The 360° View: Contextualized Virtual Reality Tours as Innovative Teaching Tool in Ecology for Elementary School Students

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ABSTRACT

Purpose of the Study. This study aims to develop and validate Contextualized Virtual Reality Tours as instructional materials for teaching ecology concepts to elementary students, focusing on enhancing students' conceptual understanding of ecological relationships and environmental awareness in a local context.

Methodology. The study employed a descriptive-developmental research design and used the ADDIE model to create Contextualized Virtual Reality Tours. Tools included a 64MP mobile camera for video production, AI-generated voice narration, and a 4-point Likert scale assessment for validation. Data analysis was performed with Microsoft Excel.

Main Findings. The Virtual Reality Tours significantly improved students' conceptual understanding, moving their performance from low to mastery level. Expert evaluations indicated high validity across content, instructional, and technical quality, and students rated the tours as highly acceptable and effective in increasing their engagement and comprehension of ecology concepts.

Novelty/Originality of this Study. This study introduces a localized, semi-immersive Virtual Reality Tour model for ecology education, making science concepts accessible to students without field trips. Integrating contextualized ecological elements addresses the gap in immersive science education tools for local environments, promoting relevant and cost-effective learning.

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1. INTRODUCTION

Science plays a critical role in shaping contemporary life, influencing technological advancements, policy decisions, and societal progress [1]-[5]. Despite its importance, science education faces significant challenges, including complex content delivery, students' lack of engagement, and poor performance in national and international assessments [6][7]. For instance, in the Philippines, despite the introduction of the K-12 curriculum-a spiral progression approach to science education, integrating multiple disciplines at every grade level and promoting inquiry-based learning that is learner-centered [8]. Studies reveal that only 1% of junior high school students are proficient in science, with the country ranking second lowest in science performance among 78 nations in the 2018 PISA results [9]-[11]. Similarly, the National Achievement Test (NAT) scores for science consistently fall below the 75% standard achievement threshold, indicating a pressing need to enhance science teaching strategies [12].

These persistent challenges call for transformative educational tools that bridge the gap between abstract concepts and practical understanding [13][14]. Virtual Reality (VR), with its immersive and interactive capabilities, stands out as a promising solution [15]-[17]. In science education, VR offers opportunities to bridge the gap between theoretical knowledge and practical application by creating realistic, interactive experiences [18]. VR can simulate ecological systems, visualize abstract processes, and provide access to inaccessible or hazardous environments [19][20].

However, VR integration in education remains underutilized due to high costs, limited accessibility, and misconceptions about its use as an entertainment tool [21]-[23]. Research on VR's impact on science education, particularly in localized and contextualized settings, is limited. Existing studies often focus on general applications of VR without addressing its use as a contextualized teaching tool. Additionally, research on VR's effectiveness, particularly in teaching ecology concepts, remains sparse. Ecology, a critical branch of biology, is often cited as one of the most challenging topics for students due to its abstract concepts and the need for field-based learning experiences [24] [25]. A survey among British A-level students ranked ecology as the second most challenging topic in biology, with concepts like energy flow, populations, and biomass pyramids posing significant difficulties [26] [27]. This highlights the need for innovative research to explore how VR can be tailored to local contexts, making learning more relevant and accessible to students.

This study addresses these gaps by developing and validating contextualized VR tours as instructional materials for teaching ecology. The novelty of this approach lies in its dual focus on leveraging VR's immersive capabilities and emphasizing contextualization, where ecological concepts are grounded in the local environment. By integrating locally relevant elements, the VR tours aim to make learning more relatable and engaging for students, fostering a deeper understanding of ecological principles. Moreover, the study responds to the growing demand for authentic learning experiences in science education. While traditional field trips and on-site learning are valuable, logistical and safety concerns often limit their feasibility. VR tours offer a safe and practical alternative, enabling students to explore realistic simulations of ecological systems and processes without leaving the classroom [20][28]. This innovative approach supports learning continuity, particularly in times of disruptions caused by natural hazards or other unprecedented events.

In this context, the researchers posit that VR, as a revolutionary, contextualized, and technology-driven educational tool, has the potential to bridge the gaps in science education. By developing contextualized VR tours for teaching ecology, this study not only advances pedagogical strategies but also aligns with national educational goals to enhance science literacy and 21st-century skills. In an era where technological innovation drives education, this study offers a model for harnessing VR to transform how students learn ecology by bridging theoretical knowledge with local contexts and immersive experiences.

2. RESEARCH METHOD

2.1. Research Design

This study used a descriptive developmental research design, which is a combination of descriptive and developmental approaches. This design was chosen because it is most suited for studies examining, documenting, and evaluating a created product or process [29]. In contrast to essential instructional development, developmental research is the systematic study of generating, implementing, and analyzing instructional programs, methods, and products that must meet internal consistency and effectiveness requirements [29]. Contextualized Virtual Reality Tour was developed and created using this approach. The researcher also used the Analysis, Design, Develop, Implement, evaluate (ADDIE) model to suit the purpose of this research because it is a widely recognized and efficient model for educational studies and has strong associations with high-quality design, clear learning objectives, and content, and assessment closely tied to desired learning outcomes [24].

2.2. Sampling Procedures and Respondents

The study used purposive sampling to choose the respondents to validate and evaluate the developed Virtual Reality Tour, consisting of nine (9) experts and thirty (30) student respondents. The experts are Master Teachers in Science ICT experts with almost five years of teaching experience in the field. Given their background and expertise, the researchers believe that they can provide insightful feedback on the content and technical quality of the VR tool. At the same time, the thirty Elementary students came from a Science, Technology, and Engineering (STE) class in one of the public elementary schools in the province of Sorsogon and are officially enrolled for the school year 2022 – 2023.

