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Integrating Augmented Reality and Artificial Intelligence to Enhance the Spatial Ability Skills in the Field of Geography

Anireddy Srilakshmi[1], Archana Mantri[2], Deepti Prit Kaur[3]

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Abstract: Augmentation Reality (AR) is popular in the field of education, especially as a teaching aid. As evident from the past research, it's been exhibited that the students found it easier to comprehend complex topics when AR is used. The integration of dynamic spatial data and outdoor AR delivers a solid conceptual basis and technological medium to supply new concepts and innovative access to geospatial visualization depiction. Further, the combination is also dedicated to improving and broadening the participant's spatial thinking and reasoning capabilities. In addition to AR technology, one of the e-learning platforms, namely chatbot developed using Artificial Intelligence (AI), has become a mainstay in providing long-term support for learning. Thus, this research work nominates an AR-AI framework which was developed as a new way to help middle-school students learn about their surroundings (both inside and out environs). The integration of AR-AI techniques enhances the impact of recognizing dynamic spatial data. This research work sought to meet the academic needs of middle school students in learning their geographic-oriented studies through the proposed AR-AI system.

Keywords: *Augmented Reality, Artificial Intelligence, Spatial Ability, Geography, Education.*

1. Introduction

Augmented Reality (AR) is a rapidly advancing technology that combines real-world surroundings with digital information that is contextually relevant (Azuma, 1997). With the increasing usage of smartphones in various aspects of our daily lives, their hardware and software have evolved to offer us an AR experience. The software of smartphones provides a framework for developers to create AR encounters. To enhance what the camera captures, AR relies on three crucial components: World Tracking, Scene Estimation, and Anchored Overlay Rendering. World Tracking is aware of its location in space and movement, the orientation of the device, and the environment relationship with the use of spatial computing. IMU (Inertial Measurement Unit) is used for spatial computing in smartphones. It contains several miniature gyroscopes and accelerometers used to measure linear and rotational acceleration. The tracking uses Sensor Fusion and SLAM (Simultaneous, Localization, and Mapping). The search for AR is stabilized by using SLAM, along with IMU. Scene Estimation is used to analyze the scene when the device camera is pointed toward an object, and Anchored Overlay Rendering is used to make virtual objects appear and stay in place with the AR scene by using anchors (Sommerauer and Müller, 2018, Radu, 2012, Sangeeta, and Urvashi Tandon, 2021).

The recognition of AR features is done in different ways, such as Marker-based AR (Images, Objects), Detection of Plane (horizontal, vertical), and Detection of Face and tracking. Figure 1 shows what the marker-based AR looks like, Figure 2 represents plane detection, and Figure 3 is an example of face detection and tracking.

Fig. 1. Marker-Based AR [4]

Fig. 2. Plane Detection [5]

Fig. 3. Face Detection and Tracking [6]

The computer vision system detects features as reference points or spatial anchors. It continuously monitors the current video

1 Chitkara University Institute of Engineering and Technology, Chitkara University,Punjab 140401, India
ORCID ID : 0000-0002-2414-9630
2 Chitkara University Institute of Engineering and Technology, Chitkara University,Punjab 140401, India
ORCID ID : 0000-0002-1036-3214
3 Chitkara University Institute of Engineering and Technology, Chitkara University,Punjab 140401, India
ORCID ID : 0000-0003-2363-0753
** Corresponding Author Email: author@email.com*

frame reference points and tries to match them with the previous reference points. SLAM is used to identify the virtual object attached to a future end [7].

1.1. Augmented Reality and Artificial Intelligence in Education

AR and AI enable user-system interaction and can superimpose virtual information over the real world. This automation lets the actual world and virtual data be layered in real time on the same screen or location, improving our learning experience through interaction and visualization. The fundamental steps in using such applications are gathering scene data, processing it, creating virtual data, and displaying a virtual representation of real-world fusion. Additionally, three customized interaction functions—enlarging, shrinking, and rotating—are designed using the interactive scripts of Unity3D to deepen learning in geography (3,9,10,18).

