EXPLORING THE APPLICATION OF ADVANCEMENTS OF INSTRUCTIONAL TECHNOLOGY IN GEOSCIENCE EDUCATION IN NIGERIA

ABSTRACT

Geoscience Education is the formal academic study of the Earth's physical features, systems, processes, and its history influenced by both natural and human-caused events. In Nigeria, geoscience education has evolved from its mid-twentieth-century purpose of developing professionals for the oil and gas sector to addressing contemporary environmental challenges and diversifying into sub-disciplines such as Medical Geology.This evolution necessitates the integration of instructional technology to enhance teaching and learning experiences. This paper focuses on the application of instructional technology, particularly virtual field trips (VFTs), as a complementary tool in geoscience education. It highlights the challenges faced by Nigerian universities, including students' limited exposure to geology and the abstract perception of geosciences. VFTs are an instructional technology that gained prominence globally during the COVID-19 pandemic. The paper outlines how VFTs can be adapted for teaching in Nigerian universities, especially in areas where physical fieldwork is not feasible. It underscores the need for this transition from traditional methods to virtual implementations to improve educational outcomes. Recommendations for maximizing virtual experiential learning through intergovernmental partnerships and international collaborations are presented to improve educational outcomes for all stakeholders involved.

Keywords: Geosciences, Geoscience Education, Virtual Field Trip, Virtual Experiential Learning

1. INTRODUCTION

1.1 Geoscience Education

Geoscience education, also referred to as, Earth Science education, is a branch of science education that refers to a formalized academic study of the Earth's physical features, systems, processes, and both natural events and anthropological activities that have shaped the planet throughout its history. It is composed of a diverse range of disciplines, including geophysics, geochemistry, environmental science, and climatology among several others. Geoscience education is a key factor in the academic, scientific, and professional progress of any modern society (Martinez-Frias &Mogessie, 2012) Geoscience education is central to developing future generations of geoscientists and policymakers. Consequently, it plays a critical role in advancing scientific literacy as well as answering questions and perspectives that lie at the heart of environmental awareness, resource utilisation, sustainable development, and economic development, especially in the wake of the global energy transition.

1.2 Instructional Technology in Geoscience Education

Instructional technology refers to the systematic design, development, and evaluation of instructional materials and experiences that enhance learning. In the context of geoscience education, it encompasses both the application of scientific knowledge for practical purposes and the machinery and equipment developed from such knowledge. The integration of instructional technology in geoscience education can significantly improve student engagement and understanding, particularly in a country like Nigeria, where traditional teaching methods may fall short. In geoscience education, it includes tools like virtual field trips, which provide interactive and immersive learning experiences, bridging the gap between theoretical knowledge and practical application (Duggan-Haas & Kessel, 2016).

1.3 Geoscience Education and its History in Nigeria

Geoscience education involves the study of geological and related natural phenomena, including the Earth's structure, minerals, rocks, soils, water, and environment. In Nigeria's rural coastal areas, geoscience education is crucial, particularly in the Niger Delta region, which accounts for a significant proportion of the country's oil production (Olugbenga & Caleb, 2019). Geoscience education exposes the student to the peculiar distribution of resources, oil, and gas in the Niger Delta in this instance, and equips them with the necessary skills to solve the pressing problems associated with this distribution.

The history of geoscience education in Nigeria dates back to the mid-20th century. Geoscience education gained momentum in the mid-twentieth century as a result of the oil boom in Nigeria. The Nigerian government established several public universities and schools of geoscience, such as the University of Ibadan, the University of Nigeria, and the Nigerian Institute of Mining and Geosciences, to train geoscientists, geologists, geophysicists, and other professionals in related fields (Saliman &Oghorada, 2019; Chijioke et al., 2023). The timeline stretches from this throughout the late twentieth century when it was necessary to have this discipline address environmental sustainability challenges. To further strengthen geoscience education in Nigeria, it is crucial to introduce the subject at the school and college levels. Currently, the level of geoscience content in the formal educational curricula of Basic and Senior High schools as well as colleges of education in Nigeria is very low. Introducing geoscience as a subject in the Senior High School curriculum and improving the geoscience content in the Basic School curriculum can help build a strong foundation for students interested in pursuing geoscience-related fields. Additionally, encouraging more universities to offer degree programs in geoscience and introducing geoscience degree programs in colleges of education can help train the next generation of geoscientists and educators.

