DIGITAL TOOLS FOR STEM EDUCATION

Deyana Peykova, Kosta Garov

Abstract. This paper shows the role of technology in Science education and provides a review of digital tools that supports students' learning in different integrated science, technology, engineering, and mathematics (STEM) learning environments. Technology can be used to increase student engagement, expand experiences, and accelerate learning. Technology can facilitate the exploration of STEM subjects and provide support for students to connect different disciplinary ideas, for example, when using simulations. Technology encourages students to explore scientific and mathematical ideas in a new way. This work presents different digital tools that teachers can use to support students' learning in STEM education.

Key Words: *digital tools, technology, STEM education*

Introduction

The term "STEM education" refers to teaching and learning in the fields of science, technology, engineering, and mathematics. STEM education removes the traditional barriers between the four disciplines by integrating the four subjects into one. The engineering component puts emphasis on the process and design of solutions instead of the solutions themselves. This approach allows students to explore math and science in a more personalized context, while helping them to develop the critical thinking skills that can be applied to all facets of their work and academic lives. Engineering is the method that students utilize for discovery, exploration, and problem-solving. The technology component allows for a deeper understanding of the three other parts of STEM education. When we talk about digital tools and solutions for STEM education, we consider this as teaching and learning the scholarly material of science education classrooms through the application of technology. Using digital tools to teach STEM could improve students' learning outcomes [1].

It is difficult to keep today's students engaged as they are learning about science. Today's students are so accustomed to high levels of interactivity and games that they easily become disengaged when teachers use traditional methods. And because of high costs and lack of resources, many schools are unable to provide their students with adequate access to science facilities such as laboratories. As a result, students may lack the opportunity in school to learn practical science, which is an essential part of science education [2, 3].

Digital tools can help students learn math and science, especially when used alongside a variety of teaching methods. They are most effective when are used for explaining complex and abstract content, such as geometry and the visualization of chemical compounds or in physics classes.

Using digital tools in STEM education gives an engaging and interesting way for learners to interact with science, while also increasing their access to practical science education. Interactive virtual laboratories with gamification elements such as an immersive 3D universe, virtual and augmented reality, mobile apps are the most often used digital tools that support STEM education.

That simulations can never replace physical laboratories but practice in the virtual laboratory makes students entering the physical laboratory feel more confident and better prepared. There is also learning content that can not be shown to students for example how to form atoms and molecules or it is dangerous for students – for example chemical reactions [4].

Digital tools can provide access to information that is otherwise invisible: how seeds sprout roots and grow into plants; how shadows shift as the sun passes overhead; or how wind patterns move storms across the globe. They also can provide models to children and adults about how to ask questions about the world in which we live, and can provide guidance to adults on how to help children conduct experiments, ask questions that can be tested, and provide explanations for phenomena based on the data they collect through their own experiments and through observations of others.

STEM learning and teaching can be enhanced if technology is used to:

- Provide models of real engagement for educators, parents, and children;
- Connect educators to a community of fellow learners (e.g. provide access to professional development opportunities that support STEM content and skills that are appropriate for early learning settings);
- Provide ready access to teacher training resources, such as teaching guides and adaptable student activities, using a variety of modalities;
- Expose children and adults to phenomena and visual and auditory information that they might not otherwise have access to;
- Engage children in tasks using technology that invite sharing, collaborating, and discussing, such as paired playing of digital games;
- Provide tailored learning opportunities that reflect an educator’s level of prior knowledge or experience [5].

The inclusion of digital tools in education process (either by teachers or by students themselves) can contribute in increasing students’ motivation for the different aspects of the teaching and learning processes.

Selecting the right digital tools teachers should follow some criteria (Table 1) and to make an evaluation to identify the reason for using the digital tool. Digital tools must focus students’ needs. With identified needs in hand, teachers are prepared to begin the selection of digital tools.

Table 1. Criteria of selection of digital tools

Criteria	Questions to be considered
Relevance	The material has a strong connection to the curriculum or the topics teachers use it for. • Is the material appropriate for the student? • Is the content factual and reliable? • Does it align with your learning goals?
Navigation	Ease of use when students use a new tool. • Does the material use the touchscreen effectively throughout its use? • Is it intuitive to use? • Is there a help function or tutorial available?
Customization	Complete flexibility to alter content and settings help teachers meet student needs. • Does it offer personalized or adaptive skill levels? • Does it offer flexibility to customize content to meet student needs? • Does it let users personalize the user interface?
Interaction	Deeply engaged students come alive and are more motivated. • Is the feedback specific and does it result in improved student performance? • Is the material inviting to use? • Are students motivated to use the tool and select it to use often?
Accessibility	Many materials can help teachers reach students with special learning needs to access abilities. • Does the material let users personalize the user interface? • Does the tool offer flexibility to alter settings to meet student needs? • Does the material work with accessibility features on the mobile device?