The teaching and learning of geography are mostly approached in a conventional pedagogical manner. Geography contains more abstract concepts, and the conventional approach leads to conceptual misunderstanding, poor academic performance, and low retention. The abstractions require a depth of understanding and visualization skills in understanding, such as concepts in geography. The low spatial ability leads to conceptual misunderstanding (18). Thus, the difficulties in performance and interpreting topographic relief on maps, like switching to 2D to 3D representations in geography, cause a high failure rate (18), which would affect students' performance. Therefore, choosing a suitable technology for teaching and learning abstract concepts would minimize the student's misconceptions about understanding the concepts. The latest technologies would help the students improve their spatial ability in Geography (18).

1.2. Spatial Ability

Spatial ability is the combination of spatial visualization and spatial orientation skills. Geographical learning requires spatial thinking to work with maps, including interpretation and comprehension skills like the process of reasoning, concepts of space, and tools for representation (13). The middle-school students require interpretation skills to oriente the locations, the distance between different places, and their distribution through maps, graphs, and GIS (Geographical Information System). Along with interpretation skills, comprehension skills (map reading skills) are required to provide the process of reasoning like different ways to think about the spatial scenario. The interpretation and comprehension skills address the i) Middle-School student's possible inability to process the details of 2D shapes, ii) Problems faced with 2D orientation and 2D visualization (mapping an image, changing the time with rotation), iii) Issues in orienting the 3D image with 2D image, and iv) the ability to address the skills like directions through compass, measuring the distance, interpreting the height and locating the coordinates (13).

2. Significance of Geographical Education

Use Researchers found that students' geographical awareness improved due to utilizing graphics and digital interactive maps during a social studies program. Due to various prior studies on this issue, this research wants to discover and Table 1 presents the students' requirements as well as Social Studies instructors' perceptions and perspectives when they make choices focused on the students' map abilities. The below concerns are taken from different school teachers and middle-school students of different schools. These research queries will be answered as a result.

From Table 1, it is shown that the AR-based teaching programs provide flexibility in defining the problems and proposing solutions for these problems. This also enhances the field knowledge, general culture, and field teaching skills. The existing methods investigate what factors have more influence on the outcome of education and apply the constraints thus identified for designing more effective AR-based experiences. However, future research could, in turn, provide more insights into the effective application of AR and enhance educators' skills.

Table 1 Students-Instructor Concerns

Instructors Concern	Students requirements
In Geography-oriented studies, how do instructors feel regarding their students' map-reading abilities?	Map activities can't be done becauseof the restricted class time.
When it comes to developing students' map abilities, how successful do they believe the geography course programme has been?	The teaching method offers less timefor practicing map activities.
Should teachers/instructors be focusing on improving the map skills of the students in their class?	It's a rigid framework that restricts the flexibility of the educator.
Face difficulties while trying to help students improve their map-reading abilities?	It's a lengthy and complex course.
Suggestions for increasing students' ability to maneuver using a map?	

The existing conceptual framework was provided by looking at memory purely from the input or encoding end. The questions were limited to a few by considering multi-store models in memory research. The experimental design with TUI (Tangible User Interface) teaching students about the concept of probability in that specific study used video presentations instead of a schoolbook chapter. Similar results were found, which suggested that TUIs were the finest interface used as a discovery learning environment. The applications based on ARLE require a critical review system, the assessment of which yields better results. Adding AR with the recognition of objects and sharing features socially will upgrade the gamification model, which may result in an improved learning process. From existing methods, it is known that AR applications maximize the learning outcomes by implementing AR classrooms, including integration, empowerment, awareness, flexibility, and minimalism. Tracking is the difficulty of real-time post-determination or the betterment of the position and inclination of an object in 3D space and time. AR supports tracking through vision-based tracking or hybrid tracking. Vision-based tracking is adequately fast and accurate without the need for external

wiring. However, it becomes too fragile due to various issues that hinder vision-based tracking like occlusions, complexity, and variability. AI is the most emerging technology used for machines and computer systems to simulate human intelligence.

3. Development of AR-AI Application

Compared to Virtual Reality or Augmented Virtuality, Augmented Reality (AR) is considered to be more suitable for educational purposes as it allows learners to retain a sense of reality. Apart from interacting with computer-generated virtual objects, learners can also interact with real-world objects naturally. AR can be experienced through various mediums such as handheld devices like Mobile AR and Wearable AR, or through desktop environments such as Tabletop AR and Nonwearable AR. This study employs AR as a teaching and learning tool by building an AR-AI environment that is suitable for use in classrooms and laboratories. The development of the AR-AI framework entails several stages, including Conceptualization, Design, Deployment, and Implementation.

