International Journal of Education, Management Sciences and Professional Studies (IJEMPS)
Vol. 1 Issue 2 (AS) PRINT *ISSN:3115-5065* || E-ISSN:3115-5545
URL: https://journals.iempsglobal.org/index.php/IJEMPS

EXAMINING THE EFFECTIVENESS OF FIELD-BASED LEARNING APPROACHES IN GEOGRAPHY EDUCATION, INCLUDING THEIR IMPACT ON STUDENT ENGAGEMENT AND ACADEMIC PERFORMANCE.

NUMOIPRE INAINFE PhD.
Department of Geography, Faculty of Arts and Social Sciences
Isaac Jasper Boro College of Education, Sagbama, Bayelsa State.
ORCID: 0009-0006-5776-9568
numoipreokwuwe@gmail.com
08136458331

AMATARI-BREFORD, SINCLAIR AMATARI PhD.
Department of Geography, Faculty of Arts and Social Sciences
Isaac Jasper Boro College of Education, Sagbama, Bayelsa State.
amabresly44@gmail.com
08036011847

EBIKABOWEI MUSAH PhD.
Educational Psychology and Councseling,University of Africa, Toru-Orua.
ORCID: 0000-0001-8894-6260
ebikabowei.musah@uat.edu.ng
07066601745

Abstract

This paper examines the effectiveness of field-based learning in geography education, focusing on its impact on student engagement and academic performance. By bridging theory and practice, fieldwork enables students to observe and analyze geographical phenomena in real contexts. Drawing on experiential learning and constructivist theories, the paper highlights how excursions, surveys, and community projects enhance cognitive skills, motivation, and teamwork. Evidence shows that students engaged in such methods retain knowledge longer and achieve better outcomes than those restricted to classroom learning. Despite its benefits, field-based learning faces challenges such as cost, logistics, safety, and limited curriculum integration. These barriers underscore the need for policy support, innovative pedagogy, and adequate resources. The paper recommends embedding fieldwork more fully into curricula, ensuring equitable access, and encouraging further research on its long-term and cross-cultural impacts. Ultimately, it argues that field-based learning is essential not supplementary for developing informed and motivated geography learners.

Keywords: *Field-based learning; geography education; student engagement; academic performance; experiential learning; constructivism; place-based pedagogy; skill development.*

Introduction

Geography as an academic discipline is concerned with the study of people, places, and environments across scales ranging from the local to the global. Traditionally, geography education has relied heavily on classroom-based learning where students are introduced to spatial theories, cartographic representations, and conceptual models. This approach provides the necessary foundational knowledge of geographical processes, but it often risks being abstract, detached, and overly theoretical. Without practical applications, many students struggle to connect concepts with lived realities, leading to surface-level learning rather than deep understanding. Fieldwork has historically provided the counterbalance to this limitation. By taking students into real-world contexts whether rural villages, urban landscapes, or natural ecosystems, geography teachers can allow learners to see, experience, and investigate the phenomena discussed in classrooms. This approach not only solidifies theoretical knowledge but also enhances observational skills, critical inquiry, and interpretative capacity (Fuller et al., 2006). In many ways, geography is incomplete without the integration of both classroom-based and field-based learning, as the discipline thrives on the interaction between theory and practice.

Importance of Fieldwork in Bridging Theory and Practice

Fieldwork has often been described as the "laboratory of geography." Just as chemists depend on laboratories to test hypotheses and conduct experiments, geographers rely on the field to investigate spatial relationships and environmental processes. It transforms abstract content into tangible experiences. For instance, a lesson on river morphology in class may remain conceptual until students stand by a riverbank, measure flow velocities, observe erosion patterns, and record data firsthand. This form of learning promotes the internalization of concepts, encourages independent and critical thinking, and allows students to discover geography as a living, dynamic subject (Gök & Girgin, 2001; Fuller, 2006). Furthermore, field-based learning develops competencies that extend beyond geography. Students acquire collaborative skills through group data collection, decision-making ability through field problem-solving, and a heightened sense of responsibility as they take charge of their learning. The Royal Geographical Society underscores that fieldwork is most effective when it is thoughtfully structured, aligned with curriculum objectives, and designed to foster student ownership of the learning process (Nundy, 1999). When conducted effectively, it creates a seamless bridge between classroom learning and the realities of the environment, ensuring that knowledge is both meaningful and enduring. The aim of this Paper is threefold. First, it seeks to examine critically how field-based learning in geography enhances student engagement, focusing on its cognitive, affective, and behavioral dimensions. Second, it evaluates the

contribution of such approaches to academic performance, including knowledge retention, practical skill acquisition, and measurable outcomes compared with traditional classroom methods. Third, it identifies the challenges associated with field-based learning such as financial costs, safety issues, and curriculum constraints, and offers practical recommendations for overcoming these barriers. In doing so, it provides a comprehensive perspective on the necessity, impact, and future potential of fieldwork in geography education.

