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Development and Validation of Digitized Science Lessons for Learners' Scientific and Digital Literacy

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Abstract— *This study focused on the design and validation of digitized science learning materials, named Scixplore, tailored to address the least learned PISA competencies among Grade 10 students in three national high schools within the Tago district, Surigao del Sur. Employing a Developmental Research Design, a systematic approach centered on the iterative process of designing, developing, and evaluating educational programs, processes, and products, the study aimed to enhance students' scientific and digital literacy. The four identified least learned competencies, focusing on the nervous system, electromagnetic radiation, and plate tectonics, guided the creation of interactive digital resources. To assess the validation of the developed materials, a Field Try-out was conducted in the Tago district, Surigao del Sur, involving 60 students. Prior to this, validation by subject matter experts, ICT specialists, and school heads/master teachers resulted in high compliance ratings (87% - 92.51%), confirming the materials' accuracy, instructional design, and language appropriateness. The field try-out demonstrated a significant improvement in student post-test scores (M=18.72, SD=1.32) compared to pre-test scores (M=7.97, SD=2.36), yielding a large effect size (Cohen's d = 4.95). Feedback from both students and teachers indicated "Outstanding" ratings across content, format, presentation, accuracy, and user interface, with no significant difference in their overall perceptions. While minor challenges related to content clarity and technical accessibility were noted as slightly challenging to neutral, the study concludes that thoughtfully designed digitized learning materials significantly enhance student engagement and understanding. The study recommends the adoption and further enhancement of these materials into a Scixplore Smart Science Learning Suite (SSSLS) with improved interactivity, accessibility, and ongoing support for effective science education in the digital age.*

Keywords— *Digitized Science Lessons, Scientific Literacy, Digital Literacy, PISA Competencies, Learning Materials Design*.

I. INTRODUCTION

Nowadays, information and communication technology have developed rapidly and have been widely integrated in educational setting [1] [2]. One of which is the 2025 Program for International Student Assessment (PISA) shifting to computer-based testing in which many students, especially in rural areas, face challenges due to limited digital skills and test anxiety [3]. Philippine's performance in PISA which ranked last in PISA 2018 and near the bottom in 2022, highlighting an urgent need for innovative strategies [4]. This condition has implications for pedagogical innovation involving (ICT)based-instruction that may improve students' test-taking skills and create engaging learning environment to potentially increase their scientific literacy [5]. Thus, this study developed digitized lesson materials aligned with the least learned PISA competencies in Science to improve student performance and enforce online assessment to increase digital literacy among students.

Several studies have explored the factors contributing to the Philippines' low PISA performance in Science, revealing critical insights that emphasize the urgent need for educational reform [5][6]. Many students display low interest and motivation in Science due to traditional, unengaging teaching methods [7]. Additionally, limited access to digital platforms and resources exacerbates the problem, depriving learners of interactive and relevant instruction [8]. In response to these identified factors, creating digitized concepts in Science can make the lesson easier to understand, help increase retention rate, provide additional knowledge, and clear explanation, and allows recognition of importance of the lessons delivered [9]. Making it imperative to implement innovative ICT-based teaching materials that align with modern educational demands and the competencies measured by PISA.

Based on the 2024 pretest results of computerized PISA assessment conducted at Clarence Ty Pimentel National High School, the data revealed a concerning 38% performance rate of the students which is below the passing percentage, underscoring the urgent need for Science instruction reform in response to persistent low national and international PISA outcomes. While digital education has gained traction globally, the integration of PISA competencies within Science-focused digital resources remains underexplored in the Philippine context [10]. To address this demand, the study sought to innovate Science education by developing digitized lesson materials specifically designed to target the least-learned Science PISA competencies. The researcher aimed to fill this gap.

This study hold significant contribution in reinforcing the scientific and digital literacy of the students. It developed digitized lesson materials on the least learned PISA competencies, which were projected to improve students' experiences in Science education through their validation and implementation process [11]. By assessing the impact of these instructional materials, the study aimed to enhance students' experiences in Science instruction by providing them with digitized lesson materials that they could access anytime, which could also potentially increase their confidence in online test-taking [12]. For educational stakeholders, this approach presents an opportunity to align teaching strategies

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with international standards like PISA, fostering students' competencies needed for the 21st century [13].

