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Design and Development of the Stemdunoise Prototype as a Noise Detector in Classrooms

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Abstract *– Excessive classroom noise poses a serious challenge to effective learning, particularly in physics education, where conceptual clarity and experimental observation are essential. Addressing this issue, this study aims to design and evaluate the STEMDUNOISE prototype an Internet of Things (IoT)-based device that monitors and classifies real-time classroom noise levels to support better learning environments. The research employed a Research and Development (R&D) method based on the Borg and Gall model, encompassing needs analysis, system design, prototyping, and preliminary trials. The system integrates an ESP32 microcontroller, MAX9814 sound sensor, ESP32-CAM for automatic video capture, and visual alerts through OLED and LED displays. Testing was conducted in both laboratory and classroom settings to ensure the accuracy of performance and user acceptability. Results show that STEMDUNOISE effectively categorizes noise into three levels: low (45–55 dB), medium (55–65 dB), and high (65–90 dB), providing immediate feedback through colored LEDs and real-time data via the Blynk platform. Its novelty lies in the combination of real-time sound analysis and automated video documentation in a compact and reusable tool. Conclusions indicate that the system enhances noise awareness, supports classroom management, and improves student engagement and focus during physics instruction. The findings contribute significantly to physics education by fostering distraction-free environments, promoting self-regulated learning, and offering data-driven solutions for educational policy and instructional improvement.*

Keywords: *IoT; noise monitoring; physics classroom; sound detector; stemdunoise*

I. INTRODUCTION

Noise in the classroom is a significant environmental factor that can greatly affect the quality of learning (Cayubit, 2022; Mulang, 2021). This phenomenon often results from various activities occurring inside the classroom, including interactions between teachers and students, as well as external noises, such as vehicles or activities outside the room. Excessive noise may arise from intense verbal interactions, the use of audio-visual equipment, or disorder within the classroom environment (Mogas-recalde et al., 2021). Several studies have documented the detrimental impact of such noise on the teaching and learning process. Classroom acoustics are an important element influencing the educational experience, and environmental characteristics like background noise must be carefully managed to facilitate effective learning (Mogas-recalde et al., 2021). Differences in school building design and quality result in varying types and intensities of noise exposure for students, contributing to unsatisfactory acoustic conditions in classrooms (Minichilli et al., 2018; Mogas-recalde et al., 2021). Noise impairs children's performance, with younger students being particularly vulnerable to disturbances, which negatively affect their ability to concentrate and absorb information (Gheller et al., 2023). Excessive noise can cause difficulty in speech comprehension and significantly disrupt the learning environment, leading to reduced attention spans and diminished concentration among students (Ali et al., 2023). Teachers face challenges in managing classroom dynamics due to poor acoustic conditions and disruptive noise levels (Pervaiz et al., 2024; Zhang. D et al., 2024). By identifying and addressing these noise sources, educators can develop strategies to create a more conducive learning environment, ultimately improving educational outcomes.

Excessive noise levels in classrooms can impair students' concentration and focus (Bulunuz et al., 2021) and may lead to hearing impairment, mental fatigue, and a decline in cognitive abilities (Ali et al., 2023; Mogas-recalde et al., 2021). Prolonged exposure reduces students' ability to respond quickly and accurately to information. A clear relationship exists between classroom noise and decreased student concentration, supporting the finding that noise negatively impacts learning experiences (Brink et al., 2021). High noise exposure not only reduces cognitive capacity but also impairs students' responsiveness (Stansfeld & Clark, 2015). Therefore, monitoring noise levels is essential to create a conducive learning environment that supports optimal academic development.

In educational settings, the urgency to monitor noise levels has increased. IoT technology offers innovative real-time solutions for this purpose. IoT-based noise sensors provide valuable data for detecting noise that exceeds safe limits (Minichilli et al., 2018). Such monitoring enables classroom managers to promptly respond when noise disrupts teaching, thereby fostering a better learning environment (Matthew, 2022). Technology to measure and manage noise can significantly improve teaching quality and students' learning experience (Tomek & Urhahne, 2022). The development of IoT monitoring systems holds potential for better classroom noise management and maintaining the physical and mental health of students and teachers (Foraster et al., 2022). Efficient noise monitoring is expected to create a more conducive classroom environment and improve education quality overall (Shield et al., 2015). Consequently, a real-time noise monitoring system is necessary for classroom managers to take timely action to enhance learning environments.

