the percentage of exercises that use integration of more than one STEM method?
- To what extent do these exercises reflect the characteristics of effective STEM methods?

Table 1. Distribution of exercises from the curriculum in the different STEM fields

	STEM digitalization – Virtual reality, augmented reality and artificial intelligence	Sustainable STEM Education - Green Technologies	Hands-on learning and experiential learning	Gamification of STEM education	STEM Interdisciplinary Learning
How to do experiments within sustainable practices of STEM technologies?	✓	✓	✓		✓
Analysis of the structure of molecules from inorganic chemistry. The practices for their integration with STEM technologies.	✓		✓	✓	✓
Understanding wind energy systems and their integration into STEM technology methodologies for sustainable energy production.	✓	✓	✓	✓	✓
Research on renewable energy sources, solar photovoltaic technologies for sustainable energy and life cycle impact assessment through advanced computational tools within STEM technologies.	✓	✓	✓		✓
Understanding an integrated lesson on how to eat healthy? within sustainable STEM technology practices.			✓	✓	✓
Harnessing the potential and applications of chemical simulations within the principles of STEM technologies.	✓		✓	✓	✓
Harnessing the potential and applications of hydropower within the framework of STEM technology principles.		✓	✓		✓

Searching for solutions to geothermal energy, environmental pollution through the prism of sustainable practices of Green STEM technologies.		✓	✓	✓	✓
Exploring innovative methods to create fruit batteries in accordance with sustainable frameworks of STEM technologies.			✓		✓
Understanding plant anatomy within the scope of STEM technology practices.	✓		✓		✓
Exploring vertebrate life cycles and their compatibility with sustainable STEM technology frameworks.	✓		✓		✓
A visual exploration of the human body and its relevance within STEM technology initiatives.	✓		✓		✓
Newton's understanding of light through STEM technologies.	✓		✓		✓
Research on sustainable imaging methods - Marie Curie Laboratory	✓		✓		✓
Explore interactive lessons with 3D - the birth of quantum mechanics and fission of the atomic nucleus STEM technologies.	✓		✓		✓

Source: Author research

Table 1 presents the distribution of exercises in the curriculum according to the different STEM methods: digitalization, sustainable education, practical learning, gamification and interdisciplinary learning.

In the STEM digitization category, which includes virtual reality, augmented reality, and artificial intelligence, a large number of such exercises are noticed. These exercises employ tools like chemical simulations and visual exploration of the human body, among other things that enhance the learning process. Sustainable STEM education is mainly about green practice and technology, such as renewable energy impact assessment and sustainable energy production methods.

Practical experiential learning is a type of learning that encompasses all the exercises, it mainly focuses on practical learning and its application in the real world. This subcategory is made up of experimenting and anatomy of study plants and animals. Many of the teachers are adopting the method of gamification, that is, the use of gaming principles and techniques to motivate people.

Interdisciplinary learning includes all the exercises in one section, it is a process of cooperation among various subjects to discover the solution to a complex problem. We have mentioned a couple of them, for example, wind energy systems and interactive healthy eating units.

When you look at the exercise distribution, practical and interdisciplinary learning are the most important of all modern STEM subjects, and consequently, they are the ones that receive the highest representation. The influence of the other two, digitalization, and sustainable education are at the forefront, while gamification, through its unconventional strategies, maximizes the learners' involvement in the process of education.

Table 2. Percentage of exercises that can be completed with different STEM methods

Method	Percentage
STEM Digitization - Virtual Reality, augmented reality and artificial intelligence	73.33%
Sustainable STEM Education - Green Technologies	33.33%
Hands-on learning and experiential learning	100.00%
Gamification of STEM education	33.33%
STEM Interdisciplinary Learning	100.00%

Source: Author research

Table 2 shows the percentage of exercises that can be completed with each of the several modern techniques that are incorporated into the university curriculum. The most adaptable and broadly applicable approaches are practical training and transdisciplinary training, which cover every exercise (100%). This highlights their usefulness and significance in the educational process, giving students the chance to acquire real-world skills and understand how many disciplines relate to one another.

Virtual, and augmented reality and artificial intelligence have been the main technologies, and they have been the ones covering very high rates of exercises, i.e, 73.33%. These applications represent innovative and new ways to engage students to learn and apply complex things in an easy way. However, the other key technologies, sustainable STEM education and gamification, are responsible for a lower percentage of the exercises, 33.33% each. This means that these types of quizzes are brought into play not only in the field of general education but also special contexts. On one hand, sustainable education focuses on ecological and social aspects, and on another hand, the use of gaming rules in the classroom to encourage students' learning and participation.

Overall, they act as the evidence of the various manner in which STEM teaching has been done, with all the different pedagogical modes adding value to the achievement of the lid learning objectives.

4. TO WHAT EXTENT DO THESE EXERCISES REFLECT THE CHARACTERISTICS OF EFFECTIVE STEM METHODS?

Practices in the various STEM areas are a perfect fit for effective STEM methods. One of the most important factors is student interactivity and engagement. This is particularly important for the effective acquisition of knowledge and skills, as interactive learning promotes better understanding and retention of material, and interactive lessons with 3D visualizations and chemical simulations provide students with the opportunity to immerse themselves in the learning material and learn through experience.

The analysis of renewable energy sources and their impact on the environment offers students practical knowledge and skills that can be used in the real world. The technological shift is also an important element that the exercises include. Using the newest technologies, e.g. virtual reality, artificial intelligence and digital simulations, is strongly promoted, and challenges the conventional ways of learning and research.

A huge emphasis is placed on green tech practices, which is a rarity in the present STEM methods. This creates demand for students to not only think ecologically but also develop ways to protect the environment.

5. CONCLUSION

STEM education's future is promising because of inventions such as virtual reality, augmented reality and artificial intelligence which transform the learning process into a more interesting and effective one. These technologies are designed to visualize difficult abstract concepts and also to personalize the education while the sustainable STEM education that the students receive, in turn, creates in them an environmental awareness. Students are engaged in self-directed learning as they are oriented to the solution of real-world issues and learn to collaborate for a better future for our environment and society.

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