2.3. Research Instruments

To collect relevant data for the study, the researcher utilized the following instruments: Developed Virtual Reality Tour Ecosystem Video (VRT). The primary components of the instructional materials were the Virtual Reality Tour videos presenting concepts within the identified learning competencies in Ecosystem Topics for Biology. The researchers developed separate videos for each component, which were loaded into the Head-Mounted Display for viewing. LRMDS Assessment and Evaluation Tool of DepEd. The rating scale and matrix were based on the Department of Education's Guidelines and Processes for Learning Resources Management and

Development System (LRMDS) Assessment and Evaluation specifically for non-print materials (2009) [https://lrmds.deped.gov.ph/docs/LRMDSGuidelines.pdf]. The developed VRT was evaluated by the experts using the LRMDS tool along with (1) content quality, (2) instructional quality, (3) technical quality, and (4) Accuracy. The rating instrument was a 4-point Likert Scale, which served as the foundation for the revision, customization, and improvement of the VRT.

Validation of Contextualized Features. A 5-point Likert scale from the study of [30] was adopted to evaluate the presence of features in contextualization. The expert utilized this to explore the contextualization and localization of elements within the developed instructional material, VRT. Student Acceptability Checklist. The student-respondents used this to evaluate the developed VERT specifically along (a)clarity of the information and concepts, (b) usefulness of the material, (c) adequacy of the ideas and information presented, (d) timeliness of the tool, (e) appropriate use of visuals and illustrations, and (f) the presentation of the material. The rating instrument utilized a 4-point Likert scale on all evaluation criteria and was adapted from the study of [30].

Conceptual Understanding Test on Pre and Posttest. Conceptual understanding is one of the fundamental competencies in learning science; it is inseparably linked to science concepts in knowledge competencies. Therefore, students must possess conceptual knowledge to learn Science successfully. When assessing science learning, one of the most significant research issues has always been the conceptual understanding of learners [31]. The 50-item test tool was adapted from the study of [32] and covered the competencies in Biology, particularly in Ecosystem topics. The tests were administered to the student respondents at the beginning and end of the implementation phase.

2.4. Data Collection

This study utilized the Analyze, Design, Develop, Implement, and Evaluate (ADDIE) Model to develop and validate the Virtual Reality Tour Ecosystem Videos, which will be integrated into the Ecosystem Lessons in Biology. The data collection procedures are explained as follows:

2.4.1. Analyze Phase

This phase was carried out to analyze the needs, review the literature, and identify the cause of the problem, thus requiring the development of new models or innovations. It is realistic to anticipate that the public health catastrophe brought on by the COVID-19 pandemic has worsened the poor academic performance of Filipino kids. Due to the frequent lockdowns, there has been limited face-to-face interaction under the new normal, leaving students dependent on their study materials to complete the coursework. This has led to a learning crisis where low-quality modules and materials for distance learning are standard. The inadequate public investment in education can contribute to these severe learning obstacles [32].

It is highly intriguing to talk about innovation in teaching and learning activities since it is believed that using an appropriate approach to instruction will improve student learning outcomes. Education quality could be improved through innovation in teaching and learning tools [33]. Creating a more stimulating learning environment for students is a critical advantage of using technology in instructional design. It is difficult to ignore how technology has changed our teaching and learning. Teachers can use technology to convey material in more engaging and original ways [34]. With the learning gaps mediated by educational disruptions in the Philippines, developing innovative instructional and learning materials is critical [35].

2.4.2. Design Phase

Students can better comprehend the subjects being tackled if teachers contextualize the content. Additionally, students can better comprehend and use this information in their future academic endeavors [36]. The Virtual Reality Tours were designed through contextualization, in which the elements presented in the material were relevant to the locality of Gubat, Sorsogon. Ecology, as the principal concept of the subject area, was deemed appropriate for the use of virtual Reality – to which the environment and ecosystem could be explicitly introduced and displayed. The inclusion of localized items was subjected to environmental awareness, conservation, and preservation. The developed material was identified to be administered within the elaborate part of the lesson, which could be appropriately assimilated within the lecture. Moreover, the use of the VR Tour could also be observed in the Extend part for horizontal and supplementary discussion.

2.4.3. Development Phase

Creation of Virtual Reality Tours. The identified and cumulative concepts in Ecology supported the development of the instructional tool. The contextualized elements were integrated into the Virtual Reality Tours. The creation of the material encompassed three (3) procedures: (1) Film Production: raw videos were collected and recorded in the immersed environment; (2) Video Synthesis: the films were combined and edited. Features such as appropriated transitions, integration of dimensional movement, stability, frame orientation, and audio narration assimilation were included. Artificial Intelligence or AI-generated narration with a Standard American-English accent was used as a voice-over in the video; and

(3) Dimensional Fitting; the screen frame of the video was modified through split-screen conversion, best fitted for the Head-Mount Display (HMD). There were three identified Learning Competencies as a basis for the development. Thus, a total of three VR Tour videos were created: (a) Biotic and abiotic components in the local ecosystem, (b) different ecological relationships observed, and (c) the impact of changes in the abiotic factors on the local environment.

Semi-immersive design. A semi-immersive VR experience allows for a virtual tour while remaining connected to reality. With the help of VR glasses, the user can enjoy a virtual environment without any physical feelings. It denotes that a semi-immersive VR experience allows users to immerse themselves in a new reality while being aware of their physical surroundings. This type of virtual Reality is often used in training and educational contexts. In semi-immersive VR, physical movement is not used. The simulation experience is visual, with the user at the center of all actions [36].

