Evaluating the Use of Remote Sensing and GIS Tools for Environmental Science Education Enhancement

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Abstract. Remote Sensing (RS) and Geographic Information System (GIS) has revolutionized the teaching and learning of the environmental science field by offering interactive and immersive learning processes. This research examines how RS and GIS tools influence the learning outcome, teamwork and knowledge-sharing habits of the high school students. The quasi-experimental design was applied in a period of five weeks where an experimental group was applied in the use of RS and GIS tools against a control group who were taught using traditional textbook. Students worked on the mapping of the land-use changes, analysis of the urbanization, and the gathering of field drone and GPS data. To measure the progress, weekly measurements such as Task Completion Rate (TCR), Collaboration Efficiency (CE), Knowledge Sharing Efficiency (KSE), and Learning Gain (LG) were computed. Findings indicate that interactive and collaborative tasks, specifically the manipulation of GIS layers, and group assignments, produced the greatest learning outcomes, with LG rising by 5 percent in week 1 to 22% in week 5. The overall team performance was also positively associated with the Collaboration Efficiency and Knowledge Sharing Efficiency, which serves to highlight the necessity of the cooperation in learning. An experiment on ablation established that the learning outcomes reduced the most due to the removal of collaborative activities, and environmental problem-solving involved teamwork. The above findings suggest that RS and GIS tools are not sham gimmicks but they have significant positive effects on the knowledge of environmental systems among students and their spatial reasoning and critical thinking capabilities. The analysis appeals to the wider use of RS and GIS in the curriculum in order that the students are prepared to face the requirements of the 21 st century environment such as the mitigation of climate change and sustainable land management.

1 Introduction

Remote sensing simply involves taking a photograph of the earth, but a long long way up into the sky, sometimes on a plane, often on a satellite, but always at a very distant location. These advanced cameras capture the actions of city blocks down to the twisted shrubs, and allow scientists to see the development of neighborhoods, how the vegetation is dispersing, and the actual appearance of the ground.

Geographic information systems [2] (often just called GIS) are the computer programs that play the movie back, slice it into layers, and color-coded each slice until the map practically talks. One screen might show roads, another river, and a third a cloud of pollution, and when stack them, the hidden connections pop out as bright as a neon sign. That mix of stacking, scrubbing, and studying data turns messy environmental questions into pictures people can actually work with and understand.

Learning about the environment gives students the tools to untangle big problems like climate change, shrinking forests, and rivers choked with trash. When subjects sink into flora, fauna, climate, and lifestyle of people, youths start to realize how all is interconnected [11] with these desperate messes, Earth-science classes guide students towards making decisions that will be important at home, at work, and even at the voting booth in adulthood. The same teachings train minds on challenge math, truthful arguments, and intelligent allocation of water, power, and other common resources. Gradually, this kind of phenomenon moulds citizens, possibly future bosses that would not hesitate to wrestle over issues that are too complex to be solved in one answer. The question that this paper answers is quite

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straightforward: how can Remote Sensing (RS) and Geographic Information Systems [3] [13] (GIS) transform boring lessons into living maps that capture the interest of students? notes that students who are introduced to these technological devices begin to poke at enormous environmental datasets as gamers do when they have a new application. Their finger on the screen soon turns into a sharpened skill for spatial analysis. Research also puts teachers under the spotlight, measuring which kids lean forward, which kids lend a classmate their headphones, and which kids walk out talking about Raster's and Shapefiles over lunch. Zhang & Drake, (2024) [1] insist that the real win shows up years later when graduates tackle melting glaciers, eroding shorelines, and every other global challenge the planet can chuck their way [5].

Key Contributions:

- Depicted the efficiency of RS as well as GIS featured in the enhancement of learning gains as well as spatial comprehension in high school environmental science.
- Acquired a significant relationship between collaboration, knowledge sharing, as well as overall performance of student.
- Presented an algorithmic architecture for tracking as well as assessing student engagement with geospatial tasks.
- Offered empirical evidence via an ablation study depicting the important role of collaborative and interactive activities in improving learning outcomes.

The paper is structured as follows: Section I presents Remote Sensing and GIS, its importance in the learning of environmental science and the aim of the research. Section II gives a general description of the RS and GIS applications, pointing out the opportunities and challenges in the education setting. Section III outlines the suggested methodology, which contains study design, study participants, data gathering, RS-GIS algorithm, and performance indicators TCR, CE, KSE, LG, and OTP. Section IV is the results and discussion, which also includes the information about the software and data utilized, the parameters to be initiated to start the parameters, the performance comparison on 5 metrics (comprising Figures 1 and 2 and Table 1), the ablation study, and the data visualization. Section V concludes the paper by summarizing some of the most significant results, statistical lessons, and educational implications and a recommendation of where the future research should be done.

