OpenAI's Adaptive 3D Periodic Table With Braille: Revolutionizing Chemistry Education for the Visually Impaired

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Abstract

In our developing times, the development of technological tools has a special impact on the field of education. In particular, it is necessary to use various technological tools to ensure the education of students with special needs. However, even with better tools, Kazakhstan has not developed well-developed methods of teaching chemistry to blind students. Blind students can familiarize themselves with the periodic table of chemical elements only by tactile means. These tictal tools make it difficult to understand complex concepts in chemistry and reduce students' enthusiasm and interest in chemistry lessons. To solve this problem, a new project was organized jointly with students of SDU University. As part of this research effort, a unique interactive periodic table was printed using 3D printing technology, which was created using OpenAI technology. This periodic table allows blind students to study chemical concepts in a convenient format, keeping up with other students. It was printed on a 3D printer, and each element was made in the format of a button on a keyboard. At the same time, the surface of each element was made in Braille. To obtain information, the Nano Arduino sensor system was used, which received data and later sent processed information to the smartphone via a wireless network or mobile Internet at the touch of a button. The transmitted information, which made it possible to send audio information to students via a smartphone. As a result of the work done, this device was presented to students. This modern device significantly contributes to the increase of blind and visually impaired people's interest in chemistry and the memorization of data. In addition, it allows us to apply such modern methodology in inclusive education. AI also makes a great contribution to using special students in modern education. We are confident that this modern method will contribute to education for every student in the world. It is not only beneficial for students in Kazakhstan but also for general standards.

Keywords: OpenAI, 3D printer, braille, accessible chemistry education, nano arduiпo, tactile learniпg, inclusive learning, AI-powered educatioп

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Introduction

The Periodic Table of the Chemical Elements is a fundamental tool in the language of chemistry (Limpanuparb et al., 2024). This educational tool reflects all chemical elements and the main concepts of chemistry. Periodic Table is used not only in chemistry, but also in other scientific fields such as physics, biology, and biotechnology. In chemistry education, it helps explore all things made of matter (Mhlongo & Sedumedi, 2023).

Education aims to prepare people for life by providing them with knowledge and skills that will help them find a common language with the constantly evolving world around them (Karakoç & Aslan, 2022). Meanwhile, all students should study chemistry and other subjects equally in order to be able to use them in their lives (Wandy, 2020). Science is necessary for every student, as it develops vital abilities. Because of this, general education programs around the world divide science according to each student's ability to accept information, respecting their cultural background and inclusivity. But considering students with visual impairments or blindness, we need a different learning approach that includes tactile and auditory aids (Karakoç & Aslan, 2022). According to Steele (2015), tactile graphics and Braille is a font that promotes learning through touch, gaining basic concepts and information according to each subject and concept. Despite the fact that the Periodic Table of Chemical Elements is presented in various formats, it remains a difficult problem to adapt it for visually impaired and blind students (Bonifacio, 2012). The authors Melaku et al. (2016) argue in their study that instructing chemistry to students with visual impairments is a challenging endeavor in educational institutions. To address this issue, the researchers propose hands-on activities to enhance students' engagement. To address this issue, certain investigations have proposed the utilization of multi-modal instruments that facilitate the process of learning in the field of natural sciences (Koehler & Wild, 2019). In a paper authored by de Oliveira et al. (2017), the authors highlighted the challenge of teaching chemistry to visually impaired students in Brazil, which is exacerbated by the extensive use of symbols in the subject, making it more challenging to accommodate.

To solve the problem of adapting the periodic table of chemical elements, Zhang et al. (2022) created a project at Michigan State University. This project aims to create an adapted version of the periodic table using 3D printing. The goal of this project is to make the periodic table more accessible to people with disabilities. To achieve this, researchers used 3D printers and CAD software to create the table elements. During the process, students in the STEAM laboratory as a task, each student studied individual elements. Each element included ASL signature, Braille text, and the atomic number. The finished pieces were assembled into one table. In the recommendations, the authors noted that such projects offer opportunities for students with limited abilities, as well as the use of 3D printing in the modern world can be a good product for education. Another study aimed at using 3D printing and STEM education includes a different adaptation of the periodic table. Researchers Laconsay et al. (2020) used the molecular structure of each element or compound to create spherical models using 3D printers. According to the authors, blind and visually impaired students can process spatial information in the same way as sighted students. The article also provides remarkable examples of successful blind scientists in organic chemistry, as well as examples of blind teachers in chemistry. Additionally, the authors investigate audio applications such as Titration ColorCam and software such as NavMol 2.0 and BrileChem that use voice synthesis to interpret molecular structures. This study was conducted on the British Virgin Islands. The authors note that implementation of this model requires precise formulation and a slow learning pace. In the British Virgin Islands, Melaku et al. (2016) also studied a slightly