Geoscience education became crucial in addressing environmental challenges, such as degradation, pollution, and loss of biodiversity, which arose due to oil exploration and exploitation activities in the region. Additionally, geoscience education was necessary to improve the living conditions and livelihoods of the rural communities in the region by providing sustainable solutions to environmental issues (Ahmadu & Akpan, 2015).

Along with traditional methods of geoscience education, innovative approaches such as community-based research and experiential learning have been adopted to provide geoscience education in the rural coastal areas of the Niger Delta. These methods have increased the involvement of local communities in the process of environmental recovery and management, as well as the development of sustainable oil and gas exploitation practices (Chijioke et al., 2023) Community-based research and experiential learning are two methods employed for practical applications beyond the geosciences classrooms, community-based research being collaborative research between stakeholders (academic-academic or industry-academic) and experiential learning being undergraduate/graduate internships and outdoor field courses students and academics participate in a school semester.

Geoscience is fundamentally a field science, with the natural environment serving as its laboratory where observations can be made directly. The field component is an integral element of geology curricula, allowing students to apply theoretical knowledge in real-world settings.

In recent years, the availability of advanced computer software has further transformed geoscience education. Tools such as Geographic Information Systems (GIS), remote sensing software, and modeling applications enable students to analyze geological data, visualize complex processes, and simulate various environmental scenarios. These technologies enhance learning by providing interactive and immersive experiences that complement traditional fieldwork.

Incorporating these software tools into the curriculum not only prepares students for modern geoscience careers but also equips them with essential skills for addressing pressing environmental challenges. As such, while field experiences remain crucial, integrating technology into geoscience education is vital for developing a comprehensive understanding of the discipline.

1.4 Community-based Research (CBR)

Community-based research (CBR), referred to in some literature as *community-based participatory research* (CBPR), is an equitable approach to research in which researchers, organisations, and community members collaborate on all aspects of a research project (*Community-Based Participatory Research*, n.d.) CBR is a collaborative enterprise between academic researchers (professors and students) and community members. CBR's purpose is to create or discover knowledge that meets a community-identified need, but the role of community members goes beyond simply identifying the research topics or questions. Indeed, the ideal CBR project is fully collaborative—that is, where community people work with professors and/or students at every stage of the research process: identifying the problem, constructing the research question(s), developing research instruments, collecting and analysing data, interpreting results, producing the final report, issuing recommendations, and implementing initiatives (Strand et al., 2003)

1.5 Experiential Learning (EL)

Experiential Learning (EL), developed by Kolb in 1984, is a paradigm for resolving the contradiction between how information is gathered and how it is used. It is focused on learning through experience and evaluating learners in line with their previous experiences (Sternberg & Zhang, 2014). Experiential learning constitutes a learning progression that brings about higher-level learning, a stage of learning beyond memorisation that teaches the formation and the connection of concepts, visualisation, problem solving, questioning, idea generation, analytical (critical) thinking, practical thinking/application, and synthesising.

In the Nigerian geosciences education pathway, experiential learning includes mandatory internships ranging from 3 to 6 months. These internships, known as the Students Industrial Work Experience Scheme, were established by the Federal Government to promote practical experience within academic disciplines. Students do not only learn the practical applications of their field of study, but they also equally discover how broad the geosciences industries, extending from oil and gas down to engineering and construction.

Experiential learning in Nigerian Geosciences Education pathway also exists as field courses—in some instances, *field mapping*—mandatory academic courses with class credit taken by students to gain a direct exposure to the outdoors and Earth's topography, applying the concepts learned in the classroom. Teams of students and lecturers travel to select parts of the country to study the geology and rock type distribution present in the region, and apply the first principles spanning igneous, metamorphic, and sedimentary petrology and structural geology taught in the lecture hall. Depending on the structure of the field course, students may engage in an independent field mapping exercise; students engage in the outdoor geological study with minimal to zero lecturers' supervision, analyse findings and draw geological maps that accurately represents the rock type distribution in the region.

2. STATE OF THE ART IN GEOSCIENCE EDUCATION IN NIGERIA

2.1 Overview of Current Practices

Geoscience education in Nigeria has traditionally focused on oil and gas exploration but is now expanding to address broader environmental issues. Despite advancements, challenges remain, such as limited practical exposure and the abstract nature of geosciences.