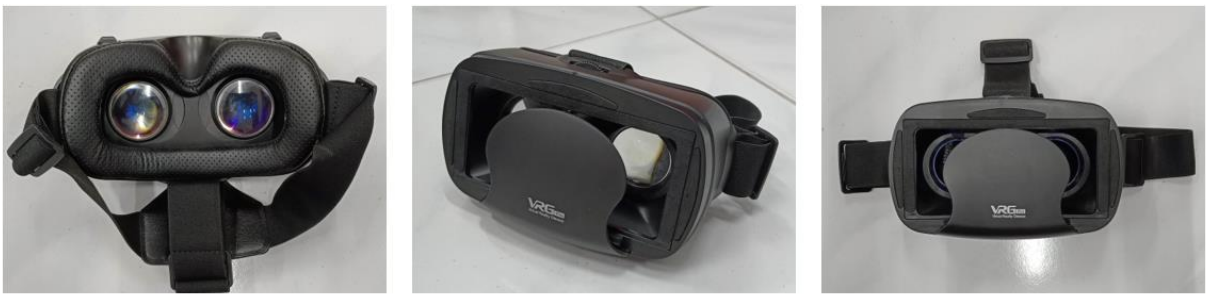
The production of Virtual Reality materials is arduous. Inadequate broadband connections, expenditure, or a lack of digital expertise are all possible obstacles to using or implementing AR/VR technologies. To address the challenges, the development and implementation of Virtual Reality should conform to the diverse users [37]. In these terms, the VR Tours were appropriated to the target users (students) and creators (educators). A fully immersive model was considered inaccessible to the instructional material level since it requires complex programs, applications, and intricate equipment; the project's features, interactivity level, and scope are considered when calculating the cost. Costs might range from $15,000 to $40,000 for an immersive VR representation with individualized interactive elements suitable for any compatible device [38]. Hence, a semi-immersive design was utilized due to its efficient costing and production, which was deemed achievable for mass use within educational institutions. VR in this format is replicable and more efficient for extensive and future use by teachers.

Furthermore, fully immersive VR requires control through locomotory navigation; this property hinders its utilization in a classroom setting due to physical constraints such as furniture and apparatuses situated within the space [39]. This would leverage the use of semi-immersive, stationary, and non-locomotive VR, which is a more efficient system for education [40].

Validation of Experts. An Expert's Validation Sheet for the evaluation of the material was prepared. The accumulated points of the indicators were interpreted using the instrument's predetermined standards: at least 30 of 40 (Content Quality), at least 30 of 40 (Instructional Quality), at least 39 of 52 (Technical Quality), and at least 16 of 16 (Other Findings). Moreover, a separate rating scale was used to measure the presence of contextualized features. The criteria highlighted the responsiveness and relevance of existent contents within the material sourced from the local ecosystem. The frequency of these parameters was utilized to derive inference from the objectives. Comments and suggestions were solicited for the improvement and revisions of the material.

2.4.4. Implementation Phase

Before the implementation, pilot testing was conducted on ten (10) randomly selected student participants from other institutions. Consequently, secondary revisions were made to this small-scale trial. The conduct of a pretest for Conceptual Understanding preceded the phase of implementation. The researchers presented the developed instructional tool comprising the Head-Mount Display, Gadget Monitor, audio headset, and a manual script for usage. The developed VR Tours were administered to the thirty (30) student participants. The integration timeline in the class setting was ensured to coincide with the allotted duration for the specified learning competencies. Reflected from the suggested span from the MELC, the administration covered two (2) weeks. The evaluation of the students' acceptability and conduct of the posttest was successful in the implementation phase at an interval of one week.



a b c

Figure 1. The head-mounted display utilized in viewing virtual reality tour materials is (a) a rear view, (b) a diagonal view, and (c) a front view.

Figure 1 shows the structure of the HMD. The LED screen and eyes of VR headsets are separated by stereoscopic lenses, which distort the image to make it appear three-dimensional and lifelike. These lenses allow the headset to transmit two images, one for each eye, much like how humans see [32]. The screen display was inserted in the HMD, and a sound output was attached through audio headsets.

2.4.5. Evaluation Phase

Utilizing instructional materials is an integral part of the teaching and learning process. However, teaching materials must be validated before wide-scale use to ensure quality [41]. The developed Virtual Reality Tours Ecosystem Videos were distributed to nine experts from various high schools in Sorsogon province who served as evaluators using the adopted evaluation rating sheet for non-print materials from the Guidelines and Process for LRMDS (Learning Resources Management and Development System) Assessment and Evaluation. The initial adjustment was done in response to the expert's remarks and recommendations. The pilot testing was conducted with ten school students utilizing a student evaluation checklist. These students' comments and suggestions were also incorporated into finalizing the produced VRT before its actual implementation. After completing all of the classes incorporating VRT, the students took the posttest and evaluated the acceptance of the material using the adapted instrument from [24]. The data was analyzed and quantified using Microsoft Excel, as well as the frequency count and weighted mean. The content analysis of the comments and suggestions of the professionals and students who used the VRT backs up all numerical results.

Furthermore, the targeted users participated in a focus group discussion after using and evaluating the material. Learners' narrative perspectives were gathered to offer comprehensive results to scaffold the acceptance test outcome. Direct quotations were used as data.

2.5. Data Analysis

The study employed descriptive statistics to analyze the experts' validation of the instructional material. The LRMDS Assessment and Evaluation Tool was used to generate inferences from the mean ratings provided by the respondents. The mean was calculated to summarize the expert responses, offering a quantitative representation of the characteristics and overall quality of the instructional material [24]. This approach ensures a systematic and objective evaluation process, as the mean serves as a critical statistic for understanding trends in the validation results and determining the material's credibility. In this study, the instructional materials were deemed credible if the percentage agreement among experts exceeded the 75% benchmark, a standard established in previous studies [42]. This threshold ensures that the material aligns with established educational quality standards and supports its relevance for the intended purpose. The validation results were compared to this benchmark to confirm whether the materials met the required standards for classroom implementation.