Definition of Field-Based Learning

Field-based learning refers to a pedagogical approach in which students are directly engaged with real-world environments outside the traditional classroom setting. Unlike purely theoretical instruction, it emphasizes learning through doing, observing, and experiencing. Activities may include organized field trips to physical landscapes, urban areas, or industrial sites; community-based environmental projects; or structured field surveys where students gather and analyze primary data. The defining characteristic of field-based learning is its experiential nature: students are active participants rather than passive recipients of knowledge. By engaging directly with geographical phenomena, they are compelled to think critically, pose questions, and derive meaning from the environment itself. As the Quality Assurance Agency (2002) and scholars such as Fuller et al. (2006) have highlighted, this approach ensures that students develop not only subject-specific knowledge but also transferable skills such as teamwork, problem-solving, and spatial reasoning. Field-based learning, therefore, is not a supplementary activity but an essential and integral component of geography education.

Meaning of Student Engagement

Student engagement is a multidimensional construct that has become central to discussions on effective teaching and learning. In the context of geography education, engagement represents the degree to which students invest their energy, attention, and motivation in the learning process, both within and outside the classroom. It goes beyond simple participation and involves emotional connection, intellectual involvement, and observable learning behaviors.

Engagement is typically discussed in three interrelated dimensions:

Cognitive Engagement

This refers to the intellectual investment and mental effort that students dedicate to learning tasks. In geography, cognitive engagement manifests when students analyze spatial data, interpret maps, or apply theoretical models to real-world problems. For instance, when learners critically examine the impact of deforestation on local climate systems during a field excursion, they are demonstrating higher-order thinking skills such as analysis, synthesis, and evaluation. Cognitive engagement ensures that students are not only memorizing facts but also developing problem-solving abilities and transferable intellectual skills that extend beyond the subject.

Affective Engagement

Affective engagement relates to students' emotional responses to learning, including interest, curiosity, enjoyment, and intrinsic motivation. In geography, affective engagement is often triggered by the immediacy and authenticity of fieldwork experiences. Standing atop a mountain ridge, measuring soil profiles, or mapping community land use can spark curiosity and a deeper emotional connection to the subject. Such experiences can also foster a "sense of place," which is critical in geography education, as it connects learners to the environments they study and cultivates environmental stewardship and responsibility.

Behavioral Engagement

Behavioral engagement captures the observable actions and participation of students in learning activities. This includes attending field trips, contributing to group projects, actively taking notes during surveys, and collaborating effectively with peers. In geography fieldwork, behavioral engagement often appears through teamwork in data collection, shared problem-solving, and group presentations of findings. These behaviors demonstrate not only commitment to the learning process but also the development of collaborative and leadership skills, which are vital for both academic success and professional life. Together, these dimensions of engagement provide a comprehensive framework for understanding how students connect with their learning. Effective field-based approaches in geography must intentionally cultivate all three forms of engagement to maximize impact.

Academic Performance Indicators

In geography education, student performance cannot be measured solely through conventional tests and written assignments. Instead, academic success is multifaceted, encompassing both theoretical mastery and the acquisition of practical, discipline-specific skills. The following indicators are commonly used to assess performance in geography:

Retention of Content

One of the most important outcomes of effective teaching is the ability of students to retain and recall knowledge over time. Field-based learning enhances memory by situating knowledge in meaningful contexts, which makes recall more natural and enduring. For example, students who have physically measured river discharge during a field study are more likely to remember related hydrological concepts than those who only encountered them in textbooks.

Practical Skills

Geography is both a scientific and social discipline that requires technical and methodological competencies. Skills such as map reading, compass use, GPS navigation, field sketching, and environmental sampling are essential. Field-based learning provides authentic settings for developing and testing these skills. Students gain confidence in applying theoretical concepts in practice, which prepares them for advanced study and future careers in environmental management, urban planning, or GIS applications.