2.2 Integration of Technology

Recent technological advancements, including Geographic Information Systems (GIS) and remote sensing, have transformed geoscience education. These tools enhance student engagement and understanding by providing interactive and immersive experiences.

2.3 Transition to Virtual Field Trips

The integration of Virtual Field Trips (VFTs) represents a significant shift from traditional fieldwork to digital learning experiences. VFTs provide simulated field experiences that are particularly valuable in regions where physical field trips are impractical. By offering virtual tours of geological sites and interactive learning modules, VFTs can enhance students' understanding of geological concepts and processes.

2.4 Nigerian University System

Nigerian universities operate under a system characterized by a mix of public and private institutions. Public universities are funded by the government and follow a national curriculum framework, while private universities are independently managed. The Nigerian university system emphasizes both undergraduate and postgraduate education, with a growing focus on research and international collaboration. The challenge for geoscience education lies in ensuring that all institutions, regardless of their funding status, can access and implement advanced instructional technologies effectively.

3. VIRTUAL EXPERIENTIAL LEARNING: VIRTUAL FIELD TRIPS

Virtual experiential learning refers to online learning options that allow students to engage with geological concepts in a virtual environment. One prominent platform for this type of learning is Virtual Field Trips (VFTs). As shown in fig. 1 below, virtual field trip is a guided exploration through the World Wide Web that organises a collection of pre-screened, thematically based web pages into a structured online learning experience (Foley, 2003). It can be defined as a digital resource that allows a user to visualise and interrogate a remote location using imagery and other materials as appropriate (e.g., data, maps, journal articles) (Hurst, 1998; Woerner, 1999; Stainfield& Fisher, 2000; Klemm & Tuthill, 2003).

Virtual Field Trips (VFTs) offer a unique and versatile approach for studying geological structures, providing an effective means for students to engage with complex geoscientific concepts without leaving the classroom. Here's how VFTs can be used to represent and explore geological structures (fig.1.1):

3.1 Representation of Geological Structures in VFTs

1. Photographs and Imagery:

- High-Resolution Photographs: VFTs often incorporate high-resolution photographs of geological formations, which allow users to closely examine rock layers, fault lines, and other geological features. These images can be annotated with labels and explanations to highlight key aspects.

- Satellite Imagery: For a broader perspective, satellite images can be used to showcase large-scale geological features such as mountain ranges, volcanic fields, and sedimentary basins.

2. 3D Models and Visualizations:

- Interactive 3D Models: These models can represent geological structures like rock formations, fault lines, and lava flows. Users can rotate, zoom, and interact with these models to better understand the spatial relationships and scale of the structures.

- Virtual Reality (VR) and Augmented Reality (AR): More advanced VFTs might use VR and AR to create immersive experiences where users can explore geological structures as if they were physically present. For example, VR could allow users to walk through a virtual cave or climb a virtual mountain.

3. Geological Maps and Diagrams:

- Geological Maps: These maps provide a visual representation of the distribution, nature, and age of rock formations across a region. VFTs can include interactive maps where users can click on different areas to learn more about specific geological features.

- Cross-Section Diagrams: These diagrams show a side view of geological structures, illustrating how different layers of rock are arranged and how they have been deformed by geological processes.

4. .Data Integration:

- Geospatial Data: VFTs can integrate geospatial data such as GPS coordinates and elevation data to provide a more comprehensive understanding of geological features.

- Geological Data: Data sets such as mineral composition, rock age, and structural measurements can be embedded into the VFT to provide detailed information about the geological structures being studied.

5. Simulations and Animations:

- Geological Processes: Simulations can demonstrate processes such as erosion, sediment deposition, and volcanic eruptions. These animations can show how geological structures are formed and altered over time.

- Tectonic Plate Movements: Animations can illustrate how tectonic plates interact to form mountain ranges, earthquakes, and other geological features.

