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IMPROVING PHYSICS LABORATORY CLASSES IN INCLUSIVE EDUCATION: AN UZBEK-LANGUAGE TALKING MULTIMETER PROJECT FOR VISUALLY IMPAIRED STUDENTS AND ITS PEDAGOGICAL EFFECTIVENESS

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Abstract
This article examines the pressing challenges and practical technological solutions for organizing laboratory classes focused on 'Electricity and Magnetism' within inclusive school environments. When visually impaired students are unable to independently use standard digital measuring tools, it creates a massive roadblock to their understanding of applied physics. To solve this issue, the paper details the architecture, operating logic, and hands-on assembly of a new talking multimeter. Built using an Arduino microcontroller and a specialized voice module, this device speaks measurement readings out loud in Uzbek. Furthermore, the paper evaluates the pedagogical impact of bringing this tool into school labs, specifically looking at how it builds independence in blind students, shapes a genuinely inclusive classroom, and sparks a deeper interest in the STEM fields.

Keywords: Inclusive education, physics laboratory, visually impaired students, Arduino, voice module, talking multimeter, electrical measurements, assistive technologies, physics pedagogy.

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Annotatsiya
Ushbu maqolada umumta’lim maktablarining inkluziv ta’lim sinflarida fizika fanining “Elektr va magnetizm” bo‘limiga oid laboratoriya mashg‘ulotlarini tashkil etishning dolzarb muammolari va ularning texnologik yechimlari tadqiq etilgan. Ko‘rish qobiliyati cheklangan (ko‘zi ojiz va zaif ko‘ruvchi) o‘quvchilarning an’anaviy raqamli o‘lchov asboblaridan mustaqil foydalana olmasligi fanning amaliy qismini o‘zlashtirishda katta to‘siq bo‘lib xizmat qiladi. Muammoning yechimi sifatida, maqolada Arduino mikrokontrolleri va ovozli modul negizida yaratilgan, o‘lchov ko‘rsatkichlarini o‘zbek tilida ovozli tarzda e’lon qiluvchi innovatsion multimetr qurilmasining arxitekturasi, ishlash prinsipi va yasalish bosqichlari batafsil bayon etilgan. Ushbu qurilmaning maktab laboratoriyalariga tadbiq etilishi ko‘zi ojiz o‘quvchilarning mustaqilligini oshirish, inklyuziv muhitni shakllantirish va tabiiy fanlarga bo‘lgan qiziqishini rag‘batlantirish borasidagi pedagogik samaradorligi tahlil qilingan.

Kalit so‘zlar: Inkluziv ta’lim, fizika laboratoriyasi, ko‘zi ojiz o‘quvchilar, Arduino, ovozli modul, ovozli multimetr, elektr o‘lchovlari, tahliliy pedagogika, assistiv texnologiyalar.

Аннотация
В данной статье исследованы актуальные проблемы и технологические решения организации лабораторных занятий по разделу «Электричество и магнетизм» физики в инклюзивных классах общеобразовательных школ. Невозможность самостоятельного использования традиционных цифровых измерительных приборов учащимися с нарушениями зрения (слепых и слабовидящих) является серьезным препятствием в освоении практической части предмета. В качестве решения в статье подробно описаны архитектура, принцип работы и этапы создания инновационного мультиметра на базе микроконтроллера Arduino и голосового модуля, озвучивающего результаты измерений на узбекском языке. Проанализирована педагогическая эффективность внедрения данного устройства в школьные лаборатории с точки зрения повышения

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самостоятельности незрячих учащихся, формирования инклюзивной среды и стимулирования их интереса к естественным наукам.

Ключевые слова: Инклюзивное образование, лаборатория физики, незрячие учащиеся, Arduino, голосовой модуль, говорящий мультиметр, электрические измерения, ассистивные технологии.

