

Use of Artificial Intelligence technologies in studying the phenomenon of electric current in physics education

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Abstract: *Utilizing software applications in Physics education to visualize and demonstrate various physical laws and phenomena is a crucial factor in achieving good learning results. The use of software tools with artificial intelligence further streamlines the learning process. This paper reviews suitable software applications for Physics instruction and shares practical experiences from teaching the topic of “Electric Current”. We used the Tinkercad application to model electric circuits and conduct experiments. Additionally, we present a practical strategy for employing the ChatGPT AI chatbot to assist students in self-training and coursework development.*

Keywords: Education, Electric current, Electrical circuit, Tinkercad, ChatGPT, Physics.

1. Introduction

Dynamically developing information technologies provide rich opportunities for the educational system, including the use of innovative technologies and software tools, through which learners can be more actively involved in the learning process. Adolescents are not only technologically literate; they are also deeply integrated with technology. This brings with it the need for the teacher to change the classic teaching approach and implement interactive methods and techniques that will attract the attention of students and help them study more easily (Raikova, 2016). The student must not only learn new knowledge but also be stimulated to engage in independent creative activities in which they can show their individual abilities (Milcheva, 2016). In order to stimulate the development of these skills and abilities, the teacher must be creative in teaching and engage learners through a variety of tasks and projects (Kirilova, 2023). They should aim to develop high-order thinking skills. As such, cognitive abilities are defined from the high levels of Bloom’s Taxonomy – analysis, synthesis, and evaluation (Bloom et al., 1956). They are important because they build qualities that help learners deal with complex life situations, analyse specific information, search for innovative solutions, generate ideas, etc.

With the advancement of information technology, teachers and students have more and more tools to visualize the studied objects, processes and phenomena – virtual laboratories, tools with built-in virtual reality, learning management systems, chatbots, software applications with artificial intelligence (AI), etc. The use of such tools in the learning process undoubtedly increases its quality.

2. Use of software applications in Physics education

There is a wide variety of software applications, including ones with AI, useful for organizing and conducting Physics lessons.

Smart Sparrow is a platform for adaptive and personalized learning (Smart Sparrow, 2023). It provides teachers with an intuitive authoring tool for creating learning resources and modeling adaptive pathways, where learning material can be adapted to the needs of each student. Teachers have real-time data analytics, accessible through the analytics dashboard, that reveal data about the learning process beyond the received grades. AI-driven algorithms monitor student progress and dynamically adapt learning materials to individual needs. The platform allows for integration with other educational software applications.

Squirrel AI Learning offers online extracurricular courses in subjects such as Math, English, Physics, and Chemistry (Squirrel AI, 2023). The project's goal is to provide each student with their own AI Super Teacher. The platform is powered by its proprietary AI-driven adaptive engine and custom-built courseware. It uses artificial intelligence algorithms to adapt the learning material to the needs of each student.

Another powerful tool for teaching Physics is Wolfram Alpha (Wolfram Alpha, 2023). With Wolfram Alpha, you can explore data on phenomena in the fields of Quantum Mechanics, Nuclear and Particle Physics, Thermodynamics, and Newtonian Mechanics. The application uses a variety of physical formulas and constants. It supports interactive calculators with which various physical phenomena can be studied easily and visually.

PhET provides interactive, research-based science and mathematics simulations (PhET, 2023). The simulations are designed to stimulate scientific skills by providing implicit guidance to students to conduct productive research. They visualize invisible phenomena, show visual mental models and different aspects of real-world processes through multiple representations, e.g. movement of objects, graphics, and numbers. At present, there are more than 100 simulations of physical experiments and phenomena. The simulations are open source and can be integrated into learning management systems with AI.

Teachers can use the Edpuzzle application for instructional purposes (Edpuzzle, 2023). It allows them to add interactive questions and remarks to video lessons on Physics. This motivates students to take an active part in the learning process, and stimulates their creativity and curiosity. Teachers receive real-time learning data analytics that helps them personalize their teaching and the assessment of students.