The choice of the digital tool deepens on the teacher, the educational content regarding the curriculum and a classroom infrastructure. [6]

Digital tools for STEM education

Phet (https://phet.colorado.edu/)

This free interactive website is filled with fun and enjoyable simulations that pertain to the four core subjects of STEM education. It has delivered over 1 billion simulations since it started in the year 2002. Teachers have access to simulation-specific tips and video primers, resources for teaching with simulations, and activities shared by the Phet community. There can be found physics, chemistry, math, earth science and biology simulations. Students are engaged through an intuitive, game-like environment where students learn through exploration and discovery. The simulations are written in Java, Flash or HTML5 and can be run online or downloaded to a computer. All simulations are open source. To help students engage in science and mathematics through inquiry, PhET simulations are developed using the following design principles:

- Encourage scientific inquiry;
- Provide interactivity;
- Make the invisible visible;
- Show visual mental models;
- Include multiple representations (for instance, object motion, graphs, numbers, etc.);
- Use real-world connections;
- Give users implicit guidance in productive exploration;
- Create a simulation that can be flexibly used in many educational situations [6].

The following example is math simulation. The Fractions: Mixed Numbers simulation allows students to engage with and compare multiple representations of fractions, including a mixed number. In the Intro screen, students can build their own fraction and see it represented as a pie, rectangle, cylinder, cake, or number line, and compare it to the numerator and denominator of an improper fraction and a mixed number.

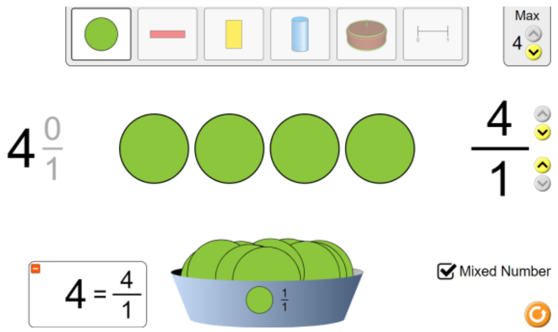

Figure 1. Math simulation – Fractions: Mixed Numbers

Students predict and explain how changing the numerator of a fraction affects the fraction’s value; how changing the denominator of a fraction affects the fraction’s value, they convert between a picture of a fraction, an improper fraction, and a mixed number and build matching fractions using numbers and pictures.

The Intro screen is often used for discussions and explanation. In this case in math simulation questions can be like that: “What does the top number of the fraction mean? What does the bottom number mean? In a mixed number, what does the large number mean? What do the top and bottom numbers mean?”. There are also Game screen and Lab screen where students can create fractions [7].

Explore Learning Gizmos (https://gizmos.explorelearning.com/)

It is a world’s largest library of math and science virtual labs and simulations. Gizmos are interactive math and science virtual labs and simulations for grades 3-12. Over 400 Gizmos aligned to the latest standards help educators bring powerful new STEM learning experiences to the classroom [8]. Virtual labs can be selected by academic standard, grade and topic and textbooks. The following figure presents the virtual lab “Phases of Water”. Students have to heat or cool a container of water and observe the phase changes that take place. They use a magnifying glass to observe water molecules as a solid, liquid, or gas and compare the volumes of the three phases of water.

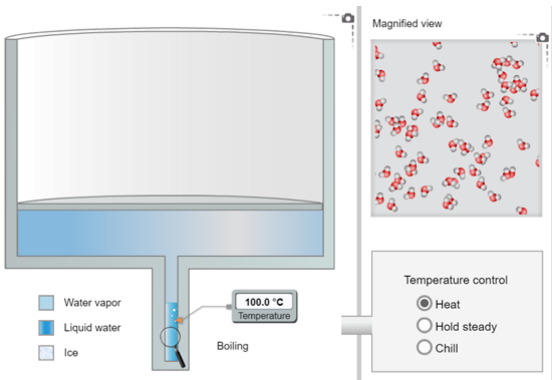

Figure 2. Virtual lab – Phases of Water

During this virtual experiment, students have Student Exploration Sheet with question they have to answer.

Planetarium (https://stellarium-web.org/)

Stellarium is a free open-source planetarium that can be use in Geography and Physics lessons. It shows a realistic sky in 3D, just like what you see with the naked eye, binoculars or a telescope. This website lets students to explore the heavenly bodies in a browser. It can be added as an extension for Google Chrome users. There is a mobile app that can be downloaded from Google Play or App store. There is a default catalogue of over 600,000 stars and extra catalogues with more than 177 million stars, deep-sky objects, asterisms and illustrations of the constellations, very realistic atmosphere, sunrise and sunset, the planets and their satellites. Visualization options are equatorial and azimuthal grids, star twinkling, shooting stars, tails of comets, iridium flares simulation, eclipse simulation, supernovae and novae simulation, 3D sceneries [9].