To evaluate students' acceptance of the material and the contextualization of its features, the study utilized frequency counts and weighted mean, interpreted through calibrated intervals generated in Microsoft Excel. This allowed for the analysis of numerical data and ensured the representation of various aspects of students' experiences and preferences. Additionally, content analysis of the experts' and students' comments and recommendations complemented the numerical results, providing qualitative insights that enriched the overall analysis [43]. The pretest and post-test results were analyzed using a combination of statistical techniques, including mean rating, an unpaired T-test, and Cohen's d-effect size, with a significance level set at 0.05. This analysis was critical to evaluating the effectiveness of the instructional material in improving students' understanding of ecological concepts. The unpaired T-test determined whether the difference between the pretest and post-test means was statistically significant. At the same time, Cohen's d measured the practical significance or effect size of the intervention. These analytical methods ensured the relevance of the tests to the research by providing robust evidence of the material's impact on student learning [20]. Specifically, the pretest and post-test comparison demonstrated the instructional material's potential to enhance conceptual understanding, making it an essential component in validating the study's contribution to science education. The integration of qualitative and quantitative analyses further ensured a comprehensive evaluation of the material's quality, contextualization, and effectiveness.

3. RESULTS AND DISCUSSION

3.1 Development and Contextualization of Virtual Reality Tours – Ecosystem Videos

Development of VRT. Utilizing the ADDIE Model, the researcher accumulated and designed frameworks as bases for the development of Virtual Reality Tours—ecosystem videos. The identified learning competencies structured the primary focus of the study, for which Ecology was selected. This dictated the content and information embedded within the instructional material. The IM includes multimedia and multisensory output of auditory and visual presentation.

The film production utilized a mobile phone for recording and capturing raw videos; the camera specification was 64 megapixels. These source footages were edited and merged through a free video editing software. The incorporation of transitions, stabilization, and modification of frame orientation was included in the program. The audio narration was created using voice booking, an online AI voice generator administered by text-to-speech technology. The dimensional fitting of the screen frame best suited for the head-mount display or VR box was executed using the same editor program mentioned. This procedure and conversion produced a split-screen video. Multiple runs and trials were accomplished to ensure the screen was correctly fitted to the ocular lens of the device. Moreover, the VRTs underwent a series of revisions bounded by the validation of experts and student participants before the implementation.

Contextualization of VRT. One of the municipalities of Sorsogon, Philippines, has become the primary setting of the study. It is a coastal municipality that provides a vast scope of biological and ecological elements, including marine to land ecosystems. Ecology, the selected topic of the developed material, was deemed fitting and appropriate for using Virtual Reality applications. From the identified competencies: (a) Differentiate biotic from abiotic components of an ecosystem [S7LT-llh-9], (b) Describe the different ecological relationships found in an ecosystem [S7LT-IIh-10], and (c) Predict the effect of changes in abiotic factors on the ecosystem [S7LT-llj-12], the Researchers derived learning objectives: (1) Cite examples of Biotic and Abiotic Factors, (2) Identify different Ecological Relationships present within the ecosystem, and (3) Relate the effects of changes in Abiotic Factors on the local ecosystem. These targets were the basis for selecting the concepts to be integrated into the material. The organisms in the video were presented with their local term, common name, and scientific name.

(a) Biotic Factors. The living part of an ecosystem is known as a biotic factor or biotic component. "biotic" is "of or about living organisms." All living things and their physicochemical components make up an ecosystem. The grassland ecosystem of the setting was encompassed of familiar animals and plants. The grazing field presented livestock animals such as cattle (Bos taurus) or "baka", from which ecologically connected organisms were also identified like egrets (Ardea alba) or "talalabong"; and the commensalism relationship between the two species was highlighted. Within the broad landscape, there were also miniature ecosystems of ponds and swaps – to which organisms such as toads (Rana bufo) or "talapang," earthworms (Lumbricus terrestris) or "bulletin," and mudskippers (Periophthalmus barbarous) were found. Beach wolf spiders (Arctosa littoralis) or "lawa", Lepidoptera such as Black-veined white butterflies (Aporia crataegi) or "kulibangbang", and Leaf Cutter ants (Atta cephalotes) or "antik" were also included.

The coastal grounds provided habitats for intertidal plants such as mangroves (Avicennia marina) or "bakawan" and Pandanus trees (Pandanus tectorius). These plants were highlighted for their ecological and community relevance, such as protecting against storm surges and resources for crafts. The integration of these biotic factors into the VR tours allowed students to visualize and explore local ecosystems dynamically. By presenting familiar species and their interactions, the tours made abstract ecological concepts understandable, fostering more profound learning and engagement.

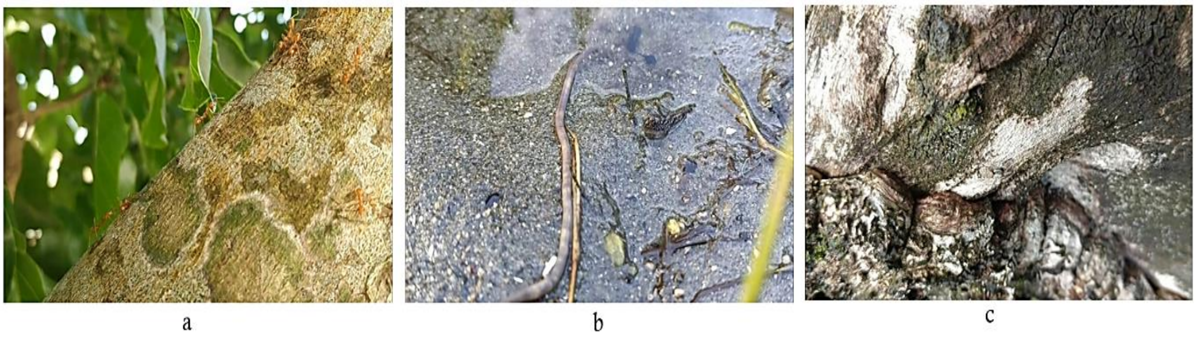


Figure 2. Sample screenshots from the actual video using the device showing different biotic factors present in the locality, such as (a) colony of ants in the mangrove branch, (b) earthworm and mudskipper in the same waterscape, and (c) the camouflage of the beach wolf spider in the tree log.