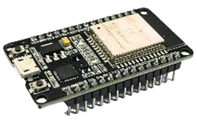
The development of IoT-based noise measurement tools is highly relevant due to their effectiveness in improving noise management. This technology is expected to help maintain more controlled noise levels, supporting higher quality and conducive learning. Although several studies have examined the impact of noise on learning and highlighted the importance of feedback in noise management, the real-time implementation of IoT technology for classroom noise monitoring remains limited (Tabuenca et al., 2023). their studies, such as Imlawi (2021), focus on noise impacts in e-learning but do not address classroom-specific needs. Therefore, this research aims to develop an IoT-based classroom noise measurement tool to automatically and data-drivenly address noise issues. Real-time noise monitoring allows teachers to create more conducive learning environments (Marques & Pitarma, 2020). The tool also supports hearing health and wellbeing by detecting excessive noise exposure. Additionally, collected data can assist educational administrators in making evidence-based decisions about classroom management (Wolff et al., 2016). This tool offers practical solutions for noise management and opens opportunities for further research on IoT applications in education.

In physics education, classroom noise presents unique challenges. Physics teaching relies heavily on demonstrations, experiments, and explaining abstract theoretical concepts, requiring sustained attention and minimal auditory distraction (Lai & Cheong, 2022). Noise interference during demonstrations or labs can prevent accurate observation and understanding, diminishing inquiry-based learning effectiveness. Furthermore, the cognitive load required to understand abstract physics topics (Zou et al., 2025), such as electromagnetic induction or wave interference, is significantly increased in noisy environments, reducing retention and conceptual clarity. Thus, ensuring optimal acoustic conditions is crucial not only for general classroom management but also for supporting deep learning in physics. The development of real-time noise monitoring systems like STEMDUNOISE is intended to meet these pedagogical needs by fostering focused engagement and meaningful learning experiences in physics classrooms. Studies have examined classroom noise's impact on science learning, particularly physics. For instance, Al-asmar (2025) and Renterghem (2019) reported that high ambient noise reduces students' ability to follow physics demonstrations, causing conceptual gaps. Similarly Gheller et al. (2023) highlighted that background noise in labs negatively affects data interpretation and critical thinking. More recently (Tan. H et al., 2024) emphasized that excessive noise in smart classrooms correlates negatively with student engagement in abstract subjects like physics and mathematics . These findings underscore the necessity of integrating real-time acoustic monitoring tools into physics classrooms to prevent environmental noise from hindering meaningful learning.

II. METHODS

This study adopted a Research and Development (R&D) approach based on the model proposed by Borg & Gall (1983), which includes the steps of needs analysis, product design, development, validation, revision, and dissemination. This model was chosen to ensure a systematic process addressing real instructional needs, especially in physics classrooms where acoustics significantly impact learning outcomes. In this study, the focus was on the initial stages: design, prototype development, and preliminary testing to evaluate the feasibility and educational utility of the STEMDUNOISE system. Table 1 displays the characteristics of the Stemdunoise noise detector.

Table 1. The characteristics of the Stemdunoise noise detector

No	Attribute	Detail
1.	 Esp32	Microcontroller module with dual mode features, namely Wi-Fi and Bluetooth, used to facilitate users in creating various applications and projects based on IoT (Internet of Things)
2.	 Modul Microphone Amplifier MAX9814	As a sound detection sensor
3.	 LCD OLED 0.96 IIC 128X64 I2C	Media display output on the microcontroller module
4.	 Esp32-cam	IoT camera module
5.	 LED 3,3 V	As a cutoff marker/ indicators

No	Attribute	Detail
6.	 PCB	Cable replacement board to minimize errors in cable connections

The components are described as follows:

1. Esp32

ESP32 is a microcontroller module equipped with Wi-Fi and Bluetooth connectivity, enabling wireless data communication. In this research, ESP32 serves as the main processor that receives data from the sound sensor and processes it to determine classroom noise levels. Additionally, ESP32 can send data to a display medium or IoT server for further analysis and remote monitoring.

