Volume 15 | Issue 3 | November 2025 ISSN 2182-0287

Journal of Integrated OMICS

a methodological journal

JIOMICS

Journal of Integrated OMICS

Focus and Scope

Journal of Integrated OMICS, JIOMICS, provides a forum for the publication of original research papers, preliminary communications, technical notes and critical reviews in all branches of pure and applied "-omics", such as genomics, proteomics, lipidomics, metabolomics or metallomics. The manuscripts must address methodological development. Contributions are evaluated based on established guidelines, including the fundamental nature of the study, scientific novelty, and substantial improvement or advantage over existing technology or method. Original research papers on fundamental studies, and novel sensor and instrumentation development, are especially encouraged. It is expected that improvements will also be demonstrated within the context of (or with regard to) a specific biological question; ability to promote the analysis of molecular mechanisms is of particular interest. Novel or improved applications in areas such as clinical, medicinal and biological chemistry, environmental analysis, pharmacology and materials science and engineering are welcome.

JOURNAL OF INTEGRATED OMICS

A methodological Journal

ORIGINAL ARTICLES

ORIGINAL ARTICLES

JOURNAL OF INTEGRATED OMICS
A METHODOLOGICAL JOURNAL
HTTP://WWW.JIOMICS.COM

ORIGINAL ARTICLE | DOI: 10.5584/jiomics.v15i3.250

Transformational Goal for Science Education: The 1Student–1Apparatus (1S1A) Model

Inês F. Domingos [1,2], André Q. Figueiredo[1,2], Hugo Miguel Santos[1,2] Carlos Lodeiro[1,2], Orfeu Flores[3], Gonçalo Doria[3], Rodrigo Patricio[3,4], Ivo Lopes[3,4], Laura Mercolini[5], Tereza Cartaxo[6], Jerome Zoidakis[7,8], José Luis Capelo[1,2,*]

[1]LAQV-REQUIMTE, Department of Chemistry, NOVA School of Science and Technology, NOVA University of Lisbon, Lisbon, 2829-516 Caparica, Portugal; [2]PROTEOMASS Scientific Society, Caparica, Portugal. [3]STAB VIDA Lda, Caparica, Portugal. [4]Department of Computer Science, NOVA, School of Science and Technology, NOVA University of Lisbon, 2829-516 Caparica, Portugal. [5]Alma Mater Studiorum Università di Bologna, Bologna, Italy. [6]University of Pernambuco, Institute of Biological Sciences – Recife (PE), Brazil. [7]Department of Biology, National and Kapodistrian University of Athens, Greece. [8]Department of Biotechnology, Biomedical Research Foundation, Academy of Athens, Athens, Greece.

Available Online: November 2025

ABSTRACT

Limited access to hands-on laboratory equipment remains a significant barrier to effective science education. To address this challenge, we evaluated the analytical performance of the Doctor Vida® Education platform - an ultra-compact, low-cost, multifunctional analytical device designed under the 'One Student–One Apparatus' (1S1A) model. Using the Bradford method, we quantified total protein in urine and serum samples and compared results against those obtained from a commercial CLARIOstar® microplate reader. Calibration curves constructed from eight independent replicates revealed comparable slopes and intercepts between the two systems, with Doctor Vida® Education device demonstrating high linearity and repeatability. Despite the CLARIOstar® achieving lower limits of detection and quantification, the Doctor Vida® Education device showed superior reproducibility, with consistently lower relative standard deviations across operators and experimental conditions. Statistical analysis of urine and serum measurements confirmed strong agreement between methods, with no significant differences in most samples and improved precision observed with Doctor Vida® Education device in serum analysis. With a unit cost below 1000 €, the Doctor Vida® Education device platform proves to be a reliable, robust, and accessible solution for individualized, competence-based learning in analytical sciences.

Keywords: 1S1A, Science Education, Protein Quantification, Urine, Serum, Bradford Method.