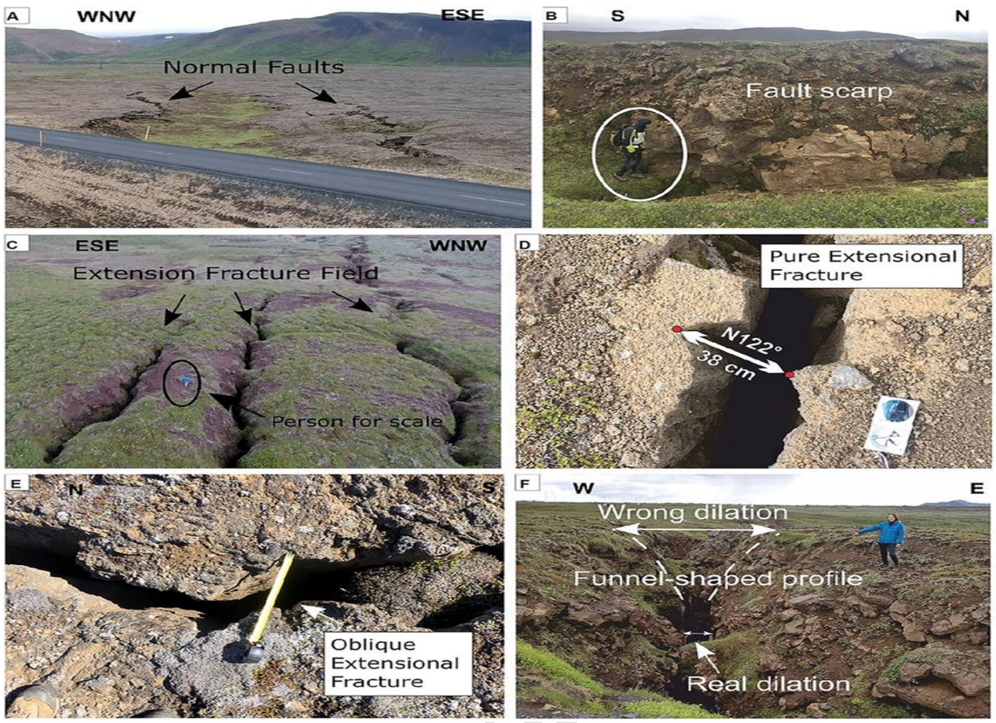

Fig. 1. Diagram showing representation of geologic structures using VTFs

Virtual field trips provide an alternative strategy for engaging students in the study of the real world (Klemm & Tuthill, 2003). Virtual field trips can either be immersive or non-immersive.

3.2 Types of VFTs

There are two types of Virtual Field Trips (VFTs): immersive and non-immersive.

Immersive virtual field trips simulate a near-presence in a field and provide participants or users with varying degrees of agency, such as on where to go and what to look at. This is due to a virtual reality property granting 360° imagery; it allows one to look around one's environment, which is different from still photography. 360° imagery provides greater potential for creating educational activities based on independent exploration and investigation in the (virtual) field. An example is Google Street View because of its 360° imagery property. A local example in Nigeria is the 2023 Virtual Field Trip (Fig. 2), the continuing education program arm of the Nigerian Association of Petroleum Explorationists (NAPE), which provides both student and lecturer participants with exposure to the distribution of unconventional hydrocarbons and Cretaceous reservoirs present in southern

Nigeria. Just like the actual field outcrops observed during an in-person field trip, virtual outcrops are examined and analyzed in virtual field trips.

While virtual field trips are indeed valuable for experienced geologists, they also offer significant benefits for fresh geological students. For newcomers, these virtual experiences can provide foundational exposure and learning opportunities, helping them grasp key geological concepts and features before participating in hands-on fieldwork. Thus, virtual field trips serve as a practical tool for both seasoned professionals and those new to the field.

A virtual outcrop (VO), sometimes called a digital outcrop model or virtual outcrop model, is a photorealistic model of a geological outcrop (Xu et al., 2000; Pugsley et al., 2022). It is a digital representation of geological features that allows users to explore and analyze rock formations and structures remotely. This tool mimics the experience of observing physical outcrops but in a virtual environment. Virtual outcrops are used extensively in virtual field trips to offer detailed views of geological formations, complete with interactive elements like annotations, data layers, and 3D models.

1. Discussing virtual outcrops further, they serve several educational and research purposes:

Enhanced Learning Experience: Virtual outcrops provide students with a detailed view of geological features that might be difficult to access physically. They can interact with different rock layers, observe structural details, and examine features from multiple angles.

2. Accessibility and Convenience: Unlike physical outcrops, virtual outcrops can be accessed from anywhere, making them an invaluable resource for students and researchers who may not have the opportunity to travel to field sites.

3. Integration with Educational Tools: Virtual outcrops often include educational tools such as clickable labels, explanatory text, and links to related resources, helping users to better understand the geological context and significance of what they are observing.