different adapted version of the periodic table of chemical elements for students with visual impairments. The authors believe that practical modules help students better understand chemical concepts. For this module, scientists used toy blocks as an adaptable material. According to researchers, these blocks allow you to build and modify, helping students understand periodic changes in elements and the atomic structure of atoms. The modules also demonstrate changes in atomic radii and cationic charges. Most importantly, toy models show ionization energy and electronegativities of elements. To evaluate the effectiveness of the modules, the authors surveyed students in the British Virgin Island and sighted students, and the results showed that students positively assessed their usefulness for learning chemistry. The authors claim that building blocks - modules can be useful for both blind and sighted students.

Eldem and Basçiftçi (2013) have developed an adapted electronic periodic table. The main objective of this study was to develop an electronic and computerized device for studying the periodic table by blind and visually impaired students. For this purpose, materials such as PIC16F877 microchips were used to program the circuits. Further communication between PIC16f877s and computers is organized via serial ports. As a result, RC6 PICs were used to transfer data via serial port. In order to fully adapt, periodic tables were placed on boards with buttons for each element. Based on the principles of operation, visually impaired people can feel elements with their hands and hear names of elements. Additionally, Braille is used to write names of each element above buttons. This system was tested with four visually impaired students, and learning using this system took less time compared to traditional learning.. The authors noted that test results confirmed the effectiveness of the system. Researchers de Oliveira et al. (2017), in their study, believe that tactile perception does not always provide a complete understanding for the blind and visually impaired. They believe smartphones can be a good tool to teach the blind in this case. The study was conducted in Brazil, where about 6.5 million people suffer from vision problems, and schools are not always prepared to teach blind children. To do so, teaching chemistry requires adaptation to visual perception, which is why QUIMIVOX MOBILE was designed for smartphones. This app helps to study the periodic table and chemical properties of elements. In the experiment, the program was tested with the participation of 10 blind users, including those who were blind from birth or had preserved visual memory.. After using the application, users completed tasks related to the periodic table. According to the results, all users successfully completed the tasks and the completion time was satisfactory. The results showed the effectiveness and usefulness of this program, but despite this, researchers argue that the program needs to be improved because there are problems with the accessibility for blind users, where tap readers cannot interpret the interface structure or content.

All data from the literature review was collected from several sources, which include a search engine such as Google Scholar, the SDU University article search engine, the Web of Science database, as well as journals of chemical education. All selected articles were published in the period from 2012 to 2024. *Table 1* provides various modern methods and inclusive methods of the periodic table of education, especially aimed at blind and visually impaired learners. The studies considered include such methods as tactile learning using periodic table toy cubes printed on a 3D printer with braille, as well as mobile audio applications with voice outputs, and others to improve conceptual understanding and motivation for accessibility in chemistry education.

Table 1
Modern and Inclusive Methods of the Periodic Table in Chemistry Education

Author(s), Year	Method / Tool	Key Findings
Limpanuparb et al., 2024	Inclusive language-based approach	Enhances initial engagement with the periodic table
Mhlongo & Sedumedi, 2023	Analysis of theory-practice gap	Conceptual learning is difficult without visual or practical tools
Karakoç & Aslan, 2022	Interviews with special school teachers	Highlight the need for adapted methods for visually impaired students
Steele, 2015	Tactile graphics and Braille	Support sensory-based conceptual understanding
Bonifacio, 2012	QR-coded audio periodic table	Increases accessibility via mobile learning
Melaku et al., 2016	Toy block learning modules	Improve understanding of atomic structure and periodic trends
Zhang et al., 2022	3D periodic table with Braille and ASL	Boosts accessibility and engagement through STEAM learning
Laconsay et al., 2020	3D molecular models + audio tools	Confirms that blind students process spatial data effectively
Eldem & Basçiftçi, 2013	Electronic tactile-audio periodic table	Faster learning outcomes for visually impaired students
de Oliveira et al., 2017	QUIMIVOX mobile app	Effective tool, but needs better interface accessibility

The aim of this study is to evaluate the conceptual understanding of the periodic table of chemical elements among students in Kazakhstan, as well as to assess the willingness to apply the periodic table in practice, as well as studying the effectiveness of inclusive and modern teaching methods such as an adapted 3D periodic table with artificial intelligence in Braille for students with vision problems.