2. MAX9814 Microphone Amplifier Module

This module acts as the primary sensor for detecting noise levels in the environment. Equipped with Automatic Gain Control (AGC), it automatically adjusts sensitivity, allowing accurate sound to capture even amid high noise variations. It sends audio data to ESP32 for analysis and displays noise level information.

3. LCD OLED 0.96 IIC 128X64 I2C

The 0.96-inch OLED LCD serves as a real-time noise level display. Its I2C interface enables direct communication with ESP32 with low power consumption and clear resolution. This screen allows users to monitor noise conditions without additional devices like computers or smartphones.

4. ESP32-CAM

The ESP32-CAM IoT camera module supports visual analysis by capturing images or videos when noise exceeds a threshold, enabling users to observe environmental conditions causing noise increases. This module can integrate with AI-based systems to detect noise sources or behaviors disrupting classrooms. It aids documentation, provides insights for teachers and administrators, and can function as a security monitoring tool to maintain conducive learning environments.

5. LED (3.3 V)

The LED provides a visual alert when noise levels surpass predefined thresholds. Different colors (e.g., green for low, yellow for medium, red for high) indicate noise severity, allowing immediate alerts without continuous monitoring of the OLED screen.

6. PCB (Printed Circuit Board)

The PCB connects all system components neatly and stably compared to wired connections. It reduces risks of connection errors or disruptions due to loosen cables, enhancing device reliability. PCBs also make the device more compact, easier to install, and more resistant to vibrations or environmental changes.

The research began with creating a dB meter program using ESP32 and the MAX9814 microphone. The sensor measures environmental noise and converts it into digital data usable by the microcontroller. This program reads sound signals and determines noise levels in decibels (dB). After successfully developing the noise measurement system, noise value thresholds were established to classify sound levels into categories such as low, medium, high, and very high. Defining these thresholds ensures the system responds appropriately to environmental noise variations. Figure 1 illustrates the STEMDUNOISE prototype development procedure.

Figure 1. Prototype development procedure

A program for ESP32-CAM was developed to capture video when noise exceeds certain thresholds, allowing users to monitor conditions during significant noise increases. Subsequently, an IoT program utilizing Blynk software was developed to send noise data to a cloud platform, enabling real-time monitoring via a mobile application. Blynk serves as an intuitive interface for users to view noise levels and receive warnings when thresholds are exceeded. Next, ESP32 was integrated with Blynk to enable hardware-IoT application communication and automatic noise data transmission. This integration allows instant notifications on smartphones and remote system control. Once all programs and communication systems were operational, circuit assembly was completed using PCB to ensure stable, durable connections, minimizing disruptions caused by wiring issues.

The final stage involved testing the device in various environmental conditions to verify accurate noise detection and appropriate system response. Testing scenarios included an empty classroom, active teaching sessions, and group discussions. Trial results were analyzed to assess reliability and guide improvements as needed. Through effective monitoring and control of classroom noise, the developed device aims to contribute to creating a more conducive learning environment.

III. RESULTS AND DISCUSSION

The results and discussion are presented together in a clear and concise manner. Results are displayed using figures, tables, and descriptive explanations to facilitate reader comprehension. The discussion focuses on the implications and benefits of the findings, avoiding repetition of results. Tables and figures present unique data, and the analysis reliably addresses the research questions. References in this section avoid repetition of those in the introduction and include comparisons with previous studies.

This research developed a noise monitoring system based on sound sensors and microcontrollers to classify noise levels and provide appropriate responses. The system starts with a noise sensor that captures sound from the environment and sends it to a microcontroller, which processes the data to determine noise levels against predefined thresholds. The STEMDUNOISE prototype is shown in Figure 2. Initially, noise thresholds were set according to UNESCO standards: noise between 35 and 55 dB triggers a green indicator representing light or normal sound; 56–70 dB activates a yellow indicator signaling moderate noise requiring attention; 71–85 dB triggers a red indicator warning of high noise that may disturb the environment.