Statement of the Problem

With the inclusion of PISA Competency for students' scientific and digital literacy, the goal of this study was to create and evaluate the validity of the digitized learning materials for the Grade 10 students at Gamut National High School, Purisima National High School, and Clarence T. Pimentel National High School for the S.Y. 2024-2025. Specifically, it sought to answer the following questions:

1. What learning material can be developed based on the least learned PISA competencies in science to improve students' scientific and digital literacy?
2. What are the validation results from the following experts regarding the digitized science learning materials?
   2.1. Subject Matter Experts
   2.2. ICT Experts
   2.3. School Heads/Master Teachers
3. What is the pretest-posttest results based on the field try out?
4. What is the extent of students and teachers' feedback on the developed material as to:
   4.1 Content
   4.2 Format
   4.3 Presentation and organization
   4.4 Accuracy and up-to-datedness of information
   4.5 User Interface
5. Is there a significant difference of the evaluation rating as perceived by the students and teachers' respondents?
6. Is there a significant difference between the pretest-posttest of the students based on the field try out?
7. What are the prevailing challenges in the utilization of the proposed material?
8. What enhanced output can be proposed based on the findings of the study?

II. Materials and Method

The study employed a Developmental Research Design to systematically create, refine, and evaluate digitized Science lesson materials aimed at improving students' proficiency in the least-learned PISA competencies. This iterative design process involved expert validation, field testing, and data collection through pre-test and post-test assessments, ensuring the instructional materials were both pedagogically sound and practically effective. The study was conducted in three secondary schools in Tago 2—Clarence Ty Pimentel National High School, Gamut National High School, and Purisima National High School—chosen due to their low Science performance and participation in the upcoming 2025 PISA test. The respondents included 60 Grade 10 students and 18 Science teachers, selected through quota sampling, while the validators consisted of ICT experts, school heads, and educational supervisors selected through purposive sampling.

The research tools included a validated PISA-like questionnaire to measure students' scientific literacy, and structured evaluation tools to assess the quality, usability, and impact of the digitized materials. After obtaining approvals from education authorities, the digitized materials were developed using interactive web-based content and underwent expert validation. Pre-tests were administered to establish baseline data, followed by classroom implementation of the digitized lessons, and post-tests to assess improvements in learning outcomes. Surveys were then conducted among students and teachers to gather feedback on the materials' usability. Based on the results, the materials were revised for improved effectiveness. Ethical standards were strictly observed throughout the study, including informed consent, data confidentiality, and voluntary participation.

III. Results and Discussion

Development of Learning Material based on the least learned PISA competencies

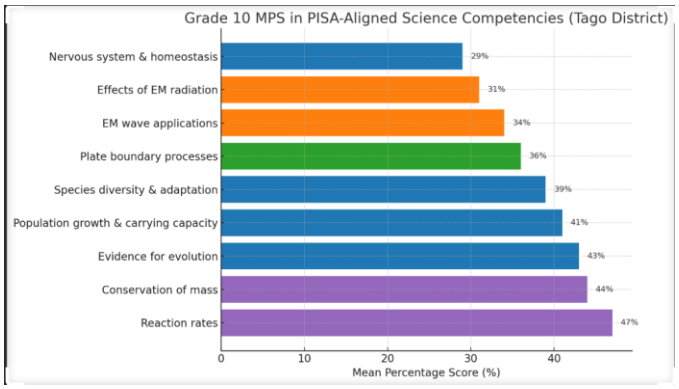

Figure 1. Least Learned PISA Aligned Competencies

Based on the Mean Percentage Scores (MPS) presented in Figure 1, the four least learned Grade 10 Science competencies in Tago District under the Division of Surigao del Sur are: describing the nervous system and homeostasis (29%), explaining the effects of electromagnetic (EM) radiation (31%), citing EM wave applications (34%), and explaining plate boundary processes (36%). These competencies are aligned with PISA science domains such as explaining phenomena scientifically, evaluating and designing scientific inquiries, and using scientific information for decision-making.

Integrating digital learning tools enhances students' critical thinking, problem-solving, and scientific reasoning—skills emphasized in the PISA framework [12][13][14]. Likewise, the Department of Education underscores the role of ICT-based resources in improving the quality of science education [15]. Digitized materials, such as Scixplore, which feature simulations, animations, and virtual experiments, provide engaging, inquiry-based learning experiences that help bridge comprehension gaps. These tools also promote both scientific and digital literacy, aligning with 21st-century learning goals and contributing to better performance in science competencies [16].