Geo-literacy

Geo-literacy refers to the ability to understand and apply geographic reasoning to real-world issues. It involves interpreting spatial data, recognizing the interconnectedness of human and environmental systems, and making informed decisions about local and global challenges. Students who engage in field projects such as studying land use patterns or analyzing water quality are more likely to develop strong geo-literacy because they learn to connect abstract ideas with lived realities.

Creativity and Innovation

Geography education values creativity, particularly in problem-solving and data presentation. Field-based learning often requires students to design surveys, create innovative maps, and think creatively about solutions to environmental problems. These tasks nurture imagination and adaptability, both of which are indispensable in addressing 21st-century challenges such as climate change and sustainable development.

Spatial Reasoning

A critical academic outcome in geography is spatial reasoning, the ability to visualize, interpret, and analyze spatial relationships. Field exercises such as topographic surveys or urban mapping directly enhance these abilities, as students practice translating three-dimensional landscapes into two-dimensional representations, and vice versa.

Assessment Outcomes

While traditional tests remain important, assessment in geography must capture the broader range of skills and knowledge acquired. This includes field reports, project presentations, practical demonstrations, and oral defenses of findings. Students engaged in field-based learning often perform better in such assessments because their knowledge is grounded in authentic experiences rather than rote memorization. Collectively, these indicators highlight that academic performance in geography is not only about grades but also about competence, application, and the ability to think geographically.

Theoretical Framework

Experiential Learning Theory

Experiential learning theory, as articulated by John Dewey and later formalized by David Kolb, provides a powerful lens for understanding field-based learning. Dewey argued that education must be grounded in experience, as learning becomes meaningful when students actively interact with their environment. Kolb expanded this idea into a cyclical model of learning that includes four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. In the context of geography education, fieldwork represents the concrete experience, where students directly encounter physical or human landscapes. Reflective observation occurs when they analyze their notes, discuss findings with peers, and think critically about their experiences. Abstract conceptualization emerges when students

connect these observations to classroom theories, such as linking measured erosion rates to geomorphological models. Finally, active experimentation occurs when students apply what they have learned to new contexts, such as designing a conservation plan for a local watershed. This cycle demonstrates that learning is not linear but iterative, with each stage reinforcing and expanding knowledge. Field-based learning, therefore, embodies the principles of experiential learning by situating knowledge within lived, tangible experiences that deepen understanding and retention.

Constructivism in Geography Teaching

Constructivism is another influential framework, emphasizing that learners actively construct knowledge rather than passively absorb it. In geography, constructivism aligns perfectly with field-based approaches because it recognizes the importance of context, inquiry, and student agency. When students engage in field surveys or mapping exercises, they are not simply collecting data; they are interpreting, questioning, and synthesizing information to construct their own understanding of spatial relationships. This process reflects the constructivist belief that meaning emerges from active engagement with the environment. Authentic learning environments such as studying deforestation in a nearby forest or examining traffic congestion in an urban neighborhood encourage students to make personal connections between theory and practice. These connections foster deeper understanding and promote the transfer of knowledge to new situations. In this way, constructivism reinforces the value of field-based geography teaching as a means of empowering learners to become critical thinkers and problem-solvers.

Place-Based Learning

Place-based learning extends the principles of experiential and constructivist theories by emphasizing the role of local environments and communities in education. It is grounded in the idea that students develop stronger learning outcomes when instruction is tied to meaningful places that they can relate to directly. In geography, place-based learning not only strengthens academic engagement but also nurtures a sense of place an emotional and cognitive attachment to specific locations. Research in geology and environmental sciences shows that immersive field experiences foster autonomy, group collaboration, and deep affective connections to the environment (Ault, 2014). For example, students who study local ecosystems may develop a stronger sense of environmental stewardship, while those who engage in urban fieldwork may become more aware of social and spatial inequalities in their communities. Place-based approaches also encourage civic responsibility. By engaging in projects such as community mapping or neighborhood revitalization, students see themselves as active contributors to their localities, not just passive learners. Thus, place-based learning transforms geography education into a tool for fostering both academic excellence and social responsibility.