1. Introduction

A persistent challenge in science education is the limited access students have to practical, hands-on laboratory experiences. This gap between theory and experimentation often leads to disengagement and a superficial understanding of scientific concepts. In many educational systems, science is taught in abstract terms with limited infrastructure for experimentation, particularly in secondary and undergraduate settings [1], [2]. Addressing this issue requires innovative tools that are not only effective but also accessible and scalable across diverse educational contexts, including under-resourced schools and remote learning environments [3]. A key principle for improving science education is the 'one student–one apparatus' (1S1A) model, which ensures that each learner has direct, personal access to experimental tools. Educational research consistently shows that individualized practical engagement enhances understanding, retention, and critical thinking skills [4], [5]. When students share equipment in overcrowded labs, their opportunities to practice and explore independently are limited, reducing the effectiveness of the learning experience [6]. In contrast, placing scientific instruments directly in each student's hands fosters ownership of the learning process and allows for repeated, self-paced experimentation [7].

The Doctor Vida® Education device - developed by STAB VIDA Lda, Caparica, Portugal - is a groundbreaking instrument designed with the 1S1A model in mind. Compact, portable, and battery operated, Doctor Vida® is built on energy-efficient LED technology and designed for ease of use in both formal and informal learning spaces. Measuring just a few centimeters in size and weighing less than 1 kg, the device is engineered for mobility, allowing students to perform real-time experiments whether in the classroom, in the field, or at home. Despite its modest size and eco-friendly

***Corresponding author:** José Luis Capelo, jlcm@fct.unl.pt

construction, Doctor Vida® Education supports a wide range of analytical tasks, including fluorescence and UV-Vis spectrophotometry, PCR-based DNA amplification, colorimetric assays, and time-resolved data acquisition. Its built-in microcontroller and optical sensors enable high sensitivity and reliability, comparable to benchtop equipment used in conventional laboratories. Crucially, each unit costs less than 1000 €, making it a highly affordable solution for schools and institutions with limited resources. This low cost democratizes access to experimental science, enabling broader adoption in underserved educational settings. Taking advantage of modern digital and optical technologies in a compact format, the Doctor Vida® device represents a paradigm shift toward personalized, active, and inclusive science education. It empowers students to learn by doing and promotes scientific literacy by bridging the gap between theoretical knowledge and practical skills. This approach aligns with recent global educational frameworks emphasizing competence-based learning and equity in STEM access [8].
In this work, we present the analytical performance of Doctor Vida® Education as a compact device for the quantification of total protein in urine and serum samples via the Bradford method.

2. Materials and Methods

2.1. Reagents and Protein Standards

Protein concentration was determined using the Bradford colorimetric assay with Bradford reagent (Sigma-Aldrich, B69168) [9]. Ultrapure water (18.2 $m\Omega \cdot cm^{-1}$ at 25 °C) obtained from a Milli-Q® purification system (Merck Millipore) was used for all reagent preparations and dilutions. Bovine serum albumin (BSA) analytical standard (200 mg/mL stock; Sigma-Aldrich, P5369) was diluted in ultrapure water to obtain a 100 µg/mL working solution. This working standard was used to prepare a six-point calibration curve. All calibration solutions were prepared fresh on the day of analysis. Urine samples were taken from healthy volunteers from our lab, who signed an informed consent. Serum samples were acquired previously from Haematology service of Hospital Garcia de Orta (HGO) in Almada, Portugal, the same samples used in a previous study [10].

2.2. Calibration Curve Preparation

Tube 1 (T1) was prepared by combining 200 µL of the BSA working standard (100 µg/mL) with 600 µL of ultrapure water, yielding a concentration of 25.0 µg/mL. The remaining calibration standards (T2–T5) were prepared as two-fold serial dilutions by transferring 400 µL from the preceding tube into 400 µL of ultrapure water, resulting in concentrations of 12.5, 6.25, 3.13, and 1.56 µg/mL, respectively. Tube 6 (T6), containing only ultrapure water, served as the 0 µg/mL blank.