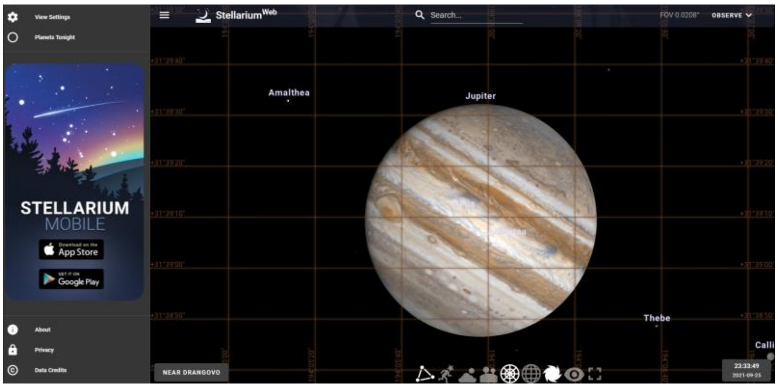

Figure 3. Visualization of Jupiter and its satellites

After log in students can have an astronomical log book where they can record their observations.

Interactive Periodic table (https://ptable.com/)

This interactive periodic table showing names, electrons, and oxidation states. It visualizes trends, 3D orbitals, isotopes, and mix compounds. There is a translation in 73 languages including Bulgarian. There is an information about all elements. Students can drag elements and make compounds [10].

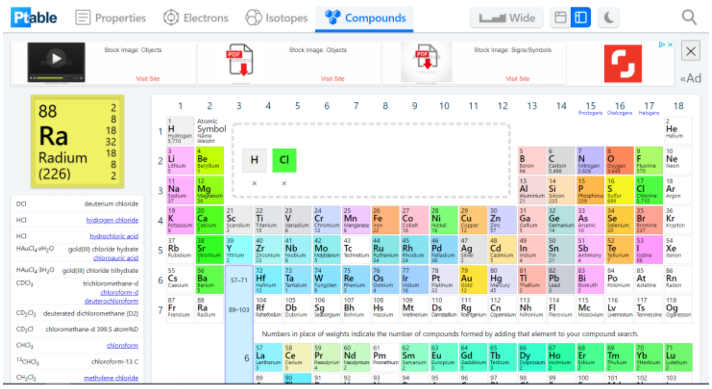

Figure 4. Making compounds using hydrogen and chlorine

Augmented reality with AR výuka

Augmented reality (AR) is one of the biggest technology trends right now, and it is only going to get bigger as AR ready smartphones and other devices become more accessible around the world. AR let us see the real-life environment right in front of us [11].

AR výuka app is a free Android Education app in Czech and English languages. The application demonstrates the possibilities to extend and improve teaching at schools. Scientific models “become alive” and each student can use an interactive 3D helper in their physics, mathematics or biology class. There are 28 visualizations and models that are connected with physics, chemistry, architecture, math, computer sciences, and biology. On Figure 5 the systems of human body are shown. Students point the phone at the ground or above a code that is printed from the application website and the systems of the human body appear in front of the students. Using the slider at the bottom, students can change which system to be displayed [12].

Figure 5. Systems of human body

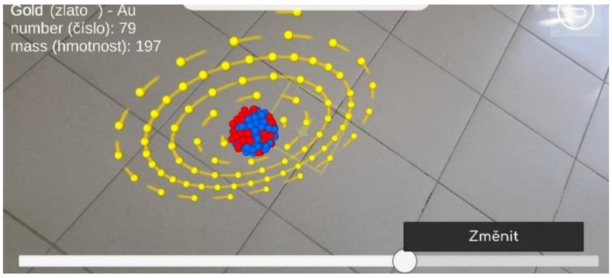

Figure 6. Atoms creation

Another simulation that can be used in Chemistry lessons is atoms creation. Using the slider at the bottom students change the number of element, they see the nucleus of the atom and how the electrons revolve around it. The information that appears is about the name and number of the element and its mass.

Conclusion

Using digital tools in STEM education (e.g., simulations, games) provides an opportunity for students to perform experiments or investigate phenomena beyond physical constraints. Virtual labs and simulations allow students to operate with data, explore variables and observe their effects to gain an understanding of the relationships between variables. Innovative technology, like augmented and virtual reality can provide contextual learning experiences and offer immersive experiences. Not many teachers in Bulgaria use different digital tools in science education. Most digital tools are in English and teachers do not feel confident enough to use them in daily practice. Teachers need professional development training courses to provide them with resources and digital tools that support STEM education and engage young learners in STEM experiences that could be an object for future research.

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