3.1. Conceptualization

The AR-AI based application developed in this research aims to enhance the learning experience of Middle-school students studying Geography by providing them with an interactive and immersive platform for exploring various concepts. The application utilizes marker-based AR technology, which involves fixing a marker with specific triggers and overlaying digital data on it when the camera is pointed at the marker.

A survey form was created with a few questions to collect feedback from middle school geography teachers. The questions included in the survey is shown in Table 2 and the responses from middle school teachers are shown in Figure 4. After collecting all the responses, the areas where teachers faced challenges in teaching and helping students understand were identified and summarized.

Figure 5 shows the topics in which middle school students are facing difficulty in understanding the concept, most of the teachers selected Land, Soil, Water, and Natural Vegetation. As per the survey, 69.7% of teachers in Figure 6 use traditional methods (chalk and board) to explain the abstract concepts of geography. This method of teaching may lead to misconceptions, that geography requires visualization.

Table 2 Teachers Survey Questions

S. No	Questions
1	Name of the Teacher?
2	What grades do you instruct?
3	How long have you been a geography/social studies teacher?
4	Board of Studies (Curriculum) that you teach
5	What is the name of the geography/social studies textbook you use?
6	What are the most difficult topics identified from the students perspective?
7	What other resources (besides the textbook) you utilise to teach Geography lessons?
8	What difficulties are you facing while instructing geographical skills to students?
9	What activities do you believe that help students to learn geographical skills easier?
10	Mention any additional topics where understanding depends on imagery.

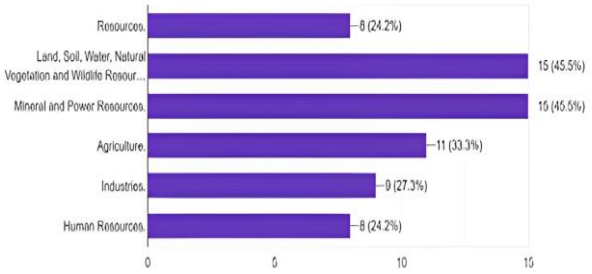

Fig. 4. Analysis of difficulty in geography topics

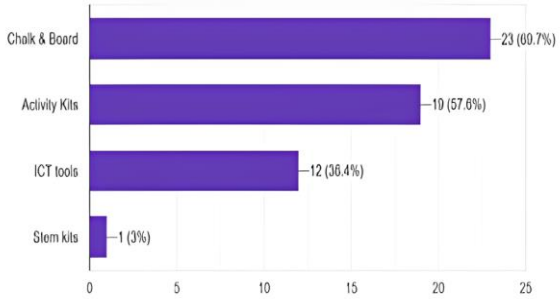

Fig. 5. Mostly used Instruction Tools

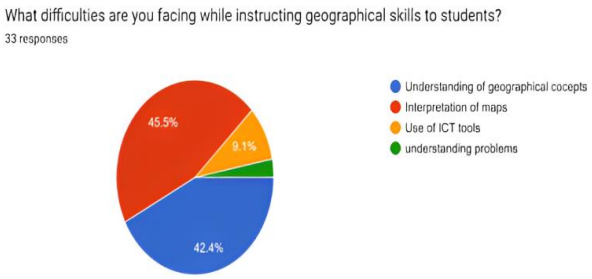

Fig. 6. Difficulties faced by teachers to instruct geography skills

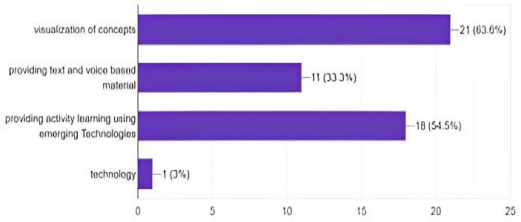

Fig. 7. Request for advanced tools to instruct geography skills

Figure 7 gives the details that teachers are facing while instructing geography skills to their students. Most of the teachers requested to provide visualizations of geography concepts using emerging technologies as the generations are too fast and due to the access of ease of technology shown in Figure 8. As per the survey, there is less usage of visualization tools in the classroom to teach geographical abstract concepts.

The understanding levels of students are very low in the field of geography as per the survey and the most difficult topics are Land, soil, water, and Natural vegetation.