2.3. Urine and Serum Samples Preparation

Urine samples were taken from healthy volunteers from our lab, who signed an informed consent. Urine samples were prepared as two-fold serial dilutions in ultrapure water at final dilution factors of 1:2, 1:4, and 1:8. Serum samples were diluted in two steps: first to 1:50 by diluting 0.1 mL of serum to a final volume of 5 mL with ultrapure water, followed by a subsequent dilution to 1:100 by diluting 0.1 mL of the initial dilution to a final volume of 10 mL. This resulted in a final dilution factor of 1:5000 for serum samples. All diluted samples were prepared immediately before Bradford analysis.

2.4. Bradford Assay using the CLARIOstar® Microplate Reader

For microplate measurements, 150 µL of each BSA standard or sample was combined with 150 µL of Bradford reagent in flat-bottom 96-well microplates (final volume: 300 µL *per* well). After gentle mixing, the plate was incubated for 10 min at room temperature to allow full colour development. Absorbance at 595 nm was recorded using the CLARIOstar microplate reader (BMG LABTECH). All conditions were analysed in technical triplicate, and blanks containing Bradford reagent and ultrapure water were included for baseline correction.

2.5. Bradford Assay using the Doctor Vida® Spectrophotometric System

For cuvette-based measurements, 50 µL of each BSA standard or sample was mixed with 50 µL of Bradford reagent in Doctor Vida® disposable optical tubes (final volume: 100 µL). After a 10-minute incubation at room temperature, absorbance at 595 nm was measured using the Doctor Vida® Education Spectrophotometric System (STAB VIDA Lda., Caparica, Portugal). All measurements were performed in technical triplicate with ultrapure water blanks for background subtraction.

2.6. Doctor Vida® Education device

Figure 1 shows an exploded schematic overview of the Doctor Vida® Education device. All analytical measurements were performed using the Doctor Vida® Education device, a compact, battery-powered, and multifunctional instrument designed to support hands-on science education and low-cost field-based experimentation. The device integrates several analytical capabilities within a single portable platform, allowing for real-time, user-directed operation in diverse learning or research environments. The core structure of the device comprises a multi-layer modular architecture, beginning with an external top cover featuring an integrated rotary encoder with push-button functionality, enabling manual control of settings and measurements. A colour LCD display is mounted on the side of the encoder for real-time output visualization. Power is supplied via a rechargeable lithium-ion battery, providing several hours of autonomous operation. A USB-C port supports both battery charging and wired communication. The device's onboard low-power microcontroller unit (MCU) includes embedded Wi-Fi and Bluetooth connectivity, allowing wireless data transfer and potential integration with mobile or cloud-based applications.