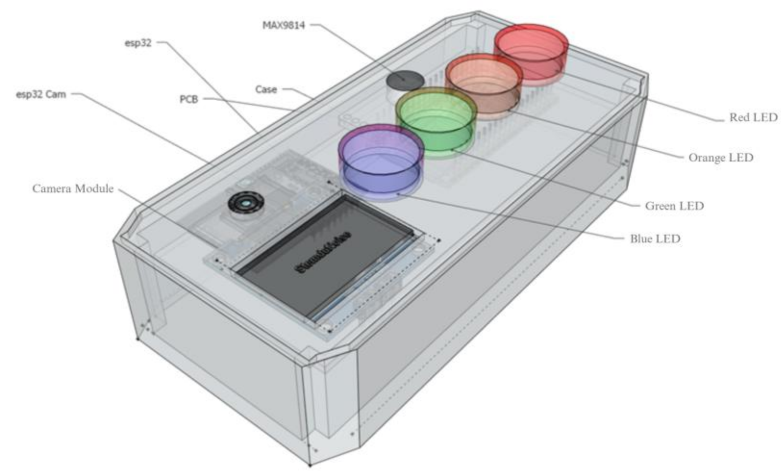


Figure 2. The stemdunoise prototipe

Based on laboratory tests and adjustments for actual classroom conditions, the sound indicator thresholds were revised: noise within 45–55 dB activates a blue indicator indicating quiet or normal classroom conditions; noise between 55 and 65 dB lights a green indicator signaling light noise, acceptable during teaching and learning; noise from 65 to 75 dB triggers a yellow indicator, warning of increasing noise needing monitoring; noise exceeding 75 to 90 dB activates a red indicator, indicating disruptive noise levels. These changes considered factors such as sensor distance from the sound source, external noise influences, and room acoustics affecting sound propagation. This system can be implemented in schools to manage noise levels and promote a more conducive learning environment.

Initially, the device was designed to activate a red indicator and buzzer warning when noise exceeded 85 dB, with user notifications to take immediate action. However, tests showed the buzzer itself was detected as a sound source, causing sensor interference and erroneous readings.

Therefore, the buzzer was replaced with a light indicator. In the final prototype, noise levels between 75 and 90 dB trigger the red light. Teachers can identify the noise source directly or remotely via a web system that displays classroom video. When the red indicator lights up, the camera automatically records classroom conditions, documenting the noise source. Recorded videos or images are accessible through a web-based platform, enabling teachers and administrators to analyze the noise and plan interventions.

Testing in the laboratory covered three conditions: quiet, slightly noisy, and noisy. Quiet noise levels ranged from 44 to 53 dB, averaging 47–48 dB. Slightly noisy conditions ranged from 48 to 78 dB, averaging 65–68 dB. Noisy conditions ranged from 44 to 98 dB, averaging 75–85 dB. These results demonstrate STEMDUNOISE's capability to accurately detect noise variations and display visual indicators consistent with the thresholds. Table 2 presents detailed measurement data for each condition.

Table 2. Measurement results under calm, slightly busier, and busy conditions

under calm		**slightly busier**		**busy**	
time	**dB Out**	**time**	**dB Out**	**time**	**dB Out**
00.00.87	48	00.00.67	78	00.00.57	88
00.01.36	50	00.01.26	60	00.01.16	48
00.01.83	46	00.01.93	64	00.01.83	86
00.02.58	44	00.02.28	48	00.02.98	74
00.03.19	48	00.03.19	66	00.03.39	78
00.03.76	49	00.03.96	64	00.03.76	80
00.04.92	53	00.04.62	58	00.04.96	86
00.04.39	44	00.04.99	64	00.04.45	44
00.05.46	47	00.05.46	66	00.05.46	77
00.05.99	47	00.05.99	67	00.05.99	88
00.06.00	48	00.06.69	68	00.06.98	98
00.07.51	45	00.07.55	65	00.07.53	75
00.08.07	48	00.08.87	68	00.08.20	78
00.08.89	44	-	-	00.08.89	94
00.09.70	50	-	-	00.09.90	60
00.11.84	48	-	-	00.11.80	48

Under quiet conditions, noise levels (dBOut) ranged from 44 dB to 53 dB, with an average of 47–48 dB. These values indicate a relatively calm classroom environment, typically observed when students are listening to the teacher's explanation, working on individual assignments, or when the classroom is silent. Minor fluctuations in dB levels suggest that even in a quiet setting, small background noises such as student movements or ambient sounds were still present. The lowest recorded value (44 dB) represents the quietest state, while the highest value (53 dB) indicates a slight increase in noise levels due to activities such as whispering or movement within the classroom.