4. Pre-Fieldwork Preparation: For students new to geology, virtual outcrops can serve as an introduction to the concepts and structures they will encounter during in-person field trips, providing a foundational understanding that enhances their practical fieldwork experience.

5. Research and Analysis: Researchers can use virtual outcrops to conduct detailed analyses of geological features, compare different outcrops, and study areas that are otherwise difficult to reach.

Virtual outcrops play a crucial role in modern geological education and research by offering an accessible, interactive, and detailed view of geological formations, benefiting both experienced geologists and newcomers to the field.

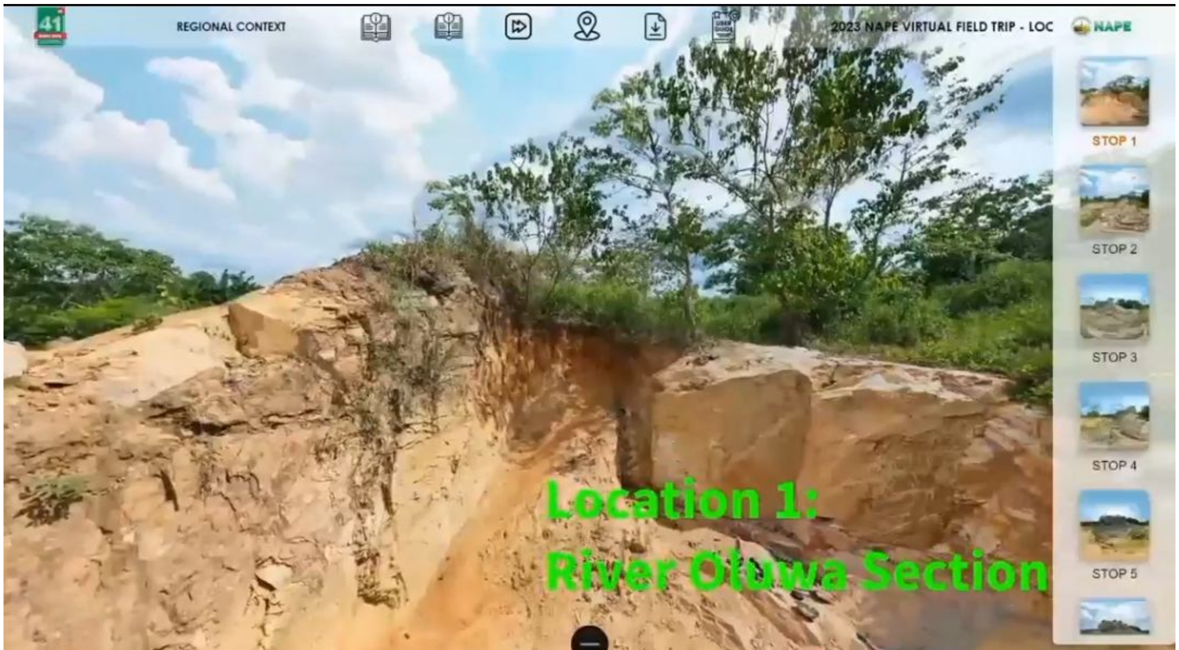

Fig. 2.The 2023 VFTs by NAPE (NAPE Nigeria, 2023)

Non-immersive virtual field trips, on the other hand, include collections of "location-specific" graphics (e.g., photos, videos, maps), which can be presented in various ways The difference between immersive and non-immersive VFTs lies in the presence and absence of virtual reality. The absence of virtual reality means less immersion and autonomy for the participant.

Non-immersive virtual field trips (VFTs) are digital educational experiences designed to simulate field excursions without the use of virtual reality (VR) or augmented reality (AR) technologies. Instead of providing an immersive, three-dimensional experience, these VFTs utilize a variety of multimedia resources to represent and explore specific locations or subjects. Here's a detailed look at what non-immersive virtual field trips entail:

Key Features of Non-Immersive Virtual Field Trips

1. Digital Media Utilization:

- Photographs: High-resolution images of locations, geological formations, or features are used to provide visual context.
- Videos: Short videos or clips may show dynamic aspects of a site, such as geological processes, fieldwork procedures, or relevant phenomena.
- Maps: Interactive or static maps offer spatial context and show the geographical distribution of features.

