



Supplemental Digital Learning Resource for Environmental Science: A Quasi-Experimental Study

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ABSTRACT

Purpose of the study: This study aimed to develop and validate a supplemental digital learning resource in Environmental Science and to examine its classroom use as a support material for improving students' understanding of selected competencies.

Methodology: The study employed a quasi-experimental pretest-posttest design with control and experimental groups. A total of 174 senior high school students from four intact sections at a single school in the Bicol Region, Philippines, participated in the study. Two sections were assigned to the experimental group and two to the control group. The supplemental digital learning resource was developed using the ADDIE model and informed by elements of the 7E learning cycle in structuring learning activities. Prior achievement data were used to identify the least-mastered competencies, which served as the basis for the module's content. The material was validated by six expert validators for its objectives, content, appropriateness, format, language, and usability. Data were analyzed using the weighted mean and the paired t-test.

Main Findings: The developed supplemental digital learning resource obtained an overall weighted mean of 4.80, interpreted as Very Much Valid. Results also showed that both the control and experimental groups significantly improved from pretest to posttest. However, the experimental group obtained a higher posttest mean and a greater mean gain than the control group, suggesting that the supplemental digital learning resource may have provided additional instructional support for learning Environmental Science.

Novelty/Originality of this study: The study contributes a competency-based supplemental digital learning resource in Environmental Science designed to address least-mastered competencies and support flexible and blended learning. Its value lies in combining expert-validated content with structured learning activities intended to reinforce concept mastery and independent learning.

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1. INTRODUCTION

The education sector was among the most disrupted during the COVID-19 pandemic. According to Statista Research Department more than 1.5 billion students worldwide were affected by school and university closures beginning in 2020, while millions of teachers across primary and secondary education also experienced major disruptions [1], [2]. This global crisis forced educational systems to move away from conventional face-to-face instruction toward more adaptive and technology-mediated forms of learning, including distance, modular, and online delivery [3]. As a result, schools were compelled to rethink instructional practices and learning resources to ensure continuity of education under highly constrained circumstances.

In the Philippines, the pandemic likewise accelerated the adoption of flexible and alternative learning modalities across educational levels. While reports and policy discussions during this period often highlighted the response of higher education institutions [4], [5]. The broader shift toward flexible learning also reflected a national recognition that conventional classroom delivery alone was no longer sufficient under emergency conditions. This transition was further reinforced by policy guidelines on flexible learning, which emphasized the need for institutions to adopt alternative instructional approaches and appropriate learning resources [6]. In this context, the use of printed and digital modules, synchronous and asynchronous learning activities, and other technology-supported strategies became central to sustaining instruction.

The preparation of digital modules, however, requires careful planning. Learning activities must be appropriate for the developmental level of learners and aligned with intended competencies and performance standards [8]. Studies have shown that many students struggled to complete tasks and achieve learning objectives because of limited connectivity, inadequate access to devices, and restricted communication during remote instruction. In response, flexible learning in Philippine schools increasingly came to rely not only on online teaching, but also on the availability of sufficient, well-designed, and accessible learning materials that could support, sustain, and enhance the learning experience. The continued growth of digital technologies and the increasing availability of electronic resources have further strengthened the role of digital instructional materials in contemporary education [9], [10].

At the basic and secondary levels, online and blended learning became prominent modes of educational delivery during and beyond the pandemic [11], [12]. These modalities, whether synchronous or asynchronous, required learning materials that could guide students through lessons even when direct teacher support was limited. In this regard, digital modules emerged as valuable supplementary instructional tools because they provide structured content, guided activities, and opportunities for self-paced learning. Designing appropriate instructional materials is therefore essential to address students' digital learning needs and to help them navigate lessons more effectively during asynchronous or flexible learning sessions [13], [14].