3. Interactive tasks in teaching Physics and Astronomy

The study subject "Physics and Astronomy" in Bulgaria is taught independently starting from the 7th grade. Until then, physical phenomena are studied within the combined subject "Man and Nature", which encompasses two natural sciences – Chemistry and Environmental Protection, as well as Biology and Health Education. The "Physics and Astronomy" curriculum aims for 7th graders to explore key aspects of "Electric Current", "Light and Sound", and "From the Atom to the Cosmos" within 54 class hours.

In the "Electric Current" section, knowledge about fundamental quantities and laws of electricity is acquired, which is further built upon during the high school stage. The effect of electric current on the human body and the measures for the safe use of electrical devices are examined. This educational material is more abstract and harder for students to perceive, so it's recommended to use visual aids to recreate specific learning situations. These aids enable students to develop their visual and auditory memory (Dimitrova, 2018). This, in turn, helps learners to successfully recall the information when encountering a situation similar to the one presented by the teacher.

Students can much more easily understand the situation with series and parallel connections of consumers in an electrical circuit when it is visually recreated through suitable software. Popular applications providing visual representation in physics and astronomy include Go-Lab (Go-Lab, 2023), PhET (PhET-2, 2023), Tinkercad (Tinkercad, 2023), and others. Go-Lab and PhET support a variety of different functionalities. They offer a laboratory environment not only related to electricity but also focused on light phenomena, the peculiarities of space, and so on. Unlike them, in Tinkercad, mainly the physical laws related to electricity can be demonstrated. Here, the teacher has a wider selection of elements for connecting in the electrical circuit, which is closer to real-life situations. This predisposes learners to be intrigued by this part of the curriculum and to learn things they can apply in their daily lives.

Tinkercad is a free application that provides multiple functionalities for modeling and experimenting with electrical phenomena and sample projects for educational purposes. Any teacher can create a virtual environment for students in a class to share educational resources, set assignments and track the progress of the students' work. In the learning process, students are given a variety of tasks related to the studied material. The aim is to develop learners' skills in applying their knowledge of electricity to new situations. The teacher demonstrates a solution to a specific task, then assigns a similar task for students to solve independently, allowing them the freedom to use different components.

Following the lessons on "Electric Current" and "Electric Voltage", students participate in two laboratory sessions. During these sessions, the teacher can intrigue the students by showing them through Tinkercad visually how to work

with electric circuits. Below are sample tasks used in the 7th-grade curriculum at the "Otets Paisiy" primary school. This school is located in the village of Topolovo, Bulgaria, and these tasks were utilized during the academic year 2022/2023.

Task 1. Make a model of an electrical circuit that contains a source of electrical energy with a voltage of 3V, a lamp as the consumer, and an ammeter.

1. How does the electric current in the circuit change when the applied voltage is doubled? Draw a conclusion about the relationship between voltage and electric current.
2. If the applied voltage is reduced by $\frac{1}{2}$ of the given value, by how much will the magnitude of the electric current be reduced?

The teacher presents the solution to the task as shown in Figure 1, then gives the students a similar task, but with the condition that they look for an alternative source of electrical energy. Examples of solutions include using a lemon or a potato, with students determining the appropriate electrical voltage for their solutions, as illustrated in Figure 2.

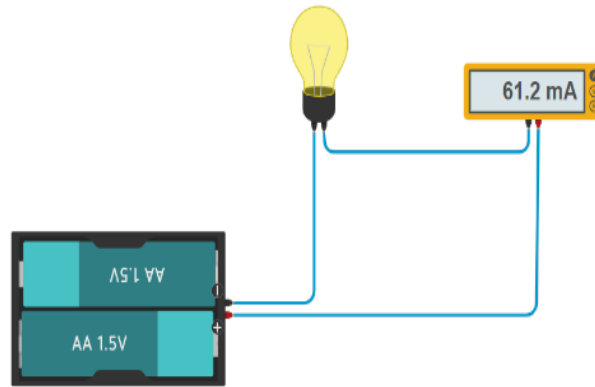


Figure 1. Electric circuit in Tinkercad with a power source, a lamp (consumer), and an ammeter

Task 2. Make a model of an electrical circuit that contains a source of electrical energy with a voltage of at least 3V, an electrical consumer, and a voltmeter.