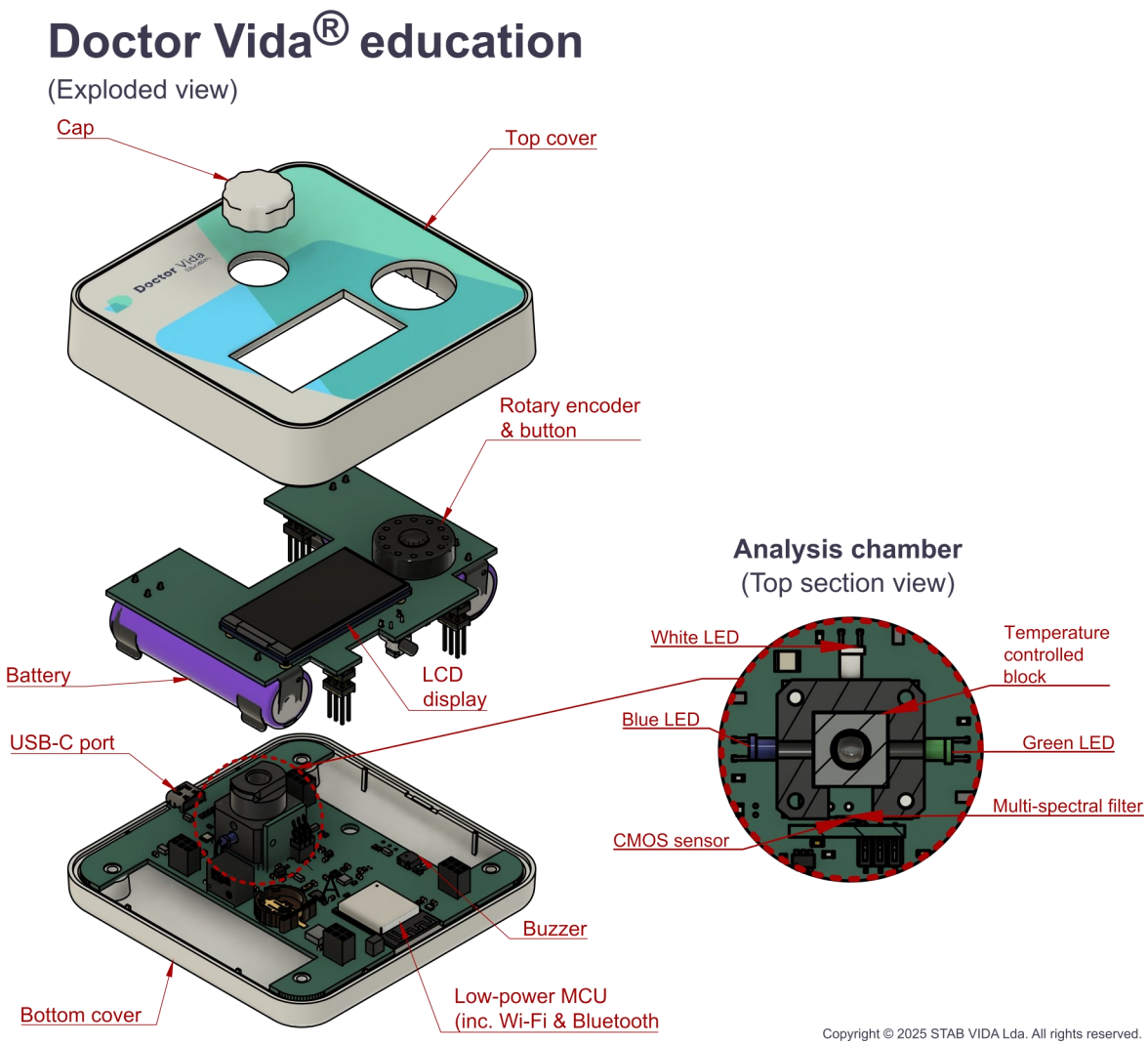

Figure 1. Doctor Vida® Education device depicting the internal structure and analysis chamber composition.

At the heart of the system lies the analysis chamber, which includes:

- A Complementary metal oxide semiconductor (CMOS) optical sensor for light detection.
- A multi-spectral optical filter enabling wavelength-specific measurements.
- A temperature-controlled block, suitable for isothermal reactions or thermal cycling (e.g., PCR).
- White, blue, and green LEDs for excitation in fluorescence and absorbance-based assays.
- This optical block allows the device to perform a range of standard laboratory techniques, including UV-VIS spectrophotometry, fluorimetry, and colorimetric assays. Additionally, its thermal control module supports nucleic acid amplification procedures.
- The bottom section houses the core processing and sensor electronics, securely mounted to a robust base plate that also contains a buzzer for audio feedback, enhancing user interaction during experimental procedures.

The total unit weighs under 1 kg and is small enough to be handheld or placed on a benchtop. All measurements in this study were conducted using individual units of the Doctor Vida® device *per* student, in alignment with the 1S1A pedagogical model.

3. Results and Discussion

3.1. Comparison of Analytical Performance

The analytical performance of both the Doctor Vida ® Education and CLARIOstar® devices was assessed based on the linear calibration curves generated from eight independent replicates for each instrument. The slope (m) and intercept (b) of the calibration lines were determined along with their respective standard deviations (mean ± SD). For the Doctor Vida ® Education device, the slope was $(1.13 \pm 0.14) \times 10^{-2}$, while the intercept was $(7.7 \pm 5.6) \times 10^{-3}$. In comparison, the CLARIOstar® device showed a slope of $(1.00 \pm 0.16) \times 10^{-2}$, and an intercept of $(6.2 \pm 5.8) \times 10^{-3}$. These results demonstrate that both systems yield calibration curves with similar slopes and intercepts. The relatively low standard deviations in both parameters confirm the good repeatability and reliability of the calibration process across devices. Furthermore, the close

agreement between the slopes indicates comparable analytical sensitivity, supporting the potential use of Doctor Vida® Education for educational and screening applications where simplified instrumentation is required.