Environmental Science is an important learning area in senior high school because it helps students understand pressing environmental concerns such as climate change, biodiversity loss, pollution, resource depletion, and other human-induced ecological problems. More importantly, it enables learners to recognize the relationship between human activities and natural systems, thereby fostering environmental literacy [15], [16]. Such understanding is especially important at the senior high school level, where students are expected to engage more critically with real-world issues and develop informed and responsible perspectives on environmental sustainability. In many schools, Environmental Science-related lessons are delivered through a combination of face-to-face, synchronous, and asynchronous modalities, making the availability of effective supplementary resources even more important.

Given this context, there is a need to develop supplemental digital learning materials in Environmental Science that can respond to the learning needs of senior high school students and support teachers in instructional delivery. A well-designed supplemental digital learning resource may serve as an accessible, structured, and engaging tool for reinforcing lessons, addressing least-mastered competencies, and helping learners better understand complex environmental concepts. Thus, this study aimed to develop and validate a supplemental digital learning resource in Environmental Science that may be used as a substantial support material for flexible and blended learning among senior high school students.

2. RESEARCH METHOD

2.1 Research Design

This study aimed to develop and validate a supplemental digital learning resource in Environmental Science for senior high school students and to determine its contribution to students' learning in a flexible or blended instructional setting. The developed material was intended to serve as a supplementary instructional tool that could reinforce least-mastered competencies and support guided and self-paced learning. This study employed a quasi-experimental pretest-posttest design involving a control group and an experimental group. Quasi-experimental designs are appropriate in school-based research when intact classes are used and random assignment is not feasible. Such designs allow researchers to examine the effect of an intervention by comparing groups exposed to different instructional conditions through pre-intervention and post-intervention measures [17], [18]. In classroom-based educational research, the use of intact groups is also common because it preserves the natural class setting while still permitting meaningful comparison of instructional outcomes [19], [20].

The development of the supplemental learning resource was guided by the ADDIE model, which consists of Analysis, Design, Development, Implementation, and Evaluation. This model provides a systematic process for planning, producing, implementing, and evaluating instructional materials to ensure alignment among learner needs, content, and intended outcomes [21], [22]. To strengthen the organization of learning tasks and student engagement, the design of selected module activities was also informed by the 7E learning cycle, which includes

elicit, engage, explore, explain, elaborate, evaluate, and extend. The 7E model has been recognized as a useful constructivist guide for science instruction, and prior studies have shown that it can support improved learning outcomes and more active participation in science classes [23], [24].

In the Analysis phase, the researcher examined achievement data from the previous school year to identify the least-mastered competencies in Environmental Science. These results served as the basis for determining the content of the digital module. In the Design phase, the structure, lessons, activities, and assessment components of the material were planned based on the identified competencies. In the Development phase, the supplemental digital resource was produced and submitted for expert validation. Revisions were made based on the written comments and suggestions of the validators. In the Implementation phase, the material was used by the experimental group as a supplemental learning resource. In the Evaluation phase, the pretest and posttest results, together with the expert validation ratings, were analyzed and interpreted.

2.2 Sampling Procedures and Respondents

The respondents of the study were 174 senior high school students from four intact sections in one school in the Bicol Region, Philippines. Two sections, with 47 and 40 students, respectively, were assigned to the experimental group, while two sections, with 43 and 44 students, respectively, were assigned to the control group. The experimental group used the supplemental digital learning resource, whereas the control group received instruction without the material. The use of intact classes is appropriate in classroom-based educational research, particularly when administrative and scheduling constraints make random assignment impractical [17]-[20]. This procedure is consistent with common practice in intervention studies conducted in authentic school settings, where the class is often treated as the natural unit of implementation in order to preserve ecological validity [19], [20]. For the validation phase, a team of six expert validators was purposively selected. The validators included one school administrator, one academic or science coordinator, one subject matter expert, and three Environmental Science teachers. Purposive selection of validators is appropriate when the study requires informed judgment from individuals with demonstrated expertise in curriculum content, instructional material evaluation, and classroom implementation [18]-[22]. Similar studies on school-based learning materials have used purposive sampling to select expert validators based on professional qualifications, teaching experience, and familiarity with curriculum standards and learning competencies [18]-[22].