Unlike the previous task where a voltmeter was not required, in this task, a voltmeter must be included in the circuit. Students should take into account that the two devices connect differently. They can experiment with various components in the circuit since the task specifies only the voltage value, which is also variable. The teacher can pose the following questions to the students:

1. How should the voltmeter be connected in the circuit to measure the correct voltage?
2. Determine if the voltage value will increase when you connect two equal-voltage electrical energy sources in series.

After studying the methods of connecting electrical sources and consumers, a more complex task can be introduced.

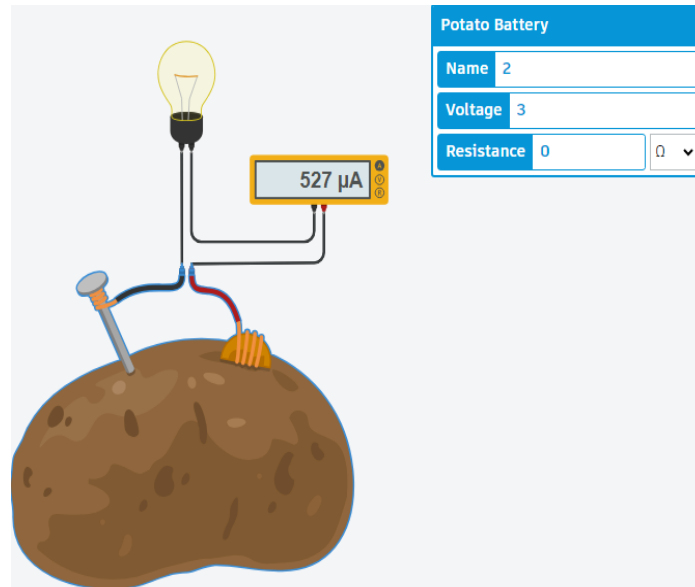


Figure 2. Exploring the potato's property as an electrical energy source in Tinkercad

Task 3. Make a model of an electric circuit with consumers connected in series. Prove the statement that when the electric circuit is interrupted, no electric current flows through either consumer.

1. What is the main difference between sequentially connected consumers and parallel connected ones?
2. Determine whether an electric current will flow if the circuit is broken between the two consumers.

In the third task, learners must apply their knowledge of electric circuit connections and visually demonstrate that when the current's path is interrupted, both consumers stop working.

Task 4. Make a model of an electric circuit with parallel connected consumers. Include at least three consumers.

In this task, students must consider the requirements for parallel connection and the number of consumers (Figure 3). It is appropriate to target them with the following questions:

1. Specify which type of connection of consumers is more suitable when building the electrical installation in a home?

- Determine whether an electric current will flow if the circuit is broken between two of the consumers.

In their work, students may encounter difficulties of a different nature. They can use the ChatGPT artificial intelligence chatbot to resolve them on their own.

4. Using ChatGPT to support students

ChatGPT, developed by OpenAI, is an artificial intelligence chatbot (OpenAI, 2023). It not only can hold a conversation by successfully imitating a person but also perform more complex activities. These activities include generating ideas and explaining concepts (Lapuschin, 2023), composing works of art (Reich, 2022), writing code (Tung, 2023), and others.

ChatGPT can be used in training, but carefully, taking into account the fact that it is not always a reliable source of information. During Physics and Astronomy labs, students can use it to help them complete assignments.