The comparison of limit detection (LOD) and limit of quantification (LOQ) obtained with the Doctor Vida® Education and CLARIOstar® systems reveals differences in analytical performance, as can be read in **Table 1**. The CLARIOstar® exhibited lower LOD and LOQ values, indicating higher instrumental sensitivity. However, the Doctor Vida® Education showed lower variability across days, users, and calibration curves, reflected in its smaller RSD values for both LOD and LOQ, demonstrating a similar precision and robustness between devices. These results suggest that, while the CLARIOstar® is better suited for detecting very low analyte concentrations, the Doctor Vida® provides consistent and reproducible measurements as well, which is particularly relevant for applications requiring analytical stability and reduced dependence on operational conditions.

Table 1. Comparison of LOD and LOQ values for Doctor Vida® Education and CLARIOstar®.

Operator	Batch	Curve	Doctor Vida® LOD[1] (µg/mL)	Doctor Vida® LOQ[2] (µg/mL)	CLARIOstar® LOD[1] (µg/mL)	CLARIOstar® LOQ[2] (µg/mL)
1	1	R1	3.6	12.2	0.9	3.1
		R2	5.1	16.9	1.0	3.2
	2	R1	4.4	14.8	0.9	3.0
		R2	4.9	16.3	0.8	2.8
	3	R1	3.9	12.9	1.3	4.3
		R2	4.1	13.8	1.1	3.7
2	4	R1	3.8	12.6	1.3	4.3
		R2	-	–	1.1	3.7
	5	R1	4.5	14.9	1.3	4.3
		R2	-	–	1.1	3.7
	Mean		4.3	14.3	1.1	3.6
	SD		0.5	1.7	0.2	0.6
	RSD (%)		12.4	12.1	16.8	15.7

[1]Calculated as three times the standard deviation of the 10 blanks divided by the slope of the calibration curve (LOD = 3σ/S). [2]Calculated as 10 times the standard deviation of the 10 blanks divided by the slope of the calibration curve (LOD = 10σ/S).

3.2. Proof of concept

To assess the analytical performance of the proposed Doctor Vida® Education platform relative to an established reference system (CLARIOstar®), a series of comparative experiments were conducted using both urine and serum matrices. Statistical tests were applied to determine whether the new platform delivers results that are both accurate and precise when compared to the commercial system. This sections present the results of this initial validation, including *F*-tests to assess precision and *t*-tests to evaluate agreement in quantitative results. Each urine sample was analyzed in triplicate using both the CLARIOstar® (established method) and the Doctor Vida® Education (proposed method) as shown in **Table 2**. To evaluate the comparability between methods, an *F*-test was initially conducted to assess the homogeneity of variances for each sample. All calculated *F*-values were below the critical threshold (F_{critic} = 19.0; df = 2, 2), indicating that the assumption of equal variances was satisfied. Consequently, a two-sample Student's *t*-tests was applied (P = 0.05, df = 4). No statistically significant differences were observed between the two methods for samples 1, 2, and 3 (t_{calc} < 2.776). In contrast, significant differences were detected in samples 4 and 5 (t = 5.01 and 4.47, respectively), which may reflect enhanced sensitivity or sample-specific variability influencing the performance of the new method. Serum samples were also analyzed in triplicate using both methods, as shown in **Table 3**. The average concentrations obtained by Doctor Vida® Education and CLARIOstar® were broadly consistent across all samples. *F*-test results revealed markedly higher variances in the CLARIOstar® measurements, with *F*-values exceeding the critical threshold (F > 19) in all cases. Due to these results, an additional Welch's *t*-test was applied to confirm whether the average concentrations obtained have any statistically difference between them. According to Welch's *t*-test (P = 0.05, df ~ 5), no statistically significant differences were detected between methods in any of the samples. This indicates that Doctor Vida® Education consistently achieved better precision, as evidenced by lower relative standard deviations (%RSD < 2%). These results further support the reliability and precision of the Doctor Vida® Education platform for serum analysis. Nonetheless, additional studies involving a wider range of concentrations and sample types are warranted to fully establish its analytical robustness. Overall, the results demonstrate a high degree of agreement between methods, supporting the potential of Doctor Vida® Education as an affordable platform for laboratory experiments at the learning laboratory.