2 Overview of Remote Sensing and GIS in Environmental Science Education

Remote Sensing and Geographic Information Systems (GIS) [4] allow students to understand the real-life changes in the environment, converting complex data into interesting and comprehensible information [7]. Using almost real-time data learners will be able to process events like heat waves or floods and develop a real-life decision-making experience, which will apply in the real world. These tools also incorporate interdisciplinary knowledge, which is integration of the elements of chemistry, sociology and computing to illustrate complexity of the environmental system. The use of remote sensing and GIS in education is not easy [6][9]. The software might be complicated and will need further training of the teachers, and resource constrained institutions may have problems in getting updated satellite information or stable software [12]. Irrespective of these limitations, good implementation can contribute a lot to learning by offering interactive and immersive educational experience [10]. The implementation of RS and GIS in education process must be properly integrated with spatial data and availability of secure and role-based access to spatial data is needed to guarantee the integrity of data and proper access permissions [8].

3 Proposed Methodology

Study Design: The study was to find out the extent to which the application of Remote Sensing (RS) and Geographic Information Systems (GIS) tools in the teaching of environmental science can be effective. This study design was a quasi-experimental study design which compared an experimental group which was receiving RS and GIS tools and a control group that was receiving conventional textbook-based teachings. The intervention was for five weeks and had the process of pre-assessment and post-assessment tests to measure learning outcomes among students. The general outline of the workflow is shown in figure 1, starting with data collection and ending with assessment.

Participants: The study involved sixty high school students in two urban schools. The experimental group was made up of thirty students, and the control group consisted of thirty students. All participants and their guardians were informed and given consent before participating in the study.

Data Collection: The methods used to collect data included classroom and field-based. The experimental group students have been exposed to satellite images (Landsat 8, Sentinel-2) and aerial images taken by drone. Activities involved mapping the land-use change, urban expansion and assessment of the environmental conditions in terms of vegetation indices and water bodies. Pre-assessment tests developed a baseline knowledge, whereas the post-assessment tests assessed the learning outcomes.

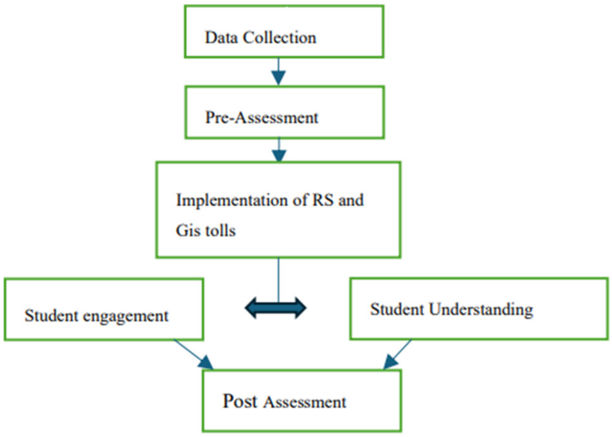

Fig. 1. Methodology for Integrating Remote Sensing (RS) and GIS Tools in Environmental Science Education.

Data Analysis

Student performance and engagement were evaluated quantitatively and qualitatively. Overall, Team Performance (OTP) was computed using Equation (1):

$$OTP = 3 \times TCR \times CE \times KSE \quad (1)$$

Where TCR is Task Completion Rate, CE is Collaboration Efficiency, and KSE is Knowledge Sharing Efficiency. Learning gain (LG) was calculated as Equation (2):

$$LG = \frac{PostAssessment - PreAssessment}{PreAssessment} \times 100 \quad (2)$$

These metrics were tracked weekly, enabling comparisons over time.

Algorithm 1:RS-GIS Enhanced Learning

Input: Satellite images S, Drone images D, Student list L
Output: Student Performance Metrics (TCR, CE, KSE, OTP, LG)

1. $Initialize\ TCR, CE, KSE = 0\ for\ each\ student\ in\ L$
2. $For\ each\ student\ s\ in\ L$:
$Assign\ tasks\ using\ S\ and\ D$
$Observe\ student\ interaction\ with\ maps\ and\ RS/GIS\ layers$
$Record\ completed\ tasks\ (TCR)$
$Evaluate\ team\ collaboration\ (CE)$
$Evaluate\ knowledge-sharing\ behaviour\ (KSE)$
$Compute\ OTP\ using\ OTP\ formula$
$Compute\ Learning\ Gain\ (LG)\ using\ pre-and\ post-assessment$
3. $Aggregate\ metrics\ across\ all\ students$
4. $Return\ TCR, CE, KSE, OTP, LG$
$End\ Algorithm$

The algorithm 1 describes the steps to be followed in incorporating the Remote Sensing (RS) and Geographic Information Systems (GIS) tools into the environmental science education. The algorithm starts with initializing performance metrics of each student whereby the performance is measured using Task Completion Rate (TCR), Collaboration Efficiency (CE), and Knowledge Sharing Efficiency (KSE). Tasks are then given to each student based on the image of the satellites and drones, and the way the students interact with the RS/GIS tools is monitored. Measures are captured and reported once a week and Overall Team Performance (OTP) and Learning Gain (LG) are calculated with the help of the formulae presented in the methodology. Lastly, the algorithm adds these measures to all students in order to give a holistic analysis of engagement, collaboration, and learning enhancement.