2. Web-Based Platforms:

- Educational Websites: Non-immersive VFTs are typically hosted on websites or educational platforms that can be accessed through standard web browsers.
- Structured Content: Information is often organized into modules or sections, guiding users through different aspects of the virtual field trip in a structured manner.

3. Interactive Elements:

- Clickable Features: Users can click on parts of images or maps to access additional information or related resources.
- Annotations: Explanatory text, labels, and markers on images or maps provide context and highlight important features.

Benefits of Non-Immersive Virtual Field Trips

1. Accessibility:

- Global Reach: They can be accessed by anyone with an internet connection, making them available to a wide audience, including those who cannot participate in physical field trips.
- Educational Equity: They provide learning opportunities for students who may face geographical or financial barriers to physical field trips.

2. Cost-Effectiveness:

- No Travel Costs: By removing the need for physical travel, non-immersive VFTs eliminate expenses related to transportation, accommodation, and field equipment.

3. Flexibility:

- On-Demand Learning: Users can explore the content at their own pace and revisit sections as needed, accommodating various learning styles and schedules.

4. Foundational Learning:

- Preparation for Fieldwork: They offer introductory insights into geological features or subjects, helping to build a foundational understanding before engaging in hands-on fieldwork.

Limitations of Non-Immersive Virtual Field Trips

1. Reduced Immersion:

- Limited Sensory Engagement: Without VR, users do not experience the full sensory engagement and spatial awareness that come with being physically present at a site.

2. Limited Interactivity:

- Static Content: Non-immersive VFTs provide a more passive experience with less interactive engagement compared to VR or AR-based trips.

3. Information Overload:

- Content Density: The volume of information presented can be overwhelming if not well-organized, potentially making it difficult for users to process and retain key concepts.

4. Engagement Challenges:

- Lower Engagement: The lack of interactive and immersive elements might result in lower levels of engagement and motivation for users.

Fig. 3 below provides an outline categorizing VFTs into location-based trips versus thematic trips and distinguishing between tutor-led and student-led delivery methods, including the blended approaches.