3.2. Design

After designing a framework with all the collected requirements from teachers and students, the next phase is to develop an application with a combination of Augmented Reality (AR) and Artificial Intelligence (AI). For the development of an AR-AI application, the set of guidelines [50] would be - Supporting students with a diverse degree of domain knowledge, Selection of Device and its working (selection of input devices must be easy to use for students), Supporting multi-modal interaction (It should have a high frame rate and low latency for visual, auditory, and haptic, smoothly and continuously integrated to the user activity) and finally, providing additional assistance with the help of Chatbot.

To create marker-based applications for the Android operating system, tools and technologies including Unity Engine, Vuforia, Blender, AR SDK, Open Scene Graph, local storage, and geolocation will be utilized [15]. Artificial Intelligence would be required to create a chatbot application, and the Chatbot would be integrated with the AR application. To deploy the application, a fixed marker with particular triggers is used, and the digital data is superimposed on the marker when the camera is pointed at it. The block diagram of an Application is shown in Figure 8.

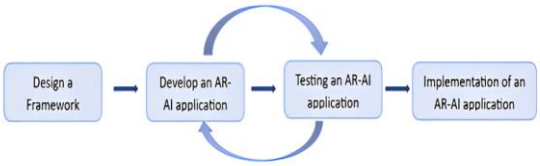

Fig. 8. Block Diagram of an AR-AI application

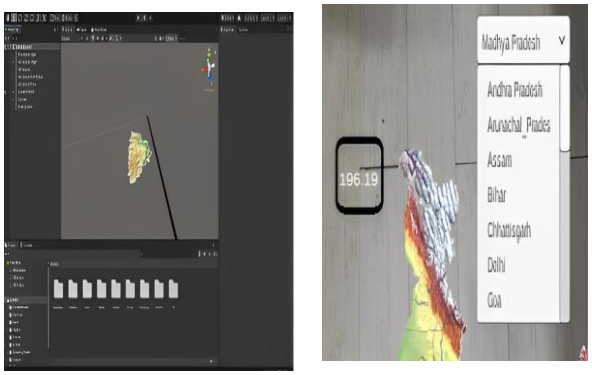

Fig. 9. Development of Indian Map and adding textures in Unity

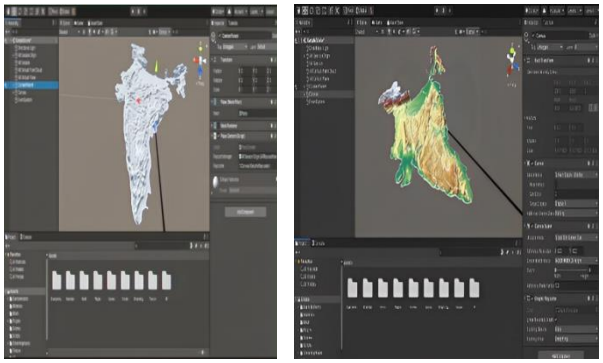

Fig. 10. Separating individual states to explore the details

Figure 9,10 shows the development of a 3D model India model, where each state is separated using tools of unity and a timer to check the usage of the application. The technologies used to develop these 3D models are Unity, Vuforia, Blender, and ARCore. C# is used for scripting the actions integrated with Unity.

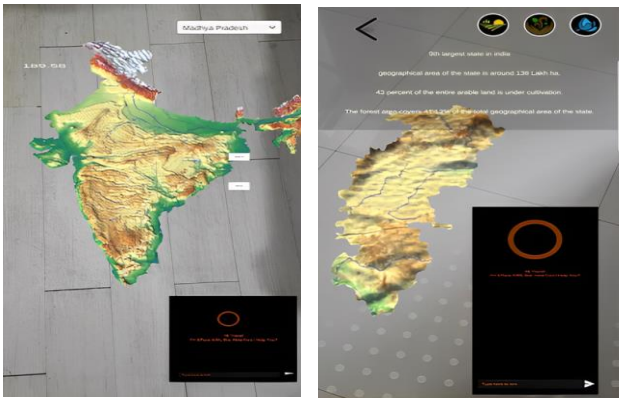

Fig. 11. Developed AR-AI application in Unity

Figure 11 contains the overall developed AR-AI application and when we click on the pointer placed on a particular state along with the required information. And 3D view of a particular state is displayed with text information about land, soil, water, and natural vegetation by clicking on the user interface. Apart from the information provided a chatbot application is integrated into this unity where it shows the answer to any question in geography. The chatbot used in the application helps students to learn beyond the syllabus and in the absence of a teacher they can use a chatbot as a guide.