(b)Abiotic Factors. Abiotic factors, the non-living components of an environment, significantly influence organisms and ecosystems. Examples include light, temperature, and nutrient availability. In the study, weather and temperature were pivotal in shaping grazing patterns and affecting organisms in ponds. High temperatures led to critical changes, particularly for tadpoles in shrinking water bodies. The soil and water salinity were ideal for intertidal plants like mangroves and Pandanus, enabling them to thrive in saline environments far beyond typical plant tolerance. However, pollution was identified as a critical abiotic factor, with waste mismanagement severely impacting ecosystems. For instance, a study on the "Marine Outfall Impact in Balud del Sur" detailed the effects of sewage, fertilizers, and agricultural runoff on marine organisms and habitats, including coral bleaching and seagrass destruction.

Integrating these abiotic factors into the VR tours served several educational purposes. Students could observe the direct impact of non-living elements on ecosystems, such as the role of salinity in plant distribution or the consequences of pollution on marine life. By embedding these real-world challenges into immersive experiences, the tours contextualized ecological principles, enhancing students' ability to connect theoretical knowledge with practical environmental issues. This approach emphasized the urgency of sustainable practices and fostered critical thinking about ecological balance.

a b c

Figure 3. Snaps from the VR Tour presenting abiotic factors and their effect on the biotic components: (a) direct hit of sunlight above the grazing field of livestock animals, (b) Pandanus tree in the shore thriving in the salinity of water, and (c) the massive amount of garbage scattered in the cost of Kalayukay.

Furthermore, these contextualized features of the VR tours—including local species, ecological relationships, and environmental challenges—were pivotal in developing the instructional tool, aligning with the principles of contextualized content in education [44]. According to [45], contextualized content enhances learning through three key principles: activating prior knowledge, promoting conceptual change, and fostering metacognition. For the first principle, prior knowledge, incorporating contextualized content in VR tours activated learners' prior experiences, enabling them to connect new concepts to their existing understanding. One of the students shared an experience while using the VR tours; "With this (referring to the VR Tour), I can easily remember the lesson, and it helps me retain information because I am familiar with those plants and animals included in the virtual reality tours." This underscores how the use of culturally relevant and location-specific examples in the VR tours made the lessons more relatable and improved problem-solving abilities.

Regarding the second principle, promoting conceptual change, contextualizing content through interactive and engaging learning tools, like VR tours, motivates students by highlighting the relevance of ecological topics. For example, the inclusion of how the massive amount of garbage caused by improper waste management may affect the organisms in the cost of Kalayukay-one of the local coasts in the area, used in the VR tour development may effectively enhance students' grasp of biotic-abiotic interactions, ecosystem dynamics, and conservation principles through an immersive experience. Lastly, for the third principle, fostering metacognition, the contextualized content encouraged students to reflect on their learning experiences. By bridging familiar, concrete examples with abstract environmental science concepts, students developed a deeper personal connection to the subject matter [46], which may help them become more environmentally aware and responsible. Thus, the contextualized features of the VR tours not only enriched the educational experience but also validated the efficacy of this instructional tool in promoting environmental education through authentic, location-specific learning contexts.

3.2. Experts Evaluation of the developed Virtual Reality Tours for Garde 7-Biology

The Virtual Reality Tours for Ecology, classified under Non-Print Material, was validated by nine (9) Science and Information Technology teachers from different high school institutions in Sorsogon, Philippines, using the DepEd LRMDS guidelines along with content quality, instructional quality, technical quality, and accuracy. A jury of experts evaluated the VRT to ensure consistency and reliability, and the researcher used frequency distribution and weighted mean scores to analyze and interpret the results. Likewise, validation does not provide a straightforward yes/no answer regarding reliability, and such can be done using parameters, which also offers a critical assessment of any remaining gaps [47]. Table 1 summarizes the experts' evaluation of the VRT.

Table 1. Experts' summary of points of VR Tours evaluation

Criteria	Experts' Mean Scores

	Points to Pass (DepEd, 2009)	VRT1	VRT2	VRT3
Content Quality	At least 30 of 40	38.89	37.70	36.25
Instructional Quality	At least 30 of 40	36.11	38.17	37.20
Technical Quality	At least 39 of 52	50.11	51.25	49.98
Other Findings (Conceptual Errors, Grammar, etc.)	At least 16 of 16	16	16	16

As shown in the table, the VRTs received passing points for all criteria set by the DepEd based on expert ratings. This infers that the developed materials scored above the 75% mark of passing points needed for the resource to be accepted and used in teaching [48]. This indicates the effectiveness and suitability of the VRTs in addressing the essential learning requirements for Biology. The results also affirm that the depth, range, and scope of the information presented in the developed materials are aligned with the learning needs and demands of the target audience. Moreover, the materials are appropriately challenging, catering to the student's developmental stage and ensuring active engagement [49]. The alignment of the material to the learners' age and academic level underscores its potential to sustain interest and promote meaningful learning experiences.

Despite these strengths, expert feedback highlighted areas for improvement, such as incorporating higher-order thinking skills (HOTS) questions within the video to enhance critical thinking and adding prompts to stimulate environmental stewardship. These suggestions were used as bases for revising the content to create a more comprehensive and engaging instructional tool. By integrating HOTS questions, the VRTs now encourage students to think critically about ecological issues and apply their learning to real-world scenarios, thereby aligning with the goals of environmental science education.

In terms of instructional quality, the VRT design effectively addressed its instructional objectives, which are clearly defined, measurable, and anchored on the essential learning competencies for Biology [50]. This alignment ensures that students are aware of their learning targets and outcomes, supporting systematic and goal-driven learning processes. Additionally, the materials were found to be enjoyable, stimulating, and appropriately challenging, fostering student engagement while reinforcing learning outcomes.