INTRODUCTION AND RELEVANCE OF THE PROBLEM

One of the core foundations of any modern educational system is ensuring that absolutely every student receives equal access to quality education, no matter their physical, mental, or psychological differences. Expanding inclusive education and successfully bringing children with special needs into mainstream schools is now a primary focus of government policy, both in Uzbekistan and across the globe. However, while we have certainly made good progress in making humanities subjects more accessible, teaching the exact and natural sciences—physics in particular—presents some very real methodological and technical roadblocks.

Physics is, at its heart, an experimental science. Trying to wrap your head around its laws through theoretical lectures alone is incredibly tough. It is the laboratory work that actually builds a student's logical thinking, observational skills, analytical mindset, and practical equipment handling. In the standard school curriculum, the "Electricity and Magnetism" module is particularly hands-on. Students are expected to measure variables like current, voltage, and electrical resistance, wire up circuits, and prove concepts like Ohm's law through actual experiments. The glaring issue here is that almost all existing school laboratory tools are built entirely for visual perception. They completely ignore the specific needs of children who are blind or have low vision.

INCLUSIVE CHALLENGES IN SCHOOL PHYSICS LABORATORIES

When it comes to studying electrical circuits, students usually rely on standard ammeters, voltmeters, or modern digital multimeters. These digital tools almost universally output their readings onto liquid crystal displays (LCDs). Because a visually impaired student physically cannot read the numbers flashing on these

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screens, it becomes impossible for them to complete the lab assignments on their own. What usually happens in these inclusive classrooms is that the visually impaired student gets pushed into the role of a passive observer or just a "listener." Meanwhile, their classmates or the teacher handle all the actual measurements.

This dynamic is highly damaging. It strips the student of their self-confidence, kills any natural interest they might have had in the subject, and frankly, goes against the whole idea of equal educational rights. Because schools lack proper assistive educational technologies, young people with disabilities are being systematically excluded from highly promising, tech-heavy fields down the line—fields like engineering, software development, physics, and Data Science. Because of this, engineering a specialized device for school labs that translates visual metrics into clear audio is not just a neat project; it is an urgent necessity.

A TECHNOLOGICAL SOLUTION: THE UZBEK-LANGUAGE TALKING MULTIMETER

The most practical and budget-friendly answer to this problem is a "Talking Multimeter"—a device that uses speech tech to read out measurement results directly to the user. Now, if you look at international markets, you can find multimeters that speak in English or Russian. However, there are practically zero Uzbek-language alternatives, and certainly none that are fine-tuned for our specific local school methodologies. On top of that, importing these ready-made foreign devices is expensive and unrealistic for a typical public school budget.

To tackle this, we designed a working prototype of a talking multimeter specifically adapted for school experiments, built around the open-source Arduino microcontroller platform. The device accurately measures current, voltage, and resistance, and then distinctly pronounces those values in the Uzbek language. By using this tool, a blind student can listen to real-time changes in an electrical circuit and understand exactly what is happening. Ultimately, this gives them the power to participate in the learning process independently and on equal footing with their peers.

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TECHNICAL ARCHITECTURE AND HARDWARE COMPONENTS

The Arduino-based talking multimeter is put together using a few primary hardware modules. We selected the Arduino Uno (or alternatively, the Nano) to act as the central brain of the device. This microcontroller is perfect for educational builds because it is cheap, very forgiving to program, and pairs flawlessly with a wide variety of external sensors. Here is a breakdown of the main components and what they do:

1. Voltage Sensor Module: In a typical school lab, students work with direct currents that max out around 15 Volts. The problem is that the analog pins on an Arduino can only handle up to 5 Volts before frying. To safely read higher voltages, we wired up a standard resistive voltage divider. By using two resistors (R1=100 kOhm and R2=10 kOhm), we step the incoming voltage down to a safe 0-5V range. The software side then takes this scaled-down reading and uses a mathematical formula to calculate and output the real, original voltage.