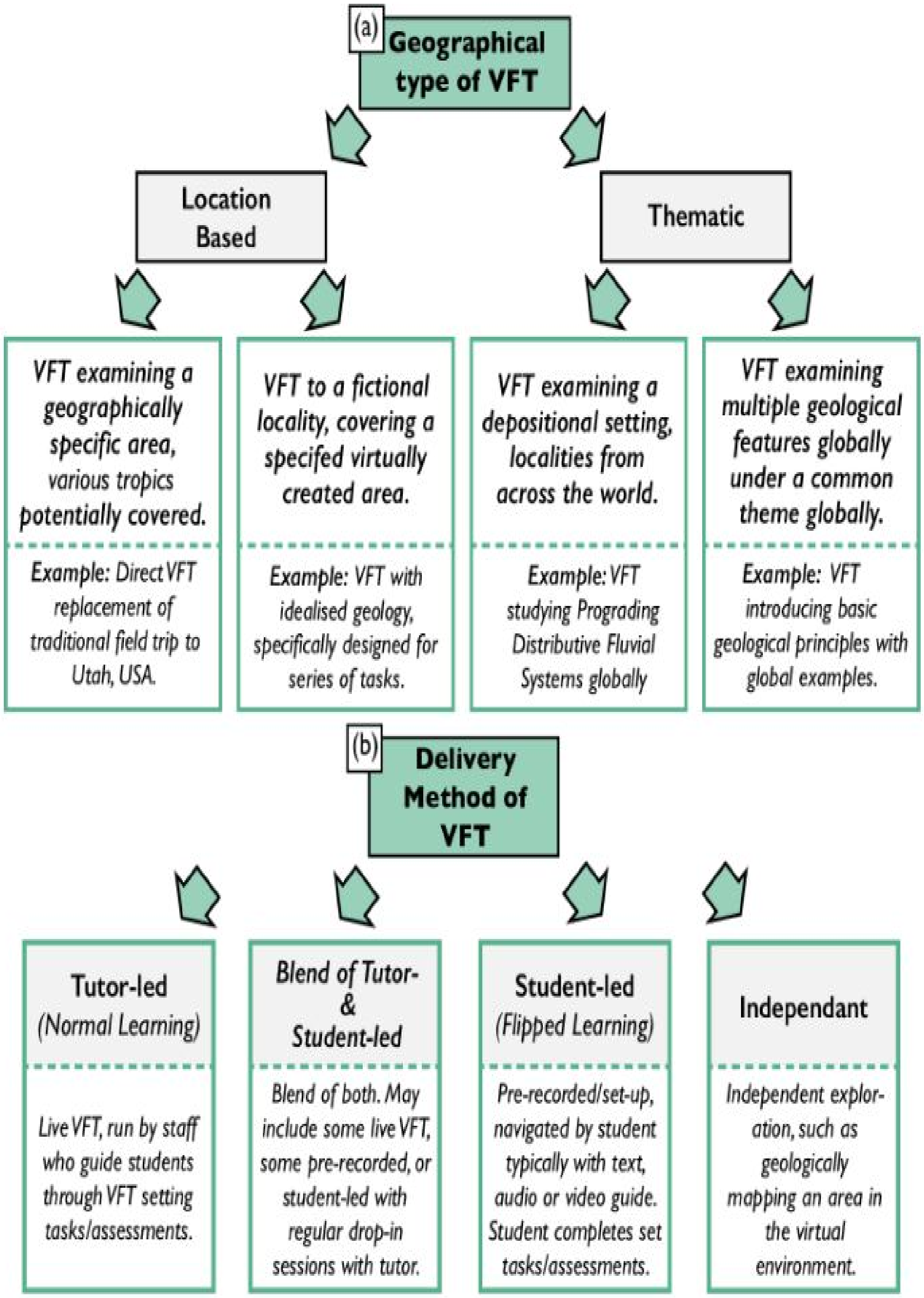

Fig. 3. Outline of types and delivery methods of VFTs. (a) Types of VFT separated between location-based trips to a specific locality and thematic trips spanning global localities with a

common theme. (b) Delivery method of VFT divided into tutor-led VFTs and student-led VFTs as well as the blended spectrum between. (Credits: Pugsley et al., 2022)

CONCLUSION AND RECOMMENDATIONS

Conclusively, Nigerian universities would greatly benefit from integrating virtual field trips into introductory geosciences courses. To achieve this, virtual field trips should be incorporated into undergraduate courses to provide early exposure to geological concepts and supplement practical exercises, while also being used in assessments to evaluate students' grasp of geoscience topics. For graduate-level studies, virtual field trips can facilitate advanced research and exploration of complex geological phenomena, with specialized modules supporting focused research areas. At the institutional level, universities should embed virtual field trips into the geosciences curriculum, invest in faculty training, and ensure the necessary technological infrastructure is in place. Additionally, virtual field trip content must meet educational standards for accuracy and inclusivity, ensuring accessibility for all students, including those with disabilities. By addressing these considerations across different levels and standards, Nigerian universities can enrich their geosciences programs, enhancing learning experiences and better preparing students for their future careers.

This paper recommends the following considerations to enhance the integration of virtual field trips into Nigerian universities' geosciences programs:

Intergovernmental/International Collaborations: Establish partnerships between technology firms to develop effective VFTs and leverage technological resources (Arukwe et al., 2022). These collaborations can facilitate the development and implementation of effective virtual field trips.

2. Curriculum Revision:Update the geosciences curriculum to Incorporate VFTs into the geosciences curriculum as a supplementary tool, alongside traditional field trips (Evelpidou et al., 2021). This revision aims to provide students with a comprehensive understanding of geosciences, integrating theoretical knowledge with practical digital tools. It is important to note that while virtual field courses offer valuable insights, they should not replace physical field trips. Whenever feasible, students should undertake actual field trips to observe geological outcrops and gain hands-on experience.

3. Establishment of Computational Labs:Set up geosciences computational labs within universities to support the hosting and execution of virtual field trips. These labs should be equipped with the necessary technology and software to enable effective virtual exploration and analysis.

Additional Considerations:

- Geoscience Curriculum Discussion:The revised geosciences curriculum should be included in discussions to provide a holistic conclusion on how virtual field trips and other updates will enhance educational outcomes.

- Community-Based Research: Incorporate CBR to enhance the relevance of academic research to local communities (Derakhshan, 2021). This fosters practical engagement with local geological issues and enhancing the relevance of academic research to community needs.

By addressing these recommendations, Nigerian universities can effectively integrate virtual field trips into their geosciences programs, improving educational quality and practical experience while also ensuring that traditional fieldwork remains a vital part of students' learning journeys.

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