Table 2. Comparison of total protein concentrations in urine samples determined by Doctor Vida Education® and CLARIOstar® devices.

Sample Number	Doctor Vida® x ± SD(µg/mL)[a]	RSD (%)	CLARIOstar® x ± SD(µg/mL)[a]	RSD (%)	F^1	$t_{statistic}{}^2$
1	43.4 ± 0.7	1.6	42.7 ± 1.5	3.5	4.6	0.76
2	50.9 ± 0.7	1.3	54.2 ± 3.1	5.8	18.0	1.69
3	45.2 ± 2.6	5.7	39.6 ± 1.6	4.0	3.5	2.60
4	41.7 ± 0.7	1.7	36.2 ± 1.3	3.5	3.5	5.01*
5	42.6 ± 0.9	2.2	38.4 ± 1.1	2.9	1.5	4.47*

[a] n= 3. [1]*F*-test for the comparison of standard deviations. [2]Paired t -test, P=0.05, df=4, $t_{critical}$=2.78. *Statistically significant difference.

Table 3. Comparison of total protein concentrations in serum samples determined by Doctor Vida® Education and CLARIOstar®.

Sample Number	Doctor Vida® x±SD(mg/mL)[a]	RSD (%)	CLARIOstar® x±SD(mg/mL)[a]	RSD (%)	F^1	$t_{experimental}$ (*Welch's* t-test)[2]
6	64.1 ± 0.6	0.96	65.9 ± 4.7	7.19	69.4	0.97
7	64.2 ± 0.1	0.16	61.9 ± 3.1	5.08	900.0	1.77
8	63.9 ± 1.0	1.50	67.1 ± 4.6	6.92	25.0	1.63
9	76.0 ± 0.9	1.13	76.0 ± 5.7	7.51	44.4	0.003
10	62.6 ± 0.5	0.83	65.8 ± 3.9	5.92	64.0	2.05

[a] n= 3. [1]*F*-test for the comparison of standard deviations. [2]$|t_{experimental}|$ value of Welch's t-test; df ~ 5; $t_{critical}$=2.57 for P=0.05.

4. Conclusion

The results confirm the reliability and analytical suitability of the Doctor Vida® Education platform as a practical alternative to the commercial CLARIOstar® system for basic quantitative analysis. Although the CLARIOstar® exhibited lower detection and quantification limits - indicating higher instrumental sensitivity - the Doctor Vida® Education demonstrated excellent robustness across operators, water baths, and calibration curves, as evidenced by its consistently lower RSD values. Statistical comparisons of urine and serum samples showed strong agreement between the two systems, with no significant differences in most cases and superior precision from Doctor Vida® Education device in serum analysis. Importantly, beyond its analytical capabilities, the Doctor Vida® Education stands out for its compact design, ease of use, and affordable cost, priced under 1000 € *per* unit. These features make it particularly well-suited for educational settings, where individual students can operate their own real analytical device. This promotes hands-on learning, fosters experimental independence, and enhances understanding of key concepts in quantitative analysis. In summary, the Doctor Vida® Education platform offers a reliable, accessible, and scalable solution for modern teaching laboratories, supporting the broader goal of democratizing access to analytical science tools.