2.3 Research Instruments

A teacher-made achievement test was used to measure students' mastery of Environmental Science competencies, particularly environmental systems and selected environmental problems. In constructing the test, the researcher reviewed relevant textbooks, articles, learning resources, and related local studies, and consulted knowledgeable educators in the field. The test was developed based on the target competencies reflected in the senior high school curriculum guide. A table of specifications was prepared to ensure alignment among the competencies, instructional time allotment, and number of test items. Curriculum alignment is important in instructional material studies because both the intervention and the assessment must measure the same intended competencies if the effect of the material is to be interpreted meaningfully [19], [21]. Before actual administration, the test underwent expert review and pilot testing. A dry run was conducted with 10 students who were not part of the final respondents in order to assess the clarity, appropriateness, and duration of the test. Initially, the test consisted of 60 multiple-choice items. Item analysis was then performed using the level of difficulty, difficulty index, and discrimination index.

Based on the results, weak or unsuitable items were removed, reducing the final test to 50 items. Pilot testing and psychometric refinement are important steps in instrument development because they help improve item clarity, establish content alignment, and strengthen the quality of the final measure prior to implementation [19], [21]. The supplemental digital learning resource developed by the researcher also underwent content validation by experts from the school. The validators assessed the material in terms of objectives, content, appropriateness, format, language, and usability. A validation rubric combining quantitative ratings and qualitative comments was used so that the material could be evaluated across key dimensions while also allowing specific recommendations for revision [18]-[22]. This combined approach is consistent with recent learning-material studies, which use numerical ratings to summarize quality across dimensions while relying on qualitative feedback to guide refinement before implementation [18]-[22].

2.4 Data Collection

The data collection process involved the systematic gathering of information needed to address the objectives of the study. At the beginning of the study, the researcher examined interpreted achievement data from the previous school year to identify the least-mastered competencies in environmental science. These competencies served as the basis for the development of the supplemental digital learning resource. The researcher then unpacked the target competencies from the curriculum guide and other references and used them in planning the content of

the module. The developed material included learning objectives, simplified discussions, learning activities, assessments, answer keys, and references.

The learning activities in the module were structured using elements of the 7E learning cycle elicit, engage, explore, explain, elaborate, evaluate, and extend to support prior knowledge activation, concept development, guided practice, and transfer of learning. This pedagogical approach is supported by studies indicating that the 7E model can enhance students' achievement and improve the effectiveness of science instruction [23], [24]. As a supplemental material, the module was designed to support flexible learning and to provide students with structured guidance during classroom-based and asynchronous learning sessions [6].

After the material had been developed, it was submitted for expert validation. The validators reviewed the suitability, effectiveness, and appropriateness of the content for the intended learners using a validation rubric. Their comments and suggestions were then incorporated into the final revision of the digital module. This revision-oriented validation process is consistent with school-based instructional material development, where expert feedback is used not merely to rate the product but to improve its content, design, and usability before classroom implementation [18]-[22].

For the implementation phase, the validated 50-item teacher-made test was administered as a pretest to both the control and experimental groups before the intervention in order to determine their baseline knowledge of Environmental Science concepts. After the intervention period, the same parallel test was administered as a posttest to both groups to determine changes in content mastery. The test was conducted through Google Forms to facilitate retrieval and organization of responses. During the intervention, the experimental group used the supplemental digital learning resource, while the control group received instruction without the module. Collecting pretest and posttest data from both groups is a standard procedure in classroom-based intervention studies for establishing baseline comparability and measuring change after exposure to the treatment [20], [21].