Digitized Science Learning Materials Validation Results from Experts

Figure 2 shows validation results of the digitized science learning materials, as reviewed by three expert groups—

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subject matter experts, ICT experts, and school heads/master teachers—revealed generally positive feedback, with minor suggestions for improvement. Subject matter experts provided the highest average compliance rating at 92.51%, with perfect scores in Learning Competencies (100%) and near-perfect scores in Assessment (98.89%), suggesting strong alignment with curriculum standards and effective evaluation strategies. ICT specialists reported a slightly lower average of 87%, with Typographical Organization receiving a perfect score (100%), but the lowest rating in Physical Attributes (75%), indicating potential areas for improvement in the materials' presentation and technical aspects. Similarly, School Heads/Master Teachers focused on language aspects and gave an average compliance of 92.93%, with Grammar and Syntax receiving a perfect 100%, highlighting the materials' linguistic appropriateness, although Coherence and Clarity of Thought, Spelling and Punctuation, and Consistency in Style also received strong ratings (above 88%).

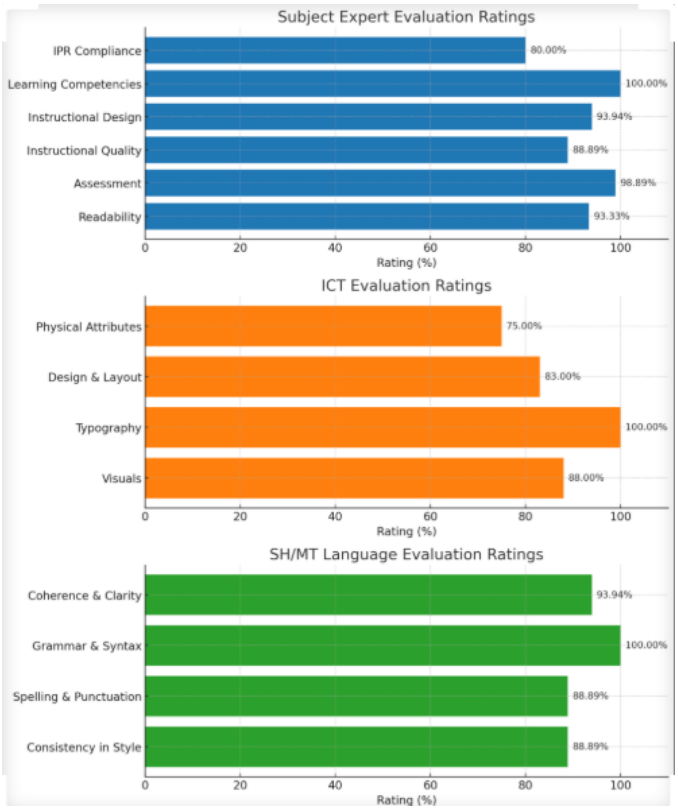

Figure 2. Validation Results from Experts

All three expert groups provided affirming feedback on the digitized science learning materials. The subject matter experts validated its academic credibility and compliance with citation standards; the ICT experts confirmed its design quality and usability; and the school heads or master teachers endorsed its linguistic clarity. Collectively, these validations support the readiness of the materials for broader implementation in digital classroom settings [17][18].

Field Try Out Pre-test and Post-test Result

Table 1 presents the analysis of Pre-Test and Post-Test results from 60 students, which reveals a significant improvement in science understanding following the implementation of digitized science lessons. Initially, the Pre-Test scores showed a low mean (M=7.97, SD=2.36) with considerable variability (range 4-14), indicating a weak initial grasp of the concepts. However, the Post-Test demonstrated a substantial increase in the mean score (M=18.72, SD=1.32) and reduced variability (range 15-20), suggesting consistent and high learning gains across the students.

TABLE 1. Descriptive Statistics for Pre-Test and Post-Test Scores

Test	Mean	SD	Min	Max
Pre-Test	7.97	2.36	4.00	14.00
Post-Test	18.72	1.32	15.00	20.00

This finding aligns with numerous studies that highlight the positive impact of technology integration in science education. For instance, one study found that computer simulations significantly boosted student engagement and understanding [19], while the Interactive Simulations [20] have also demonstrated improved conceptual learning. Similarly, interactive e-books enhance classroom engagement and learner attention [21].