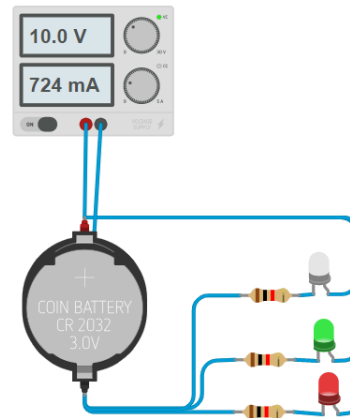






Figure 3. Electric circuit with 3 parallel connected consumers

 Certainly! To build a simple electric circuit with a 3 V power source, a lamp, and an ammeter:   

- Gather Materials:** You'll need a 3 V power source (like two 1.5 V AA batteries), a lamp suitable for 3 V, an ammeter, wires, and possibly a battery holder.
- Connect Power:** Put the two AA batteries in the holder so they're in series, giving a combined 3 V.
- Connect Ammeter:** Attach the positive (usually red) terminal of the ammeter to the battery holder's positive side.
- Connect the Lamp:** Link a wire from the ammeter's negative (typically black) terminal to one end of the lamp. Connect another wire from the lamp's other end back to the battery holder's negative side.
- Check Connections:** Ensure all connections are firm and that wires don't touch each other.
- Test the Circuit:** When connected correctly, the lamp should light up, and the ammeter will show the current in amperes (A).
- Safety:** Always ensure the lamp is suitable for 3 V. Using the wrong lamp might either not light up or burn out.
- Ammeter Position:** Remember, ammeters go in series, not parallel. They should be part of the main circuit flow, not a side branch.


This setup lets you view the current the lamp draws when powered by the 3 V source.  Regenerate

Figure 4. Question to ChatGPT and its answer, related to building a model of an electrical circuit

Students who are experiencing difficulties can use ChatGPT by asking appropriate questions related to completing tasks set by the teacher. For example, they can ask the following question on ChatGPT - "How to build a model of an electrical circuit that contains a 3V power source, a consumer (lamp), and an ammeter? ". Part of ChatGPT's response is presented in Figure 4.

To find an answer to the questions posed or to test their knowledge, students can post a series of questions on ChatGPT, for example: "How will the value of the electric current in the circuit change if we increase the voltage twice?" (Figure 5), "Can I use fruits and vegetables as a source of electrical energy? Give me some examples of such fruits and vegetables." (Figure 6), etc. In general, ChatGPT gives very accurate and reasoned answers.

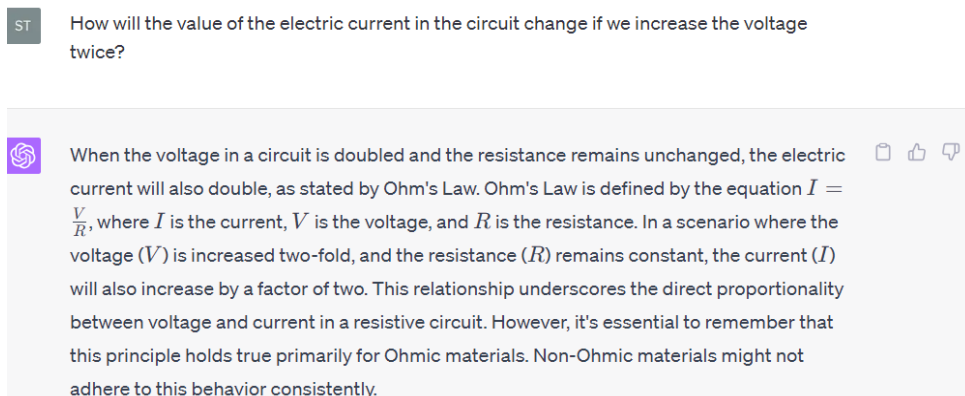


Figure 5. Question to ChatGPT – How will the value of the electric current in the circuit change if we increase the voltage twice?