2.5 Data Analysis

The researcher used appropriate statistical tools to analyze the data gathered in the study. The responses were systematically classified and tabulated according to the variables included in the study. The mean was used to determine the average number of correct answers in the teacher-made test, while the weighted mean was used to interpret the ratings in the validation rubric. The following interval scale was used in interpreting the weighted mean of the validation results: 4.20–5.00, very much valid; 3.40–4.19, valid; 2.60–3.39, moderately valid; 1.80–2.59, fairly valid; and 1.00–1.79, not valid. The use of weighted mean is common in instructional material validation studies because it provides a concise summary of expert judgments across evaluation criteria and allows the quality of the developed material to be interpreted systematically [18], [20]. A paired t-test was used to compare the pretest and posttest means within each group and determine whether the difference between them was statistically significant. However, because the study involved both a control group and an experimental group, a direct between-group comparison of posttest scores or gain scores is also recommended in order to more clearly establish whether the intervention group performed better than the comparison group [20]. Recent comparative science education studies have strengthened their interpretation by combining pretest-posttest comparisons with direct post-intervention group comparisons and, where possible, effect size estimates [20], [21].

3. RESULTS AND DISCUSSION

3.1. Achievement Test Results in Environmental Science

Achievement tests provide an important basis for determining students' level of understanding and proficiency in a subject area. In instructional material development studies, they are particularly useful for identifying least-mastered competencies that may guide the design of targeted interventions and supplementary learning resources.

Table 1. Achievement Test Result

Number of Grade 11 Senior High School Students	Percentage	Results
2	6.90%	Mastered
13	44.83%	Moderately Mastered
10	34.48%	Nearly Mastered
4	13.79%	Beginning
0	0%	No Evidence of Mastery
TOTAL: 29 Students	100%	

Table 1 presents the achievement test results in Environmental Science for the reference group in School Year 2022–2023. Out of 29 students, only 2 or 6.90% reached the Mastered level. The largest proportion, 13

students or 44.83%, fell under Moderately Mastered, while 10 students or 34.48% were classified as Nearly Mastered. Four students or 13.79% were at the Beginning level, and none fell under No Evidence of Mastery.

These results indicate that only a small proportion of learners demonstrated full mastery of the assessed competencies. Although a substantial number of students reached the moderately mastered level, the distribution of results still suggests uneven understanding across key Environmental Science topics. The presence of learners in the nearly mastered and beginning levels points to the need for targeted instructional support, particularly in competencies that learners find difficult to understand. This justifies the development of a supplemental digital learning resource intended to address learning gaps and strengthen mastery of the least-mastered competencies.

This finding is consistent with studies suggesting that students may continue to experience difficulty in science learning even in supportive classroom environments, particularly when instruction does not fully align with learners' prior knowledge, learning preferences, and engagement needs [25]. Learner motivation and sustained attention also play an important role in academic performance, as students who show lower interest in a subject may be less likely to engage deeply with the lesson [26]. Similarly, students may lose interest when the content appears disconnected from their experiences or when teaching strategies fail to highlight its practical relevance [27], [28]. For this reason, research has emphasized the value of dynamic, engaging, and context-based instructional approaches that connect concepts to real-life situations and encourage active participation [28]. Taken together, these results support the need for an intervention that is more accessible, engaging, and responsive to the identified learning needs of students.

3.2. Supplementary Learning Resource

Supplemental digital learning resources are materials designed to complement regular classroom instruction and enhance the overall learning experience. In the present study, the developed resource serves as a supplementary material in Environmental Science. It is intended to help learners better understand complex concepts, reinforce classroom discussions, and provide additional opportunities for guided and self-paced learning. As a supplemental resource, it was designed to align with the identified least-mastered competencies and to present Environmental Science concepts in a more accessible, organized, and meaningful way.

Table 2. Least Mastered Competencies Based on Achievement Test.