For Technical Quality, the experts' verdict is that the developed materials are arranged systematically and support students' independent learning [51]. The use of clear visuals (images, diagrams, animations, and videos) and audio further enhances comprehension and facilitates focused attention, leading to improved memory retention [52]. However, based on expert suggestions, the viewing duration was revised to a more optimal range of 8 to 10 minutes to sustain students' interest and engagement. Technical refinements, such as enhancing video stability, were also implemented to minimize motion-induced visual strain, ensuring a smoother and more accessible learning experience.

The validators found no faults or inaccuracies regarding accuracy, which include conceptual, factual, grammatical, or typographical. Overall, the expert's verdict of the materials entails high validity. The developed Contextualized Virtual Reality Tour materials were deemed excellent as instructional materials and may help present, enrich, and reinforce scientific concepts, specifically in Ecology. Contextualization, as a principal leverage of the material, creates a space for relevant and localized learning – accustomed to environmental awareness.

Table 2. Presence of Contextualized Features

Feature	Mean Scores			
	VRT1	VRT2	VRT3	Overall
Contextualization	3.57 (VS)	3.58 (VS)	3.68 (VS)	3.61 (VS)

Legend: S– Satisfactory, VS – Very Satisfactory

The presence of contextualization entails that the elements and concepts presented in the materials are existent and applicable in the local setting and provide relevant learning to the students. Students are purposefully engaged in active learning through contextualized materials, which also help make sense of the content. Emphasizing teaching and learning of actual applications in a particular setting that interests the student combines foundational abilities with academic or occupational information.

Prospective Utilization in School. Virtual Reality is valued in education, although some are still cautious about using technology in the classroom due to issues with accessibility and cost. Due to its high price and restricted availability, virtual reality (VR) has historically received relatively little attention in the educational setting [18]. "Virtual Reality is not promising for public school… even if "someday" would not be achieved. Projectors and television sets cannot be fully provided in public classrooms [school]. Virtual Reality can only be foreseen attainable to private schools with limited students", a validator emphasized that utilization of VR was assumed to be "unattainable" in public schools.

Meanwhile, a contrasting comment, "It is more convenient than projectors and TV since each piece costs three digits, unlike the conventional equipment [projectors and television set] are purchased for thousands… VR viewing would be possible even if the students would use it, for example, 2-to-1 or 3-to-1 ratio [in a room with 30 students]", suggested that usage of VR would be more economical and achievable. This concept of inadequacy, in unparalleled ratio, indicated that such instructional tools could be classified under specialized materials (like laboratory equipment) of grouped usage – if they cannot be purchased for all students. However, with this asynchronous use of VR, a predictable classroom scenario was ascertained by a validator, "Since the students would not be using the material all at once, and considering that they [students] would be exaggeratedly excited to use it – because it is an out-of-the-common and new equipment, it would be expected that the students waiting would clamor ."In this term, asynchronous viewing meant strengthened classroom management.

3.3. Students' Level of Performance in the Pretest and Posttest

One of the objectives of instructional materials, including VRTs, is to help students in their learning, thus increasing the students' level of performance. In this study, the level of performance is determined based on the pretest and posttest results. A statistical comparison between before and after learning was done to pinpoint the effect of the integration of VRTs on the student's level of performance. Table 3 below shows the paired t-test results, mean, performance level, and adjectival description using the Mastery Level Descriptive Equivalent (MLDE).

Table 3. Paired t-test results for pretest and post-test of students

Learning Competencies	No. of Items	No. of Points	Pre-Test Weighted Mean	Pre-Test PL (%)	Pre-Test Interpretation	Post-Test Weighted Mean	Post-Test PL (%)	Post-Test Interpretation	Effect Size
LC1-Differentiate biotic from abiotic components of Ecosystem (S7LT-IIh-9)	15	45	17.50	38.88	LM	35.53	78.51	M	2.47
LC2- Describe the different ecological relationships found in the Ecosystem (S7LT-IIh-10)	15	45	15.57	34.60	LM	33.90	75.30	M	1.82
LC3-Predict the effects of Changes in abiotic factors on the Ecosystem (S7LT-IIj-12)	20	60	20.80	34.66	LM	48.20	80.30	M	2.26
Overall Mean	50	150	53.87	36.04	LM	117.63	78.03	M	1.63
SD				8.37			5.87		
p-value					0.00				

Note: ***Significant at 0.05 level
Legend: PL- Performance level, LM-Low Mastery, M- Mastery

For the pretest results, as shown in the table, the overall mean for the pretest is 53.87, with a corresponding performance level of 36.04%, indicating a low mastery level of the topic. Meanwhile, the overall posttest registered a value of 117.63, with a corresponding performance level of 78.03%, signifying a mastery level of the topic. This shows that students' mastery levels had changed from low to mastery.

For the paired t-test result, as shown in the table, there is a significant difference between the pretest and posttest post-test results since the computed p-value is lower than the level of importance. Focusing on the value of the standard deviation of the posttest (SD= 5.87), which is lower than the pretest, also implies that the scores of the students in the posttest conform with the t-test result that there is a significant difference in the scores. This indicates that the student mastered all the learning competencies, which can be attributed to integrating Virtual Reality Tour Ecosystem Videos into the lessons. Likewise, a recent survey of teachers and students shows that 90% of educators believe VR may help increase student performance levels [53], from which VR has been regarded as a pedagogical method with the potential to increase student learning. These data suggest that the VR Tours integrated into each lesson may enable them to understand the Ecosystem concepts better. These claims were further supported by presenting the pretest and posttest mean gain, normalized gain, and the standard deviation shown in Table 4 below.