Under moderately noisy conditions, noise levels exhibited greater variation, ranging from 48 dB to 78 dB, with an average of 65–68 dB. This range suggests a more active classroom environment, likely caused by student discussions, teacher-student interactions, or small group activities. The significant variations in dB levels indicate frequent spikes in noise intensity. While the lowest value (48 dB) remained within the quiet range, the highest value (78 dB) reflects louder student conversations or increased movement within the classroom.

Under noisy conditions, noise levels increased substantially, ranging from 44 dB to 98 dB, with an average of 75–85 dB. These values suggest a highly active or disruptive classroom environment, possibly occurring during large group discussions, student presentations, or collaborative activities involving extensive verbal interaction and movement. The extreme spikes reaching 98 dB indicate moments of intense noise, such as laughter, overlapping conversations, or noise caused by objects in the classroom. The wide fluctuation between 44 dB and 98 dB indicates alternating quiet moments followed by high noise levels, for example, when the teacher speaks, followed by loud student responses.

To complement laboratory testing, a small-scale pilot test was conducted in a real classroom involving one physics teacher and 26 tenth-grade students in a public senior high school in Yogyakarta. The pilot was implemented during a lesson on sound waves lasting approximately 70 minutes. The STEMDUNOISE system was installed to monitor and visually indicate noise levels in real time. After the session, both teacher and students provided feedback through a Likert-scale questionnaire and open-ended questions. The teacher reported that the system was highly effective in managing classroom noise and improving student focus during demonstrations and discussions. Furthermore, 81% of students agreed that the color-coded indicators increased their awareness of their own behavior and encouraged quieter collaboration. This feedback confirms the system's practical relevance and usability, indicating its potential to support classroom management and enhance physics instruction quality.

This system offers an innovative solution for classroom noise management by integrating IoT technology for real-time monitoring. The use of color indicators and a Blynk-based notification system enables teachers to take immediate action when noise exceeds certain thresholds. Additionally, the system assists in documenting noise patterns, which can be valuable for school administrators when designing more effective learning strategies. However, limitations include sensor sensitivity to external sounds affecting measurement accuracy. Moreover, testing was conducted in limited environments; therefore, further studies in diverse school settings are required to improve reliability. With continued development, STEMDUNOISE has the potential to become an effective tool for creating more comfortable and productive learning environments.

The findings demonstrate STEMDUNOISE's effectiveness as an IoT-based noise detector in classrooms. Integration of IoT technology enables real-time noise monitoring, providing immediate feedback on classroom noise levels and enabling educators to foster a more conducive learning atmosphere (Tan, K-Y et al., 2024; Zhang et al., 2024). Previous research consistently shows that high noise levels negatively impact students' concentration, cognitive performance, and academic achievement (Mogas-recalde et al., 2021). Furthermore, STEMDUNOISE categorizes noise into low, moderate, and high intensity, empowering teachers to proactively manage noise, thereby supporting effective teaching and learning strategies and reinforcing the link between improved acoustics and educational outcomes (Hakim et al., 2024).

Moreover, this study highlights IoT technology's role in enhancing classroom acoustics and student engagement, while raising awareness about hearing health among students and teachers. Excessive noise exposure in educational settings has been linked to increased stress, fatigue, and long-term auditory issues (Mogas-recalde et al., 2021). By adopting a data-driven noise management approach, STEMDUNOISE addresses these concerns while improving learning efficiency. The impact of noise on health and concentration underscores the necessity of effective noise management strategies in educational contexts (Mogas-recalde et al., 2021). These findings align with research emphasizing the importance of classroom environments that facilitate student-centered learning. For example, Darling-Hammond (2021) notes that minimizing distractions is crucial for sustaining engagement and cognitive performance, especially in STEM disciplines. Similarly, Jirout et al (2024) highlight that curiosity and inquiry-based learning thrive best in structured, distraction-free environments, supporting the rationale for using tools like STEMDUNOISE. Consistent with Krajcik & Blumenfeld (2005), maintaining manageable noise levels is vital for productive group collaboration and teacher facilitation. These educational studies confirm that STEMDUNOISE not only controls the environment but also directly supports pedagogical goals in physics education. Data collected by STEMDUNOISE also provide robust evidence for policymakers and administrators, facilitating evidence-based policies that prioritize healthy learning environments (Qi et al., 2024). Thus, STEMDUNOISE aids teachers in noise management and lays a foundation for systemic educational improvements.