The objectives of this study are to analyze the current state of teaching of the periodic table of chemical elements within the framework of accessibility for visually impaired students

around the world and in Kazakhstan. It is also necessary to identify modern and critical teaching methods of the periodic table such as interactive tools, game learning, artificial intelligence applications, as well as tactile resources for visually impaired students. And the final goal is to evaluate the effectiveness of a modern tool that has an inclusive approach to learning, such as an adapted 3D periodic table with OpenAI printed in braille, in improving students' conceptual understanding and motivation.

The hypothesis of this study is: “The use of OpenAI’s Adaptive 3D Periodic Table with Braille significantly improves the conceptual understanding and academic performance of visually impaired students in chemistry, compared to traditional non-inclusive teaching methods.”

The research question of this study is “To what extent does the use of OpenAI’s Adaptive 3D Periodic Table with Braille influence the conceptual understanding and academic performance of visually impaired students in chemistry, compared to traditional teaching methods?”

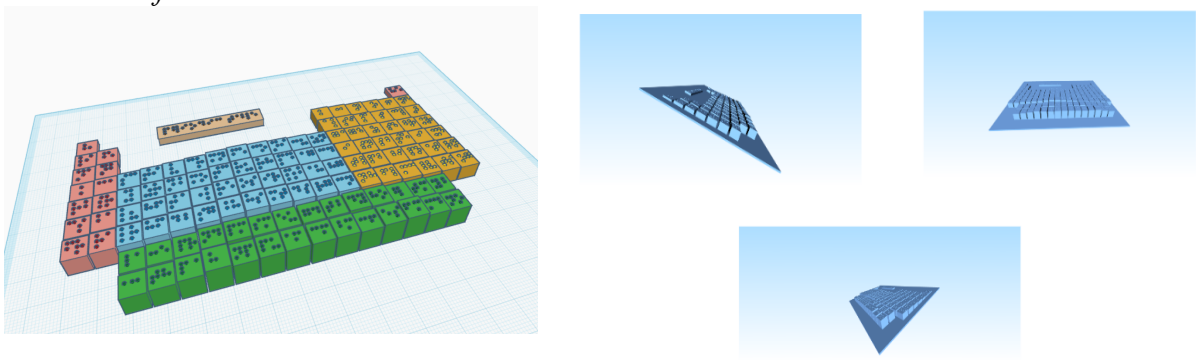
Implementation

This research paper implements an interactive system for studying the periodic table of chemical elements for use by students with visual impairment. The main goal of this project is to provide a multi-level sensory interaction, combining the tactile and auditory and visual channels of perception for students.

Periodic Table Hardware Part

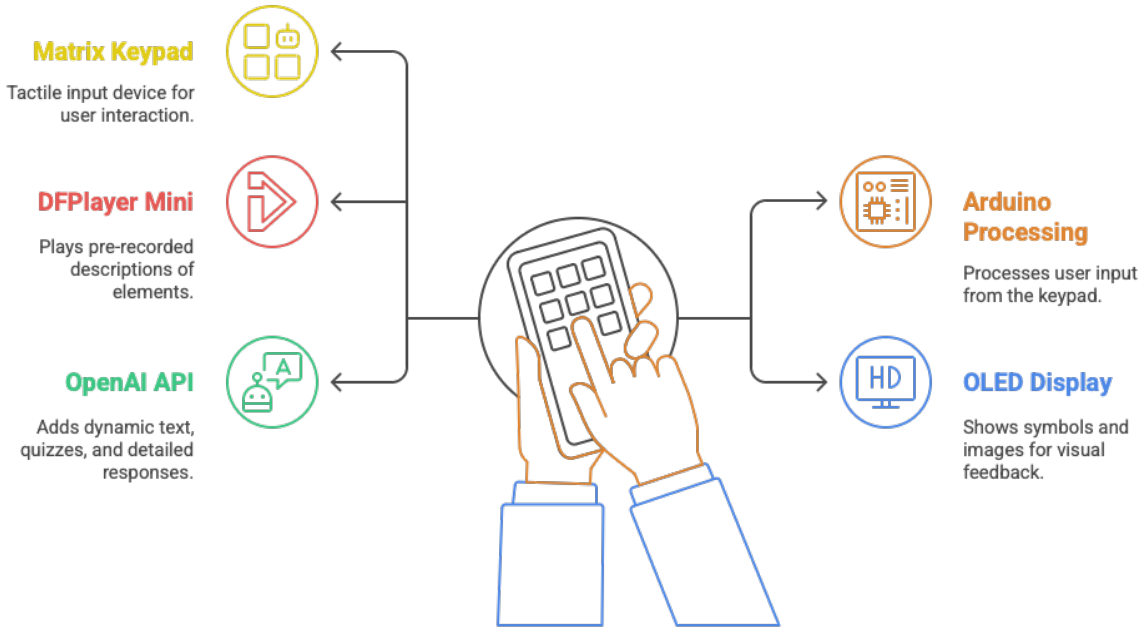
To begin, the hardware of the system is based on the Arduino Nano, which serves as the microcontroller for control. As a tactile input device, we used a 3D-printed periodic table keyboard, which forms the basis of a 4×4 matrix keypad. Each key corresponds to a specific element (*Figure -1*), and to play the name of that element, we use the DFPlayer Mini, along with a micro-CD card containing audio files that pre-record the name of each element.