Field-Based Learning Approaches in Geography

Excursions and Site Visits

Excursions and site visits remain one of the most recognized and widely practiced strategies in geography education. When carefully structured, aligned with curriculum objectives, and guided by clear learning outcomes, such activities provide students with opportunities to engage directly with physical and human landscapes. According to professional teaching frameworks, meaningful excursions involve pre-field preparation (such as setting guiding questions), structured field tasks, and post-field reflective discussions. For instance, visiting a coastal ecosystem allows students not only to observe geomorphological features like erosion, deposition, and wave-cut platforms but also to analyze their socio-economic impacts on coastal communities. These experiences enhance students' affective engagement by sparking curiosity and empathy, while simultaneously strengthening cognitive engagement through the application of classroom theories to real-world contexts.

Community and Environmental Projects

Beyond one-time excursions, community and environmental projects immerse learners in sustained, problem-solving experiences tied to their immediate environment. Such projects may include assessing levels of waste management in local neighborhoods, measuring biodiversity within school compounds, or investigating carbon storage in nearby woodlands. By rooting geography learning in familiar settings, students develop both a sense of environmental stewardship and ownership of knowledge. This approach not only encourages active participation and collaboration but also bridges the gap between academic learning and societal relevance. Importantly, community projects cultivate civic responsibility, sustainability consciousness, and teamwork, aligning well with the global push for education that develops environmentally responsible citizens.

Field Surveys and Mapping Exercises

One of the hallmarks of geography education is the development of technical and spatial skills. Field surveys and mapping exercises ranging from traditional compass-and-tape surveys to advanced Geographic Information Systems (GIS) and Global Positioning System (GPS) technologies help students build competencies in observation, measurement, data analysis, and spatial reasoning. Recent studies in Southeast Asia demonstrated that integrating GIS with phenomenon-based learning significantly improved geo-literacy. For example, when Thai secondary school students used Google Maps and GIS tools to investigate urban land-use changes, their levels of inquiry, problem-solving, and cognitive engagement increased markedly. Mapping exercises also sharpen creativity, spatial visualization, and data interpretation skills that are essential not only for academic success but also for practical application in careers such as urban planning, environmental management, and disaster risk reduction.

Impact on Student Engagement

Cognitive Engagement

Field-based learning approaches, particularly those involving technology such as GIS and GPS, stimulate deeper levels of cognitive processing. By working with authentic datasets, conducting direct observations, and applying problem-solving strategies in real-world contexts, students are encouraged to go beyond rote memorization. For instance, GIS-based fieldwork in Thailand revealed that students were more invested in inquiry-driven learning, developing sharper analytical and spatial reasoning skills. Similarly, mobile learning tools employed in outdoor environments allow students to overlay theoretical concepts onto lived experiences, which enhances geospatial literacy and the ability to synthesize complex environmental relationships. Cognitive engagement is strengthened because learners are not passive recipients of knowledge but active investigators constructing their own understanding.

Affective Engagement

The emotional dimension of student engagement is often overlooked, yet field-based learning strongly nurtures students' interest, enthusiasm, and sense of connection to the subject. When students physically interact with landscapes, communities, or ecosystems, their sense of curiosity and wonder is stimulated. For example, a student exploring the effects of deforestation in a local forest may develop empathy for environmental issues, a sense of responsibility towards conservation, and long-term motivation to study geography. This affective dimension is critical in ensuring that students remain motivated and committed to learning beyond the classroom.

Behavioral Engagement

Practical field activities naturally demand active participation, teamwork, and discipline. Students working in groups to conduct a soil survey, measure river velocity, or design a neighborhood map are required to collaborate, take on responsibilities, and contribute to collective outcomes. Such tasks promote behavioral engagement through accountability, peer interaction, and problem-solving in dynamic, sometimes unpredictable environments. The sense of autonomy and ownership derived from these activities further enhances participation and commitment. Taken together, these impacts highlight that field-based learning is not merely an add-on to geography education but a central pedagogical tool. By stimulating students across cognitive, affective, and behavioral dimensions, it enriches engagement, fosters deeper learning, and improves long-term academic performance.