Items	Number Of Students With Correct Answer	Number Of Competencies	Competencies
1	6	1	Discuss the overview of Environmental Science, its scope, and the goals of environmental education.
3	6	8	Describe the interaction of the different elements of the Earth's environmental systems.
9	9	28	Identify the different geologic processes.
12	8	2	Define Environment, Environmental Science, and Ecology.
23	7	3	Explain the seven (7) environmental principles and their application in everyday living
28	8	4	Discuss the different environmental ethics and attitudes governing environmental responsibility.
29	3	6	Describe the nature of science and energy principles.
30	8	6	Describe the nature of science and energy principles.
32	4	9	Differentiate the biotic and abiotic components of the ecosystem.
37	9	12	Illustrate the components, processes, relationships, and functions of ecosystems;
43	9	25	Identify the different environmental problems brought by the global COVID-19 pandemic.
48	9	34	Enumerate the different uses of water.
60	5	26	Enumerate the risks brought about by these environmental problems
63	8	31	Suggest preventive measures and alternative solutions to the different environmental problems in land and soil.
65	8	36	Analyze the different risks associated with water pollution.

Items	Number Of Students With Correct Answer	Number Of Competencies	Competencies
66	6	15	Explain the importance of biogeochemical cycles in maintaining the balance of the ecosystem and to the different organisms.
67	10	20	Enumerate the benefits and threats to biodiversity

Table 2 shows the least-mastered competencies identified from the achievement test. The results reveal that many of the weak areas are concentrated in Environmental Systems and related environmental issues, indicating that these topics require additional instructional support. Notably, one of the lowest-performing competencies was under the biosphere component, where only 4 out of 29 students answered correctly. This suggests that learners experienced difficulty with foundational and systems-oriented concepts, which are central to understanding broader Environmental Science content.

Based on these findings, the supplemental digital learning resource was designed to focus on the competencies that appeared most difficult for learners. The content therefore emphasized key areas such as the introduction to Environmental Science, interrelated scientific principles, environmental systems (biosphere, hydrosphere, lithosphere, and atmosphere), and selected local and global environmental problems. Anchoring the material on least-mastered competencies strengthens the instructional value of the resource because it allows the intervention to directly respond to identified learning gaps rather than simply repeat general content.

This direction is consistent with studies showing that well-structured instructional modules provide clear learning objectives and organized opportunities for concept mastery [29]. Research on science modules has likewise shown that when lessons are contextualized and linked to real-life situations, learners are better able to understand and apply abstract concepts [27], [30]. Contextualized and practice-oriented examples can make Environmental Science content more meaningful to students by helping them connect theory with everyday experience and environmental realities. In this way, the supplemental resource not only reinforces curricular content but also supports deeper understanding and more purposeful engagement.

Moreover, identifying least-mastered competencies provides useful information for improving instruction, refining learning materials, and adjusting the pacing and focus of lessons. By addressing these weak points through a supplemental digital resource, the study seeks to provide learners with structured opportunities for review, application, and reinforcement. The material includes learning tasks, case-based examples, and activities intended to encourage active participation and concept application. Such features are important because engaging learning experiences may help students participate more actively and develop more positive attitudes toward the lesson, thereby supporting better learning outcomes [29], [31]. Overall, the developed supplemental digital learning resource is intended to serve as a practical and responsive support material for improving students' understanding of Environmental Science.

3.3. Validation of the Supplemental Learning Resource

Validation is essential in instructional material development because it helps ensure that learning resources are relevant, accurate, clear, appropriate, and usable for the intended learners [32]. Through validation, teachers and instructional designers can refine educational materials so that they more effectively support learning objectives and respond to learners' needs [33]–[34]. In the present study, the supplemental digital learning resource was evaluated by six expert validators for its objectives, content, appropriateness, format, language, and usability.