Table 4. Mean and Normalized Gain of Student-Respondent's Pretest and Posttest

Learning Competencies	Student Respondents (N=30)

	Pre-Test Weighted Mean Score	SD	Post-Test Weighted Mean Score	SD	Mean Gain	Norm Gain	Interpretation	Effect Size	Interpretation
LC1-Differentiate biotic from abiotic components of Ecosystem (S7LT-IIh-9)	17.50	6.29	35.53	4.11	18.03	0.66	M	2.47	L
LC2- Describe the different ecological relationships found in the Ecosystem (S7LT-IIh-10)	15.57	8.55	33.90	6.20	18.33	0.62	M	1.82	L
LC3-Predict the effects of Changes in abiotic factors on the Ecosystem (S7LT-IIj-12)	20.80	10.28	48.20	7.31	27.40	0.69	M	2.26	L
Overall	53.87	8.37	117.63	5.87	63.76	0.66	M	2.18	L

Note: SD-Standard deviation
Legend:L- Large, M- Medium

As presented in the table, the posttest results differed significantly by obtaining an overall mean of 117.63, surpassing the pretest result with an overall mean of 53.87. This implies that the integration of the VRTs in the lesson may have a positive effect on the students' performance. This result parallels the previous studies where virtual reality tours are used in the education arena, increasing the students' involvement and interest as directly linked to high-performance levels [17]. In addition, the post-test's standard deviation showed more consistency in the scores than in the pretest. Moreover, to support the t-test result and measure how significant the difference was, the study computed Cohen's d. The same table revealed that the critical difference between the pretest and post-test results was huge (d=2.18), showing that the effect size of the integration of VRTs in the lesson is notable for student knowledge gain.

3.4. Students' Acceptability of the Virtual Reality Tour

As targeted users of the instructional material, learners serve as primary indicators of feasibility and acceptability. Before participating in the intervention, participants' opinions of the intervention's acceptability—which is referred to as treatment acceptability—can be influenced by several factors. Considered markers of treatment acceptance include participants' attitudes toward the intervention, appropriateness, suitability, convenience, and perceived effectiveness [54]. The table below presents the data from the Student Evaluation Checklist.

Table 5. Summary of student acceptability of developed contextualized virtual reality tour

Criteria	Mean Score for Acceptability			Overall
	VRT1	VRT2	VRT3	
Clarity	3.91 (VA)	3.81 (VA)	3.90 (VA)	3.87 (VA)
Usefulness	3.90 (VA)	3.87 (VA)	3.89 (VA)	3.88 (VA)
Adequacy	3.84 (VA)	3.84 (VA)	3.87 (VA)	3.85 (VA)
Timeliness	3.87 (VA)	3.88 (VA)	3.90 (VA)	3.88 (VA)
Visuals and Illustrations	3.84 (VA)	3.86 (VA)	3.87 (VA)	3.85 (VA)
Presentations	3.92 (VA)	3.93 (VA)	3.96 (VA)	3.90 (VA)
Overall	3.88 (VA)	3.87 (VA)	3.87 (VA)	3.88 (VA)

Legend: VA- Very Much Acceptable

The table implies that the developed instructional tools tallied the highest mark of acceptability rate. Along with Clarity, the VR Tour materials contained information that the learners deemed clear, simple, easy to understand, logically arranged, and suited for the level of comprehension. The material also provided a platform for developing and enhancing science concepts, which sought to relate new ideas from the previous discussion. Moreover, the tool was considered adequate information on the topic, reinforcing the targeted learning objectives.

Since the materials were geared towards contextualization, the outcome revealed that the material could mediate applications of what had been tackled in the classroom and extend these leanings outside the campus.

In terms of Clarity, while the students agreed that the VR Tours are generally clear, the use of English as the primary medium for discussion in the Science subject delimits the use of the native tongue or the local language. One of the students commented, "*Our attention focused more on the video and less on narration; it (VR Tours) could have been better if there was a Tagalog version or local Bicol (local language use in the area)*." the learners asserted that the narration was deleveraged using English as the medium for the whole VR tour. This affirmed the conventional culture of code-switching in the local classrooms – to which the participants were accustomed. Addressing students in their native language creates a sense of comfort and ease and facilitates the development of bonds. The students fully understand any given learning task's instructions, and switching back to the native tongue is the most effective approach [55]. Given this language dilemma, the student participants strongly advocated for developing the material presented in the local language, Filipino. This perspective was supported by one of the validators who recommended "*Tagalog or Bikol for a full blast of contextualization*." Differentiated instructions, particularly in the medium of instruction, are essential to ensuring inclusivity and student engagement [56] [57]. These remarks, both from the students and expert evaluators, become the basis for the researchers to improve the development of the VR Tour further. Bridging the concepts from raw knowledge to instructions tailored to the student's learning preferences, such as providing separate language versions. This highlights not only contextualization but also the novelty of the VR Tours, offering diverse learning preferences and promoting equity in learning access. Such innovation also aligns with the goals of localized and contextualized learning under the K-12 curriculum.

Furthermore, the need for contextualization underscores the broader issue of the lack of VR-specific pedagogy [58], as current practices often rely on general teaching strategies rather than frameworks designed for immersive learning technologies. Contextualization provides a pathway to bridge this gap by grounding VR materials in learners' cultural and linguistic realities, thereby enhancing relevance and effectiveness. By addressing the unique challenges of diverse classrooms, such as language preferences and learning styles, contextualized VR content, such as the present study, could contribute to the development of a pedagogy that is both inclusive and technology responsive. These findings emphasize the potential of VR-based tools to redefine instructional practices by offering culturally tailored experiences that resonate deeply with learners' contexts.