Feedback of the Students and Teachers on the Developed Digitized Material

TABLE 2. Feedback of the Students and Teachers on the Developed Digitized Material

Aspect Evaluated	Students' Mean	Descriptive Rating	Teachers' Mean	Descriptive Rating
I. Content	4.46	Outstanding	4.65	Outstanding
II. Format	4.49	Outstanding	4.55	Outstanding
II. Presentation & Organization	4.39	Outstanding	4.56	Outstanding
IV. Accuracy & Up-to-datedness	4.40	Outstanding	4.51	Outstanding
V. User Interface	4.42	Outstanding	4.66	Outstanding
Grand Total	**4.43**	**Outstanding**	**4.59**	**Outstanding**

Table 2 reveals that students rated the content of the developed digitized material with a grand mean of 4.46 (SD = 0.09), while teachers gave it a slightly higher rating of 4.65 (SD = 0.06), both interpreted as "Outstanding." In terms of format, students gave a mean score of 4.44 (SD = 0.11), and teachers rated it at 4.62 (SD = 0.08), again both falling under the "Outstanding" category. These results indicate that both students and teachers highly appreciated the quality of the content and format of the digitized material, with teachers showing a slightly stronger agreement, suggesting its appropriateness and effectiveness for classroom use.

These results align with previous research emphasizing the critical role of clear presentation and structured organization in digital learning resources [22]. Well-organized digital lessons enhance students' focus and retention [23]. Additionally, the slight difference between students' and teachers' perceptions suggests the importance of considering multiple perspectives when designing educational materials.

Significant Difference of the Evaluation Rating

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TABLE 3. Descriptive Statistics of the Evaluation Ratings on Digitized Learning Materials Between Students and Teachers

Type of Respondent	N	Mean Rank	Sum of Ranks
Students	60	37.14	2228.50
Teachers	18	47.36	852.50
Total	78		

TABLE 4. Test Statistics of the Mann–Whitney U Analysis Comparing Evaluation Ratings Between Students and Teachers

Test	Value
Mann–Whitney U	398.500
Wilcoxon W	2228.500
Z	-1.680
p-value	0.093

A Mann-Whitney U test compared evaluation ratings of digitized learning materials by students and teachers, revealing that while teachers had a numerically higher mean rank (47.36) than students (37.14), this difference was not statistically significant (U=398.500, z=-1.680, p=0.093). Despite the trend of teachers rating the materials more favorably, the lack of statistical significance suggests that both groups generally share a similar overall perception of the effectiveness and quality of the digitized learning materials, implying a potential balance in meeting the needs of both learners and educators [11].

Significant Difference between the Pretest and Posttest

TABLE 5. Wilcoxon Signed-Ranks Test Summary for Pre-Test and Post-Test Scores

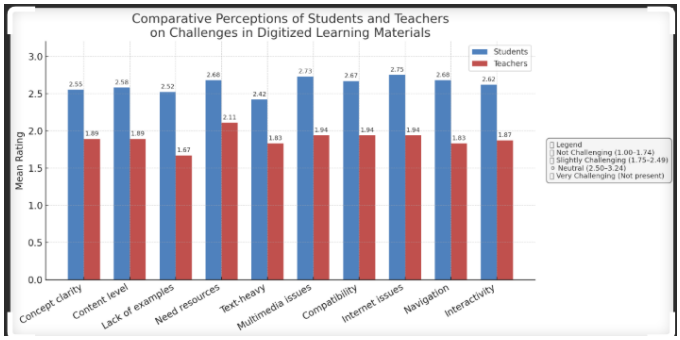
Test Category	N	Mean Rank	Sum of Ranks	Z	p-value	Interpretation	Cohen's d
Negative Ranks	0	0	0				
Positive Ranks	60	30.50	1830.00	6.755	<0.001	Highly significant	4.95
Ties	0	0	0				

As shown in Table 5, all 60 participants demonstrated an increase in their post-test scores, with zero negative ranks and no ties. This means that every single student improved after the intervention, with none scoring lower or the same as before. The mean rank of the positive differences was 30.50, and the total sum of ranks was 1830.00. Statistically, this translated to a Wilcoxon Z-value of (z=6.755, p<0.001) clearly indicating that the change in scores was highly significant.

The absence of negative ranks and ties confirms that all participants benefited from the digitized learning materials, demonstrating the effectiveness of the instructional intervention. The results imply that integrating well-designed digitized learning materials into science instruction can lead to substantial improvements in student learning outcomes [10][24].