Acknowledgements

PROTEOMASS Scientific Society is acknowledged by the funding provided to the Laboratory for Biological Mass Spectrometry Isabel Moura (#PM001/2024, #PM001/2019 and #PM003/2016). This work received support from Fundação para a Ciência e a Tecnologia and Ministério da Ciência, Tecnologia e Ensino Superior (FCT/MCTES) through the projects LA/P/0008/2020 DOI 10.54499/LA/P/0008/2020, UIDP/50006/2020 DOI 10.54499/UIDP/50006/2020 and UIDB/50006/2020 DOI 10.54499/UIDB/50006/2020. HMS acknowledges the Associate Laboratory for Green Chemistry – LAQV (LA/P/0008/2020) DOI 10.54499/LA/P/0008/2020 funded by FCT/MCTES for his research contract. AQF thanks FCT/MCTES for his PhD grant reference 2023.00528.BD. IFD thanks FCT/MCTES for his PhD grant reference 2024.00745.BD.

Funding

PROTEOMASS Scientific Society, #PM001/2019, #PM003/2016. Fundação para a Ciência e a Tecnologia/ Ministério da Ciência, Tecnologia e Ensino Superior (FCT/MCTES), LA/P/0008/2020 DOI 10.54499/LA/P/0008/2020, UIDP/50006/2020 DOI 10.54499/UIDP/50006/2020 and UIDB/50006/2020 DOI 10.54499/UIDB/50006/2020.

References

[1] A. S. Pamungkas, S. Muslim, and K. Khaerudin, "Innovation of Mobile Science Laboratories as a Solution to Access to Practical Learning in Schools: A Case Study at an Education Quality Assurance Center in Banten, Indonesia," International Journal of STEM Education for Sustainability, vol. 5, no. 2, pp. 184–198, Aug. 2025, doi: 10.53889/ijses.v5i2.700.

[2] K. Kroes, D. Lefler, A. Schmitt, and C. Supalo, "Development of Accessible Laboratory Experiments for Students with Visual Impairments," Journal of Science Education for Students with Disabilities, vol. 19, no. 1, pp. 61–67, Dec. 2016, doi: 10.14448/jsesd.09.0006.

[3] Irene Uzezi Berezi, "Virtual Learning Environment: Redefining Higher Educational Delivery for Efficiency and Accessibility," International Journal of Educational Management, Rivers State University, vol. 1, no. 1, Jan. 2025.

[4] T. M. Bhuttah, Q. Xusheng, M. N. Abid, and S. Sharma, "Enhancing student critical thinking and learning outcomes through innovative pedagogical approaches in higher education: the mediating role of inclusive leadership," Sci Rep, vol. 14, no. 1, p. 24362, Oct. 2024, doi: 10.1038/s41598-024-75379-0.

[5] D. W. Johnson and R. T. Johnson, "Cooperative Learning: The Foundation for Active Learning," in Active Learning - Beyond the Future, IntechOpen, 2019. doi: 10.5772/intechopen.81086.

[6] J. Garcia, A. Y. Uluan, I. J. Barat, J. N. Lubay, I. Macagba, and H. Mahinay, "Lived Experiences of Science Major Students in the Absence of Laboratory Activities," American Journal of Education and Technology, vol. 1, no. 2, pp. 75–82, Sep. 2022, doi: 10.54536/ajet.v1i2.513.

[7] K. T. Kotsis, "Significance of Experiments in Inquiry-based Science Teaching," European Journal of Education and Pedagogy, vol. 5, no. 2, pp. 86–92, Apr. 2024, doi: 10.24018/ejedu.2024.5.2.815.

[8] C. Jackson et al., "Equity-Oriented Conceptual Framework for K-12 STEM literacy," Int J STEM Educ, vol. 8, no. 1, p. 38, Jun. 2021, doi: 10.1186/s40594-021-00294-z.

[9] M. M. Bradford, "A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding," Anal Biochem, vol. 72, no. 1–2, pp. 248–254, May 1976, doi: 10.1016/0003-2697(76)90527-3.

[10] I. F. Domingos et al., "Dithiothreitol-based protein equalisation in the context of multiple myeloma: Enhancing proteomic analysis and therapeutic insights," Talanta, vol. 279, p. 126589, Nov. 2024, doi: 10.1016/j.talanta.2024.126589.