On the other hand, for Usefulness, the weighted mean score signifies a solid agreement among users regarding its practical benefits. Students can grasp its functions through observation of the VR application's environment, layout, and formatting. One of the students emphasizes that the VR Tour provides a highly interactive and immersive experience, allowing him to explore concepts at his own pace while enjoying the visuals and engagement. Similarly, another user affirmed, “The VR Tour brings learning closer to real-life scenarios, reducing barriers such as cost and logistics for physical field trips while maintaining the richness of exploration and learning. “The VR Tour was developed with user-friendliness as a priority. By addressing digital inequality, VR Tours help bridge the gap between learners with differing access to resources. This aligns with [59], who noted that digital inequality has become a significant issue nowadays in education. The VR Tour seeks to counter this by providing a flexible, inclusive educational tool that reduces the need for high-end equipment and internet connectivity. Education is a crucial investment, as stated in human capital theory, and disparities in educational outcomes are often tied to family resources [60]. VR tours mitigate these disparities by enabling students to explore educational content in a simulated yet realistic manner, making learning experiences more equitable, fostering engagement, and deepening conceptual understanding.

Likewise, the table indicates that the materials helped increase the learners' knowledge, understanding, and proficiency. The contents had adequate information – which also bridged the new concepts from the previous. In terms of adequacy, the materials contained a variety of situation strategies, which was reflected in the presentation of the contextualized impacts of abiotic factors. It also explained concepts and principles. The outcome also entails that the materials may be used as innovative tools for learning. As for Visuals and Illustrations, the VRTs may motivate students’ interest, making learning effective and enjoyable. Furthermore, the logical sequencing of topics ensured that learners could easily follow and internalize the lessons.

In addition, the visual dimensions of the VR Tour were recognized to entice interest and practical and fun learning. "The lesson would be more interesting if the concepts were introduced or discussed through this [virtual reality] instead of the typical projector," one of the learners affirmed. This observation is parallel to the study of [61], who argue that visually engaging instructional materials reduce cognitive load and enhance information retention. Similarly, studies indicate that heightened interest in learning positively influences motivation and retention for both educators and students [62]. However, the students commented, "We cannot ask questions regarding the topic in the middle of the video, unlike the oral way of discussion.". While this commentary underscores the challenge of integrating VR-based learning environments in the classroom, the researchers take this as an opportunity to enhance the VR Tours further. One of these is embedding interactive pause points in the VR Tours, where questions or prompts can be embedded in specific parts of the VR Tours. The VR tour pauses and then gives students time to think and respond to the questions before resuming. This enhancement in the VR

Tour may not only significantly improve the instructiveness of the tool but may also enhance students' engagement and improve conceptual understanding. Likewise, these may also reflect the broader pedagogical implications of VR, setting a precedent for integrating interactivity and contextual relevance to elevate its educational value. Research by [63] highlights how interactivity and authenticity in VR learning experiences lead to deeper cognitive and emotional connections with the content. Similarly, pause-and-reflect techniques integrated into immersive environments have been found to improve both retention and critical thinking. [64] emphasize that such strategies can encourage learners to process and apply information more effectively, leveraging the unique affordances of VR.

In addition, VR is intended to be utilized for only a short period. VR should be built as a short activity to integrate into your program when used for training. A study published in Applied Ergonomics recommends a 20-minute VR activity to avoid disorientation and simulator sickness. This was supported by a study published in the journal PLOS One, which discovered that a 20-minute VR experience has less risk of simulator nausea. In line with the narrative, Oculus, a global company manufacturing virtual reality headsets for gaming and development kits, suggested 10 to 15-minute intervals every 30 minutes of usage [65]. The virtual reality tours developed in this study were ensured in a safe duration zone within these standard recommendations. These underline the importance of designing VR-based educational tools with thoughtful interactivity, student safety, and reflective opportunities. These tools can transform traditional learning into a more dynamic, safe space, and impactful experience.

The goal of Virtual Reality, which is to bring the external world into the classroom, was evident in the experiences of the participants. One respondent noted, "There is no need for us to go too far and remote places to explore; through virtual reality, we do not have to spend much money for traveling." This observation highlights the potential of VR to minimize costs, reduce logistical efforts, and mitigate risks associated with field trips. By offering immersive learning experiences within the safety of the classroom, the VR Tour demonstrates its alignment with modern educational strategies aimed at accessibility and practicality.

4. CONCLUSION

This study aimed to develop and validate Contextualized Virtual Reality Tours (VRTs) as instructional materials for teaching Ecology, particularly on the topics of ecology. The VRTs were successfully aligned with the identified learning competencies in Biology and were validated by experts in content, instructional quality, and technical aspects. The materials demonstrated high acceptability among students and effectively enhanced their conceptual understanding, as evidenced by significant improvements in their post-test scores. The findings underscore the potential of contextualized VR-based instructional tools to address gaps in science education, particularly in fostering conceptual understanding of complex ecological concepts. By incorporating elements specific to the local environment, these tools not only support cognitive engagement but also promote environmental awareness and relevance to students' lived experiences.

Furthermore, the integration of Virtual Reality in education offers a transformative approach to delivering science concepts, especially in contexts where traditional fieldwork is constrained. Beyond conceptual understanding, VR tools can enhance student interest, engagement, and motivation, which are crucial factors in the learning process. This study highlights the importance of contextualizing educational materials to ensure cultural and environmental relevance. Moreover, this study supports the DepEd's initiative to integrate technology in making interactive instructional materials in teaching to make learning more accessible, meaningful, and engaging to students. Educational policymakers can use the findings of this study to propose the integration of VR Tours not just in the blended learning setup but also in ordinary classroom instruction. Future development efforts should consider expanding the contextualization of VRTs to include localized language options, such as Bikol and Tagalog, to cater to diverse learners and enhance accessibility. Additionally, the economic feasibility and scalability of implementing VR technologies in public schools require further investigation. This study serves as a foundation for exploring VR's application across other science disciplines and educational contexts, emphasizing its role in promoting innovative, inclusive, and immersive learning experiences. By leveraging technology and a self-directed approach, students can be more prepared to meet the demands of 21st-century learning.

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