From an educational perspective, STEMDUNOISE contributes to environmental control and improved instructional delivery in physics classrooms. By reducing acoustic distractions, the system enhances teacher-student communication, particularly during complex explanations and experimental procedures. This is especially important in physics, where clarity in explaining abstract concepts and precise observation is critical. Real-time visual feedback serves as a behavioral regulation tool (Sinclair et al., 2019), subtly encouraging students to self-monitor noise levels. In this way, the system fosters cognitive and socio-emotional development by promoting a disciplined and engaged learning atmosphere. Teachers can also utilize collected data as formative assessment to identify instructional contexts prone to higher noise levels and adapt pedagogical strategies accordingly.

In physics education, minimizing auditory distractions during critical instructional moments is essential. STEMDUNOISE supports this by alerting teachers to rising noise levels in real time, facilitating timely interventions to restore focus. For example, during formative assessments or concept reviews, ambient noise can hinder concentration and response accuracy. Similarly, quieter environments during laboratory experiments enable students to observe phenomena more accurately and discuss results more clearly in groups (Jegstad, 2024). In collaborative learning, STEMDUNOISE's visual cues help regulate behavior, promoting constructive communication over disruptive noise. These functions position STEMDUNOISE as both a monitoring and instructional support tool that enhances physics teaching and learning.

Beyond technical utility, STEMDUNOISE offers significant pedagogical value. It functions as a classroom management and instructional aid that improves physics teaching quality. In physics education, understanding relies on clear verbal explanation and focused observation of demonstrations and experiments; thus, an acoustically supportive environment is crucial. By integrating real-time noise feedback into classroom routines, teachers can foster metacognitive awareness among students about their impact on the learning environment (Maryani et al., 2021, 2022). Additionally, visual cues encourage self-regulation, contributing to a respectful and engaged classroom culture (Schoor et al., 2015). These elements align with learner-centered science education approaches where environment and student responsibility are key to meaningful learning outcomes. Consequently, STEMDUNOISE not only addresses environmental challenges but also embodies a shift toward reflective, responsive, and data-informed pedagogy in physics instruction.

Nevertheless, this study has limitations, having been conducted in specific classroom settings. Future research should explore STEMDUNOISE's application in diverse educational contexts and investigate integration with adaptive learning technologies to enhance effectiveness. Longitudinal studies could provide valuable insights into the long-term effects of noise monitoring on academic performance and wellbeing. Overall, this research underscores the potential of IoT-driven innovations to foster smarter, healthier, and more effective learning environments. By proactively addressing classroom noise through technology, STEMDUNOISE opens new avenues to improve student learning experiences and advance discourse on acoustic management in education.

IV. CONCLUSION AND SUGGESTION

This study demonstrated the effectiveness of STEMDUNOISE, an IoT-based noise monitoring system, in detecting and managing classroom noise to support more focused and productive learning environments. By providing real-time feedback and classifying noise intensity into low, moderate, and high categories, the system enables timely interventions that minimize disruptions and improve student concentration. The application of STEMDUNOISE is particularly relevant in physics instruction, where clarity during demonstrations and student engagement in abstract reasoning are critical. The tool’s integration of sound sensors, visual indicators, and smartphone connectivity also highlights its potential in promoting awareness of hearing health and supporting evidence-based decisions in classroom management.

Despite its promise, the implementation of STEMDUNOISE was limited to a specific classroom context, restricting its generalizability. Further research is needed to assess its effectiveness across diverse educational settings, including schools with varying infrastructural conditions and student demographics. Future studies should also explore the integration of STEMDUNOISE with adaptive learning technologies and conduct longitudinal investigations to evaluate its long-term impact on academic outcomes and student wellbeing.

Overall, STEMDUNOISE represents a practical and forward-looking contribution to physics education and classroom management. It aligns with 21st-century educational goals by offering a low-cost, scalable solution to a long-standing barrier to learning classroom noise. The system not only aids physics teachers in maintaining focus during instruction but also opens new pathways for educational research and policy on learning environments. By merging technology with pedagogical needs, STEMDUNOISE exemplifies how IoT innovations can empower educators, improve student experiences, and support data-informed educational decision-making.

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