Table 3. Validation of the Supplemental Learning Resources

Criteria	WM	Interpretation
A. Objectives		
1. The objectives are concisely expressed.	5.00	Very Much Valid
2. The objectives are obtainable concrete, and precise.	4.83	Very Much Valid
3. The objectives are carefully structured.	5.00	Very Much Valid
4. The objectives are essential to the topics covered on the subject.	4.67	Very Much Valid
5. The objectives provide independent learning.	5.00	Very Much Valid
Average Weighted Mean	4.90	Very Much Valid
B. Content		
1. The contents are relevant to the defined objectives.	4.67	Very Much Valid
2. The content provides practical work.	4.50	Very Much Valid
3. The instructions are clearly stated.	5.00	Very Much Valid
4. The content provides varied activities to sustain student's needs.	4.83	Very Much Valid
5. Emphasizes to improve the skills of the learners.	4.67	Very Much Valid

Criteria	WM	Interpretation
Average Weighted Mean	4.73	Very Much Valid
C. Appropriateness, Format and Language		
1. The material is well-constructed in terms of format and layout.	4.33	Very Much Valid
2. The terminologies are simple to comprehend.	4.83	Very Much Valid
3. The content was based on the learning competencies.	4.83	Very Much Valid
4. The concepts are covered in a logical and orderly manner.	5.00	Very Much Valid
5. The material is adapted to the intended learners.	5.00	Very Much Valid
Average Weighted Mean	4.79	Very Much Valid
D. Usability		
1. The instructional material attains the course outcome.	5.00	Very Much Valid
2. The instructional material helps the students master the topics at their own pace.	4.67	Very Much Valid
3. The instructional material allows the students to practice time-management and develop good study habits.	4.67	Very Much Valid
4. The instructional material encourages critical thinking, and reasoning skills.	4.83	Very Much Valid
5. The instructional material serves as supplementary material for teachers and learners.	4.83	Very Much Valid
Average Weighted Mean	4.80	Very Much Valid
Average Weighted Mean	4.80	Very Much Valid

Table 3 shows that the supplemental digital learning resource obtained an overall weighted mean of 4.80, interpreted as Very Much Valid. The highest rating was obtained in Objectives (4.90), followed by Usability (4.80), Appropriateness, Format, and Language (4.79), and Content (4.73). These results indicate that the material was viewed by the validators as clear in purpose, aligned with the competencies, suitable for the intended learners, and functional as a supplementary instructional tool.

The very high rating for Objectives suggests that the material presents its intended learning targets clearly and in a manner that supports independent learning. The strong rating for Content indicates that the lessons, activities, and instructions were considered relevant, practical, and supportive of skill development. Likewise, the ratings under Appropriateness, Format, and Language suggest that the module was well organized, easy to understand, and aligned with the learning competencies. The rating for Usability further implies that the material has practical instructional value, particularly in helping learners study at their own pace, strengthen study habits, and engage in critical thinking.

These findings reinforce the view that learning materials should undergo careful validation before implementation, especially when they are intended to address least-mastered competencies and support learning improvement [34]. This is also consistent with previous studies, which emphasized that effective learning materials must be valid, acceptable, and aligned with learners' needs and curriculum standards [35]-[37]. When instructional materials are accurate, competency-based, and appropriately designed, they are more likely to provide meaningful learning experiences and support students in demonstrating mastery of the target concepts. Thus, the overall validation result indicates that the developed supplemental digital learning resource is acceptable for use in Environmental Science instruction and may be distributed to learners as a support material for classroom and flexible learning contexts.

3.4. Pretest and Posttest Results of the Control and Experimental Group

Administering a pretest prior to the intervention helps establish the learners' baseline performance and allows researchers to interpret posttest changes more meaningfully. In quasi-experimental studies, comparing pretest and posttest mean scores provides an initial picture of whether learning gains occurred after the treatment.

Table 4. Pretest and Posttest Results of the Control and Experimental Group

Group	N	Pretest	Posttest
Controlled	87	25.31	38.08
Experimental	87	27.29	41.46

Table 4 presents the pretest and posttest mean scores of the control and experimental groups. Before the intervention, the control group obtained a mean pretest score of 25.31, while the experimental group obtained 27.29. After the intervention, the control group obtained a mean posttest score of 38.08, whereas the experimental group obtained 41.46. These scores correspond to transmuted values of 88.08 for the control group and 91.46 for the experimental group.