Figure 1
3D Model of Periodic Table



For visual information, we use an OLED display. This display is already designed for people with hearing impairments, but it also works for those who can see. The display has a resolution of 128×64 pixels, and all devices are connected to the Arduino via standard digital inputs. *Figure 2* shows the detailed functions of the interactive periodic table.

Figure 2
The Detailed Functions of the Interactive Periodic Table



Periodic Table Software Part

The software for the periodic table of chemical elements, including Arduino code, was developed in C++ using the standard library for working with the keyboard and DFPlayer Mini display. When a user clicks on a specific chemical element in the table, the software performs various actions, such as playing audio files describing the element and displaying its symbol and serial number on the OLED screen. The connected device then sends the symbol to the OpenAI API, which provides additional information about the element, such as historical facts, industrial applications, and AI games. This information can be displayed on the screen or read out using a speech synthesizer.More detailed information is provided in *Table 2*.

To demonstrate, let's take the example of the “H” element. When the user presses the button with the H symbol, the system will perform the following actions: play the audio file for hydrogen, display its symbol and number, and send the symbol to OpenAI to request information.

1. Audio of “Hydrogen, the lightest element in the periodic table” is played.
2. The letter “H” is displayed on the OLED screen.
3. Additional text containing a request is sent to the OpenAI API and the response is later converted to audio.

Table 2
Implementation Overview of Periodic Table

stage	component/technology	functions/actions	output/result
1.	Matrix Keypad 4x4	The user clicks the button to the corresponding element	And the input is received (for example, “C” = Carbon)
2.	Arduino Uno/Nano	Processing the input provided by the element	Element: name, symbol, and atomic number
3.	OLED display	Displaying of the symbol and atomic number of an element	The letter “C” is displayed on the OLED screen.
4.	DFPlayer + SD + speaker	Playback of an audio file with a description of the element	The voice of “Carbon, atomic number is 6”
5.	Serial-transfer to a PC / Raspberry Pi	Sending an element character, for example “Na” in Python	Input data for the OpenAI API
6.	Python + OpenAI	Generation of dynamic information such as history, application, diagrams, and quizzes	OpenAI's response (text)
7.	Text-to-Speech (TTS) / OLED / Braille display	Converting and responding to the user (audio or visual)	Voice / Text on display / Braille output
8.	User experience	The user perceives information through audio, visual and tactile	Multimodal STEM education

Conclusion and Limitation

In the process of implementing this research work, a prototype system was created that combines hardware components using generative AI for inclusive STEM education. In this work, multidisciplinary multilevel interactions are implemented, for example, tactile input of an element through a keyboard repeating the shape of the periodic table, as well as audio response, visual and alternative braille input of an element, as well as the generation of dynamic learning content based on the OpenAI API.

The limitations of this project are for example:

1. Physical limitations: The limitations of some buttons may not work when pressed.
2. Technical limitations: the need to connect to a PC to work with the OpenAI API.
3. Financial and time constraints: at this time, the project is still in the testing stage and requires further development.

We still have not presented this product to the students, as we want to make sure before experimenting that this tool is suitable and will not cause any inconvenience. Also in the future, we plan to add new settings to improve performance, for example, the integration of the voice input module and a full-fledged TTS module, as well as the expansion of the audio file base, the implementation of offline mode, as well as the refinement of the interface for the convenience of visually impaired and completely blind users.

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