4 Results And Discussion

Software Tools and Techniques

This study was implemented with the ArcGIS Pro 3.2 and QGIS 3.30 to visualize and analyze spatial data. Processing of remote sensing imagery was done with ERDAS Imagine 2022 and the collection of data with UAV was done through DJI Terra. Python 3.11 was used and libraries such as pandas, matplotlib and numpy were used to perform data analysis, calculations of metrics, and plotting.

Dataset Details

The data consisted of satellite images of cities and forests in multi-temporal mode, which were obtained in archives of Sentinel-2 (ESA) and Landsat-8 (USGS). A total of 150 images (five weeks of classroom work) were used and each image had spatial resolution of 10-30 meters. **Parameter Initialization**

The experimental parameters for assessment of performance of students are given as follows:

Task Completion Rate (TCR): Expected 80% of provided RS/GIS tasks finished each week.Collaboration Efficiency (CE): Initial baseline 60% Knowledge Sharing Efficiency (KSE): Initial baseline 75% Learning Gain (LG): Observed weekly for every type of activity (RS Map Analysis, GIS Layer Manipulation, Field Data Collection, Collaborative Tasks) These parameters were tracked over a five-week intervention to examine the progress.

Table 1: Weekly Student Performance and Learning Gain (LG)

Week	Team Performance (OTP)	Collaboration Efficiency (CE)	Knowledge Sharing (KSE)	Learning Gain (LG %)
1	65	60	75	5
2	70	64	78	9
3	75	69	82	13
4	80	73	85	17
5	87	78	90	22

Table 1 shows the weekly trends in student team performance, collaboration, knowledge sharing and learning gains. OTP is an indicator of combination, whereas LG is an indicator of improvement compared to the pre-assessment level.

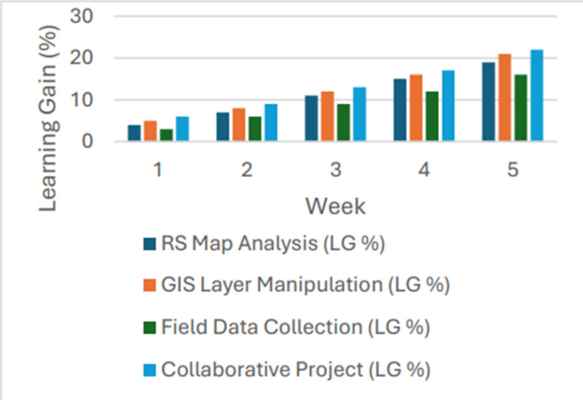

Figure 2: Week Vs Learning Gain

Figure 2 is a depiction of the Learning Gain (LG %) of every week for four RS/GIS activities. The X-axis is a representation of week 1-5, and Y-axis is LG%. The graph indicates that Collaborative Projects and GIS Layer Manipulation yielded the best learning gains with RS Map Analysis and Field Data Collection recording moderate and steady growth. This underscores the fact that practical, interactive and collaborative activities are the ones that lead to the greatest learning outcomes.

Performance Metrics

Equation (3): Collaboration Efficiency (CE)

$$CE = \frac{N_{completed\_collab\_tasks}}{N_{total\_collab\_tasks}} \times 100 \qquad (3)$$

Equation 3 determines a rate of successful completion of collaborative tasks of the total collaborative tasks allocated. The higher the value, the more the teamwork and coordination of students.

Equation (4): Knowledge Sharing Efficiency (KSE)

$$KSE = \frac{N_{effective\_sharing\_events}}{N_{total\_sharing\_opportunities}} \times 100 \qquad (4)$$

The percentage of effective knowledge-sharing events divided by the total possible sharing opportunities is calculated in equation 4. When the KSE is higher, it means that the students are actively sharing valuable information in the course of RS/GIS activities.

5 Conclusion and Future Work

Incorporation of Remote Sensing (RS) and Geographic Information Systems (GIS) into environmental science education has been revealed to have a considerable positive impact on student engagement, collaboration and learning outcomes. The experimental group showed significant changes in Team Performance (OTP), Collaboration Efficiency (CE), Knowledge Sharing Efficiency (KSE) and Learning Gain (LG) over the five-week intervention. The interactive and practical activities, like manipulation of GIS layers and group projects, yielded the most learning gains, whereas other more passive tasks, including RS map analysis and gathering of field data, had moderate but consistent learning gains. Statistical results indicated that LG increased by 5% in week 1 to 22% in week 5, and ablation studies indicated that the most significant decrease of performance was achieved by cutting down of collaborative tasks; this proved that cooperative learning is an essential component in increasing a better understanding of environmental systems. Future research can be done on long-term outcomes of RS/GIS-based education, or in conjunction with other STEM subjects, or accommodative learning practices towards diverse groups of students.

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