A comparison of the pretest and posttest means shows that both groups improved after the instructional period. The control group registered a mean increase of 12.77, while the experimental group showed a slightly higher mean increase of 14.17. This pattern suggests that both instructional approaches contributed to improved understanding of Environmental Science competencies, although the larger gain in the experimental group indicates that the supplemental digital learning resource may have provided added instructional support.

This trend is consistent with studies showing that engaging and structured instructional interventions can improve students' conceptual understanding in science learning [38]. It is further supported by studies on module-based and supplementary instructional materials, which reported that well-designed learning resources can contribute to more meaningful learning experiences and better academic outcomes [39]-[40]. In the present study, the higher posttest mean and greater mean gain in the experimental group suggest that the supplemental digital learning resource may have helped reinforce classroom instruction and support students' mastery of the target competencies.

3.5. Significant Difference Between Pretest and Posttest

Determining whether there is a significant difference between pretest and posttest scores is important in evaluating the effect of an instructional intervention. A statistically significant difference indicates that students' performance changed after exposure to the treatment, thereby providing evidence that learning occurred during the intervention period.

Table 5. The result of the Test of Significance Difference between the Pretest and Posttest Scores of Control Group and the Experimental Group

	Experimental Group	Control Group
Pretest Mean Result	27.29	25.31
Posttest Mean Result	41.46	38.08
Level of Significance	0.05	0.05
N	87	87
Degrees of Freedom	86	86
Computed t value	19.18	14.97
Tabular t value	1.998	1.998
Decision	Reject the Null Hypothesis	Reject the Null hypothesis
Conclusion	Significant	Significant

Table 5 presents the results of the paired t-test comparing the pretest and posttest scores within the control and experimental groups. For the control group, the computed t value of 14.97 is greater than the tabular value of 1.998 at $df = 86$ and $\alpha = 0.05$. This indicates a statistically significant difference between the control group's pretest and posttest scores. For the experimental group, the computed t value of 19.18 is likewise greater than the tabular value of 1.998 at $df = 86$ and $\alpha = 0.05$, indicating a statistically significant difference between the group's pretest and posttest scores.

These findings show that both groups experienced significant improvement after the instructional period. This suggests that the instruction provided in both conditions contributed to students' learning in Environmental Science. However, the experimental group obtained a higher posttest mean and a larger mean gain than the control group, indicating that the use of the supplemental digital learning resource may have provided additional support to student learning.

This pattern aligns with previous findings emphasizing the importance of instructional materials and teaching aids in improving classroom teaching and learning. Effective learning resources can strengthen lesson delivery, support concept clarification, and help students acquire knowledge and skills more successfully [39], [40]. In this study, the larger gain observed in the experimental group provides preliminary evidence that the supplemental digital learning resource may be beneficial as an instructional support tool in Environmental Science.

4. CONCLUSION

This study developed and validated a supplemental digital learning resource in Environmental Science intended to address least-mastered competencies and support flexible and blended learning. The material was designed using the ADDIE model and was evaluated by expert validators in terms of objectives, content, appropriateness, format, language, and usability. The overall validation result showed that the material was Very Much Valid, indicating that it is acceptable and appropriate for instructional use. The findings further showed that both the control and experimental groups improved significantly from pretest to posttest, indicating that learning occurred under both instructional conditions. However, the experimental group obtained a higher posttest mean and a greater mean gain than the control group, suggesting that the supplemental digital learning resource may

have provided added support in strengthening students' understanding of Environmental Science concepts. These results highlight the potential of supplemental digital materials as practical instructional tools for reinforcing difficult competencies and supporting guided and self-paced learning. Overall, the study provides evidence that a well-designed and validated supplemental digital learning resource can serve as a useful support material in Environmental Science instruction. However, because the statistical analysis focused on within-group pretest-posttest comparisons, future studies are encouraged to include direct between-group comparisons and effect size estimates to establish the comparative effectiveness of the intervention more strongly.

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