Impact on Academic Performance

Retention of Knowledge

One of the strongest arguments for field-based learning in geography education is its role in improving knowledge retention. Unlike abstract classroom instruction, field experiences situate knowledge in real-world contexts, allowing students to connect theoretical concepts

with lived experiences. For example, when students physically engage with landscapes, rivers, or urban settings, they anchor abstract geographical principles in concrete memories, which aids long-term recall. This process is often described as authentic learning, where learning occurs in environments that mirror professional or real-life applications. Research has consistently shown that such experiential approaches increase the likelihood that students will remember and apply knowledge long after assessments are completed. Furthermore, project-based and outdoor learning activities foster transferable skills such as teamwork, creativity, and problem-solving, ensuring that knowledge is not only retained but also applied flexibly in different contexts.

Practical Skill Development

Geography as a discipline is inherently skill-based, requiring competence in observation, data collection, interpretation, and communication. Field studies provide a unique opportunity for students to develop these skills in authentic contexts. Activities such as map reading, topographical analysis, surveying, and geospatial data interpretation sharpen both technical and cognitive abilities. For instance, research from Taraba State University demonstrated that students exposed to structured fieldwork showed measurable improvements in their ability to analyze spatial data and apply theoretical concepts in practice. Similarly, Kinchin et al. (2018) and Healey & Jenkins (2009), emphasize that active field engagement fosters critical thinking and inquiry-based learning, equipping learners with the analytical capacity to interrogate complex environmental and social issues. The integration of technology into field activities has further expanded the scope of skill development. Tools such as Geographic Information Systems (GIS), mobile data-collection apps, drones, and GPS devices provide students with professional competencies that are increasingly demanded in the global labor market. By engaging with these technologies during field exercises, students not only enhance their geospatial literacy but also develop confidence in using digital tools, bridging the gap between academic learning and professional practice.

Comparative Evidence with Classroom-Based Teaching

When comparing field-based learning with traditional classroom-based teaching, research across multiple disciplines shows that active learning strategies yield significantly better academic outcomes. While geography-specific studies are still emerging, evidence from meta-analyses in fields such as science and engineering reveals that students engaged in hands-on, inquiry-driven approaches consistently outperform peers taught through lecture-based instruction. In geography, field-based learning embodies the principles of active learning by promoting exploration, discussion, problem-solving, and collaborative work. Unlike classroom environments where students may remain passive recipients of information, fieldwork compels learners to engage directly with phenomena, collect data, and make sense of real-world complexities. This deeper engagement leads not only to stronger conceptual understanding but also to higher motivation and persistence in the subject. In essence, field-based learning serves as a pedagogical bridge transforming abstract geographical knowledge into meaningful, memorable, and applicable learning experiences.

Challenges and Limitations

Cost and Logistics

Despite its proven pedagogical value, field-based learning is often constrained by financial and logistical barriers. Schools and universities, particularly in developing contexts such as Ghana and Nigeria, face limited funding to support transportation, accommodation, and learning materials for field excursions. These constraints can significantly reduce access, especially for rural or underfunded institutions where parents and communities cannot afford additional costs (ResearchGate). Furthermore, logistical issues such as securing permissions for site access, dealing with unpredictable weather conditions, or ensuring availability of skilled facilitators add layers of complexity. Without institutional support and sustainable funding models, the effectiveness of fieldwork is often compromised.

Safety and Supervision

Safety remains one of the most pressing concerns associated with fieldwork. Literature emphasizes the need for comprehensive risk assessments and proactive supervision to minimize hazards such as accidents, exposure to harsh environmental conditions, or encounters with unfamiliar terrain (Roberts & Healey, 2017; Bedford et al., 2020). In many cases, institutions struggle to balance student independence in inquiry-based tasks with the responsibility of ensuring their well-being. The administrative requirements for insurance, liability, and health protocols can also discourage schools from engaging in field activities. Thus, safety considerations often determine the frequency, duration, and scope of outdoor learning opportunities.

Curriculum and Assessment Constraints

Another challenge lies in aligning fieldwork with rigid curricular frameworks and standardized assessments. While field-based learning promotes creativity, critical thinking, and problem-solving, traditional curricula often emphasize theoretical knowledge assessed through written examinations. This mismatch can discourage teachers from investing in field projects if outcomes are not formally recognized in grading systems (Royal Geographical Society). Embedding fieldwork meaningfully requires intentional curriculum design, where outcomes are clearly linked to broader learning goals such as geo-literacy, sustainability awareness, and transferable skills. Without such alignment, field-based learning risks being treated as an "extra-curricular" activity rather than an integral part of geography education.