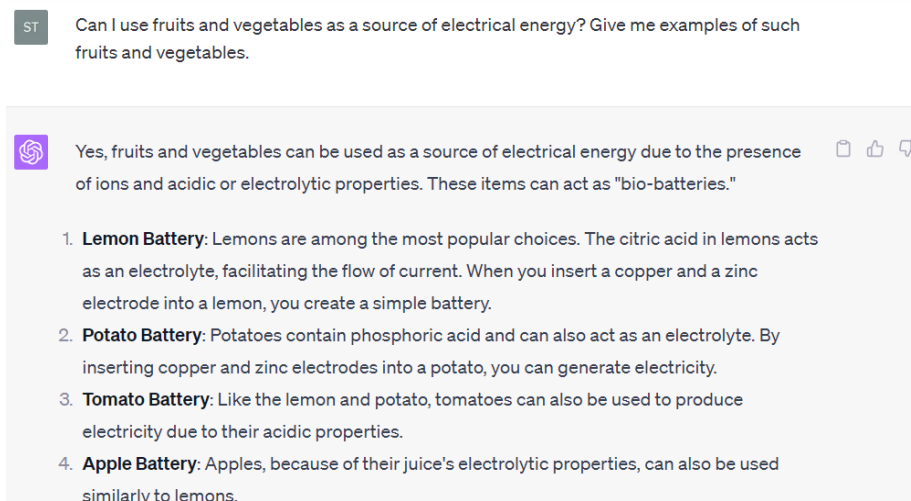


Figure 6. Question to ChatGPT about using alternative energy sources

5. ChatGPT – risks and limitations

The precision of the questions posed to ChatGPT is crucial for obtaining accurate answers. The model is sensitive to changes in question wording and may give different answers to slightly rephrased questions. For example, ChatGPT might not know the answer to a specific question but might respond correctly if the question is slightly altered. In cases where a user posts an ambiguous question, ChatGPT doesn't pose clarifying questions. Instead, it makes assumptions about the user's intent and provides a response accordingly (OpenAI, 2023).

ChatGPT often tends to be verbose and frequently uses certain phrases, emphasizing that it is a language model trained by OpenAI. In some cases, it might provide plausible-sounding but incorrect or nonsensical answers. Nevertheless, it has been successfully employed across various domains, such as learning foreign languages (Barrot, 2023), medical education (Currie, 2023), and rapid engineering (Short, 2023). To optimize the use of large language models in education, both educators and students should hone their competencies and literacies. This will enable them to better understand the technology, its limitations, and the unexpected vulnerabilities of such systems. Adopting a clear pedagogical approach, with an emphasis on critical thinking and fact-checking strategies, is essential (Kasneci, 2023).

For better or worse, AI chatbots are already visibly transforming modern education. Their benefits are undeniable – they assist teachers in creating learning content and act as online teachers by answering students' questions. The primary disadvantages include the potential for generating inaccurate or false data and the ability to bypass plagiarism detectors in situations where originality is paramount. To address the transformative effects of ChatGPT on the learning environment, educational institutions must take action (Gill, 2023). It's essential to educate both teachers and students about the opportunities and risks associated with using artificial intelligence. To ensure AI is employed responsibly and ethically in education, academic rules and regulations should be updated, specifying practices for its use and implementing stricter rules for intellectual property protection.

6. Conclusion

Education in Physics and Astronomy is important for the acquisition of fundamental knowledge about the evolution of our world and the universe. It enables students to develop observational and analytical thinking. The use of interactive methods motivates them to work actively and stimulates them to learn more easily. Such methods illustrate the practical applications of their knowledge, hone their ability to apply new insights in unfamiliar scenarios, and bolster their creativity and skills for conducting experiments.

The web-based application, Tinkercad, used for teaching 'Physics and Astronomy' subject in the 7th grade at 'Otets Paisiy' primary school in Topolovo village, has caused significant interest among the students. The experiments they

conducted, the questions they asked themselves, and the answers they found left them with lasting knowledge. This is evidenced by the good results of the conducted tests.

For more efficient work, students can also use ChatGPT artificial intelligence chatbot in their self-training. It can give ideas, look for answers to difficult questions, and detect mistakes. Considering the coming era of artificial intelligence, students must acquire a new skill – to "talk" with digital subjects by formulating their questions correctly and precisely. And of course... to remember that no one is perfect, including "Artificial Intelligence"!

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