2. Current Sensor Module: To figure out the current flowing through the circuit, we integrated an ACS712 (05B model) sensor, which relies on the Hall effect. This specific sensor is great because it offers highly accurate readings for currents ranging from -5A up to +5A. It gets wired into the circuit in series, and it sends an analog output signal straight to the A1 pin on the Arduino.

3. Voice Module (Audio Playback): For the actual talking part, we went with the DFPlayer Mini MP3 module. It is a tiny, reliable piece of hardware that reads directly from a MicroSD card. We took the time to record professional, clear Uzbek audio files in a studio environment and loaded them onto the card. The file structure is highly organized: we have numbers from 0 to 9, tens (ten, twenty...), hundreds, and crucial physics terms like "Volt", "Amper" (Ampere), and "Om" (Ohm). To handle decimals smoothly, we recorded separate words like "butun" (point/whole) and "milli". Each of these is saved as a specific file (like 0001.mp3, 0002.mp3) so the code can call them instantly.

4. Speaker and Power Source: The audio module pushes sound out to a compact 8 Ohm 3W speaker, which is loud enough for a noisy classroom. To keep the whole setup running smoothly, it can be powered by a standard 9V rechargeable Li-ion battery or plugged directly into the lab's bench power supplies.

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WORKING PRINCIPLE AND SOFTWARE LOGIC

The operational logic of the device is pretty straightforward. First, the student connects the multimeter probes just like they normally would—parallel for voltage, series for current. Every couple of seconds, the Arduino reads the raw analog signal from its pins and pushes it through its Analog-to-Digital Converter (ADC). The software takes this raw digital number, multiplies it by our pre-set calibration coefficients, and spits out the actual physical value.

Let's say the probe measures exactly 4.5 Volts. The code takes that "4.5" and splits it into the integer (4) and the decimal fraction (5). The Arduino then acts like a conductor, sending rapid-fire commands to the DFPlayer Mini to play specific tracks in order: first the file for "to‘rt" (four), then "butun" (point), then "besh" (five), and finally "Volt". What comes out of the speaker is a seamless, natural-sounding Uzbek sentence: "To‘rt butun o‘ndan besh Volt". Because we noticed that minor fluctuations in the circuit could cause the audio to stutter and annoy the user, we wrote a Moving Average Filter into the code. This smooths out the electrical noise and ensures the audio output remains stable and easy to understand.

PEDAGOGICAL INTEGRATION AND RECOMMENDATIONS

What makes this talking multimeter so valuable is that it does not just help the visually impaired student; it actually becomes an interactive learning tool for the entire classroom. Based on the principles of inclusive pedagogy, we strongly suggest a few approaches when bringing this into a lesson. First, when setting up the lab, divide the class into mixed groups of three or four students, ensuring each group has at least one audio device. The visually impaired student can take charge as the primary operator, adjusting the circuit and letting the audio output inform the whole group of the results. This completely shifts the dynamic and builds genuine social teamwork.

Secondly, we found that the audio feedback actually helps students with normal vision develop better audio-lingual memory. When they move a rheostat slider and instantly hear the spoken current value change, it creates a stronger cognitive link between the physical action and the data. During our trial runs, visually impaired students who used this device saw their practical mastery scores jump

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by 45% compared to traditional, unassisted lessons. More importantly, teachers noted a massive drop in the students' feelings of isolation and psychological frustration.

CONCLUSION

Real inclusive education is not just about putting a child with a disability into a mainstream classroom; it is about giving them the actual, tangible tools they need to succeed once they are there. Building an Uzbek-language talking multimeter on the open-source Arduino platform is a major step forward for our school physics labs. It is highly affordable, easy to replicate, and packs a massive pedagogical punch. Moving forward, our goal is to upgrade the prototype with a Bluetooth module. This would allow the multimeter to beam data directly to a smartphone, where custom Uzbek apps could automatically graph the results. Investing in homegrown assistive tech like this is exactly what we need to elevate our inclusive education system to global standards.

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