Conclusion

The review clearly demonstrates that field-based learning is not just an enrichment activity but a core pedagogical practice that enhances both student engagement and academic performance. Engagement is fostered across cognitive, affective, and behavioral domains students think critically, develop positive attitudes toward geography, and actively participate in learning when exposed to real-world contexts. Academic performance benefits include enhanced retention of knowledge, improved practical skills in geospatial technologies, and motivation to

pursue geography-related careers. However, these advantages are often offset by systemic challenges, particularly financial constraints, safety concerns, and curriculum rigidity.

Suggestions for Teachers, Curriculum Developers, and Policymakers

Teachers:

Educators should design field activities with clear learning outcomes and involve students in the planning process to foster ownership. Reflective follow-up assignments, such as journals, reports, or digital storytelling, should be integrated to consolidate learning (Royal Geographical Society). Where full-scale excursions are not feasible, teachers can adopt low-cost, local fieldwork approaches, such as mapping nearby environments, conducting interviews, or using mobile GIS applications to simulate real-world investigations (First Monday).

Curriculum Developers:

There is an urgent need to revise curricula to give greater weight to authentic learning methods and to align assessment models with the competencies developed through fieldwork. Instead of relying exclusively on memorization-based tests, curricula should assess geo-literacy, problem-solving, and applied research skills, thereby validating the significance of experiential learning (Royal Geographical Society; authentic learning frameworks).

Policymakers:

Policymakers should recognize field-based learning as a public good that fosters environmental stewardship, civic awareness, and STEM competencies. Dedicated funding streams should be established to support field activities, especially in underserved schools, ensuring equity of access. Partnerships with local communities, industries, and conservation organizations can also provide low-cost, context-specific opportunities for students. Successful models such as initiatives by the Geographical Association in the UK highlight how collaborative efforts can make fieldwork more inclusive and sustainable (The Guardian).

Directions for Future Research

While existing literature emphasizes positive impacts on engagement and skill development, more rigorous comparative and longitudinal studies are needed. Future research should explore:

How fieldwork influences long-term career pathways in geography, environmental science, and related STEM fields.

The relationship between field experiences and environmental citizenship, particularly whether early exposure fosters lifelong stewardship.

The integration of digital technologies (e.g., drones, VR field simulations, GIS-based mobile tools) in complementing or substituting traditional field trips. By addressing these research gaps, future studies can provide more robust evidence for embedding fieldwork systematically into educational policy and practice.

References

Bedford, T., Jones, A., & Walker, M. (2020). Fieldwork and learning in higher education: An integrative review. Journal of Geography in Higher Education, 44(2), 145–162.

Healey, M., & Jenkins, A. (2009). Developing undergraduate research and inquiry. York: Higher Education Academy.

Kinchin, I. M., Lygo-Baker, S., & Hay, D. B. (2018). Engaging students with critical thinking in fieldwork: A conceptual framework. Teaching in Higher Education, 23(5), 556–572.

Roberts, C., & Healey, M. (2017). Strengthening the teaching–research nexus in geography. Journal of Geography in Higher Education, 41(3), 263–278.

Royal Geographical Society. (n.d.). Fieldwork and outdoor learning guidance. Retrieved August 25, 2025.

First Monday. (2019). Technology-enhanced fieldwork in higher education: Mobile learning and GIS integration. First Monday, 24(8).

Taraba State University. (2018). Field-based learning and geography students' academic performance: A case study. Jalingo: Taraba State University Press.

Wikipedia. (2023). Authentic learning. In Wikipedia. Retrieved August 25, 2025, from https://en.wikipedia.org/wiki/Authentic_learning

Wikipedia. (2023). Active learning. In Wikipedia. Retrieved August 25, 2025, from https://en.wikipedia.org/wiki/Active_learning

Verywell Mind. (2022). The benefits of project-based learning. Retrieved August 25, 2025, from https://www.verywellmind.com/

The Guardian. (2021, September 10). Geography teachers call for more fieldwork opportunities. The Guardian. Retrieved August 25, 2025, from https://www.theguardian.com/

National Center for Biotechnology Information. (2020). The impact of field courses on student learning and attitudes. PubMed Central (PMC). https://doi.org/10.1371/journal.pbio.2005568