Challenges in the Utilization of the Digitized Learning Material

Figure shows the perceived challenges in utilizing digitized learning materials reveals a notable difference between students' and teachers' experiences, particularly in content-related and technical aspects. For content-related challenges, students reported a grand mean of 2.55 (SD = 0.10), interpreted as slightly challenging, while teachers rated the same with a lower mean of 1.88 (SD = 0.14), also described as slightly challenging. Notably, students found certain items more difficult, such as the need for additional resources (M = 2.68) and the complexity of scientific concepts (M = 2.55), compared to teachers' ratings of M = 2.11 and M = 1.89 respectively. Interestingly, while teachers viewed the lack of real-world examples as not challenging at all (M = 1.67), students still found it slightly challenging (M = 2.52), suggesting a disconnect in content expectations and learning needs. Regarding technical and accessibility challenges, students perceived these as neutral (Grand Mean = 2.69, SD = 0.05), while teachers rated them as slightly challenging (Grand Mean = 1.90, SD = 0.06). Students identified issues like internet connectivity (M = 2.75), multimedia loading problems (M = 2.73), and navigation difficulties (M = 2.68) as more prominent compared to teachers' consistently lower scores of M = 1.94, 1.94, and 1.83 respectively.



These findings suggest that while both groups acknowledge challenges, students experience more difficulty, particularly with technical limitations and content clarity—highlighting the need for better-aligned instructional design and improved digital infrastructure to meet learners' expectations [25]. It highlights the importance of robust digital infrastructure and well-designed digital content to overcome technical and content-related challenges [26].

Proposed Enhanced Output

Based on the study's findings, the proposed enhancement is the development of the Sicxplore Smart Science Learning Suite (SSSLS), a comprehensive digital instructional package designed to overcome both content-related and technical challenges experienced by students and teachers. This suite will feature multimedia-rich modules with voice-over explanations, animations, and interactive simulations to simplify complex scientific concepts, alongside adaptive content tailored to different learner levels. Real-life applications, contextual case studies, and gamified activities will increase engagement and bridge the gap between theory and practice. To address technical issues such as internet connectivity and navigation difficulties, the materials will support offline access, low-bandwidth use, and feature a user-friendly interface with intuitive menus and interactive elements. A teacher resource kit with guides, scaffolding strategies, assessment tools, and a collaborative online forum will support differentiated instruction. Additionally, a dynamic

feedback system with regular expert reviews will ensure content remains accurate and up to date. Overall, these enhancements aim to improve instructional quality, usability, and accessibility, providing an inclusive and engaging digital science learning experience grounded in the study's empirical insights.

IV. Conclusion

This study successfully designed and validated digitized science learning materials aligned with PISA competencies to enhance learners' scientific and digital literacy through a rigorous development and multi-tier validation process. Expert reviews and field trials confirmed that the materials were pedagogically sound, technically reliable, and instructionally relevant. Significant improvements in student performance were demonstrated by pre- and post-test analyses, showing a large effect size and greater consistency in achievement, which highlights the materials' effectiveness in promoting equitable learning outcomes. Both students and teachers provided highly favorable feedback on content quality, format, presentation, accuracy, and usability, although minor challenges related to content complexity, multimedia functionality, and device compatibility were noted. To address these, the study proposes an enhanced version—the Sicxplore Smart Science Learning Suite (SSSLS)—featuring adaptive multimedia content, offline accessibility, user-centered design, and continuous expert content updates. Overall, the study affirms that well-designed digitized materials can substantially improve student engagement and mastery of science in a digital context, supporting curriculum innovation and advancing digital equity and 21st-century scientific literacy among Filipino learners.

Recommendation

Based on the study's results and conclusions, it is recommended that the developed digitized science learning materials be adopted and integrated into the science curriculum, especially in contexts aligned with PISA competencies, given their demonstrated pedagogical soundness, technical robustness, and effectiveness in enhancing scientific and digital literacy. To address identified challenges in content clarity and accessibility, the development of an enhanced Smart Science Learning Suite (SSLS) is encouraged, incorporating voice-over narrations, interactive simulations, gamified elements, and adaptive content to support diverse learner needs and foster meaningful engagement. Recognizing persistent issues with internet access and device compatibility, offline and low-bandwidth versions—such as downloadable HTML5 packages and USB-based modules—should be created to ensure accessibility in remote or underserved areas, alongside improvements in user interface design for greater functionality and inclusivity. A dynamic feedback and update mechanism is also advised to maintain content accuracy and relevance through regular expert reviews and integration of user input.

To maximize implementation success, teacher training and support programs, including workshops and instructional guides, should be prioritized to empower educators in effectively utilizing the digitized materials. Finally, further research is recommended to evaluate the long-term impact of these digital resources on student achievement and engagement, and to explore their applicability across other subjects, grade levels, and school settings, thereby supporting continuous innovation and the advancement of 21st-century learning competencies among Filipino learners.

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