The application is also enhanced with a video link integrated with a content-based questionnaire to assess accuracy as shown in Figure 12.

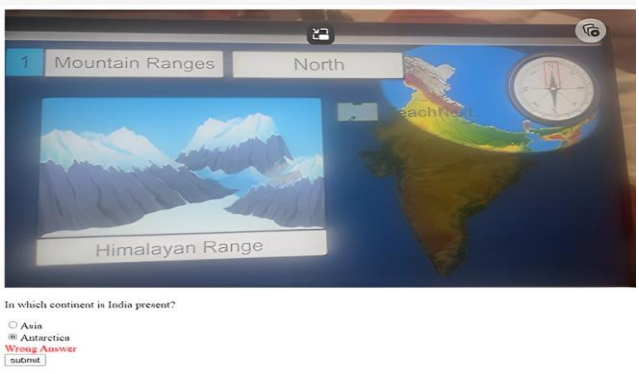

Fig. 12. Interactive Video of an AR-AI application

3.3. Deploying

The Geographical maps and concepts are challenging to understand and require in-depth knowledge of the phenomenon through visualization skills. The application is deployed on a group of middle school students by integrating and enhancing the features.

The features incorporated in the developed applications:

1. The AR-AI application incorporates images, materials, and videos to enhance user engagement.

2. A timer has been integrated to monitor and evaluate the efficient utilization of application time.
3. A provided URL link facilitates navigation to the NCERT Page for additional resources.
4. Furthermore, the application is enhanced with a video link and a chatbot feature for extended assistance.

The interactive video link is used to test the impact of AR-AI applications on student's accuracy. Two different types of videos are created one is normal, the other video contains checkpoints if the student gives the wrong answer then the video starts from the beginning as shown in Figure 13.

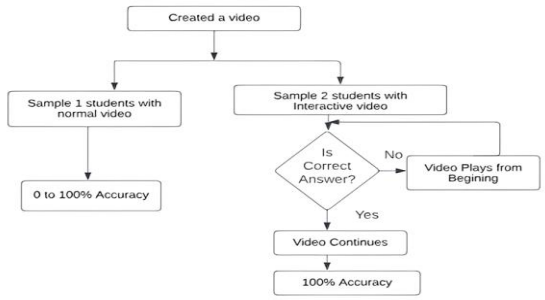

Fig. 13. Framework to assess the impact of Interactive Video

Tests Performed	Overall Accuracy (%)
With Normal Video	64.66
With Interactive Video	100

Table 3 Accuracy Rate of Answering Questions

Table- 3 shows the pilot survey conducted with a sample size of 1 each and the results show that the utilization of the AR-AI application significantly impacts students' Attention, Motivation, Relevance, and Satisfaction in geography education, as their performance improved after using the demo applications.

A demonstration of an AR-AI application was given to a group of students as part of an educational initiative and a pilot study. The demonstration's goal was to assess how well the chatbot with augmented reality integration improved student spatial thinking abilities. The students took a pre-test before the demonstration to gauge their baseline familiarity with the subject. A post-test was given to the students after the demonstration to gauge their learning outcomes.

Overall, the project's findings demonstrate how the AR-integrated chatbot can improve students' spatial thinking abilities and their educational experiences. The creation and use of technologically enhanced learning settings will be significantly impacted by these findings. Future studies could concentrate on examining the particular characteristics of the AR-integrated chatbot that contributed to its efficiency and looking into methods to enhance the technology for wider adoption in educational settings.

4. Discussion

A demo application was demonstrated with a sample of 30 students, a pre-test was conducted to check the spatial-ability skills in the natural resources topic of geography. Later the same topic was explained by using an AR-AI application and the students were tested with a post-test. After analyzing the results an AI-AR application is suggested to enhance the spatial-ability skills in geographically oriented studies among middle school students. Students were allowed to participate in educational activities that enhanced their desire to study and perspective toward map-based learning.

Table 4 Pre-Test and Post-Test Results

Tests Performed	Overall Accuracy (%)
Pre – Test Analysis	36.36
Post – Test Analysis	68.75

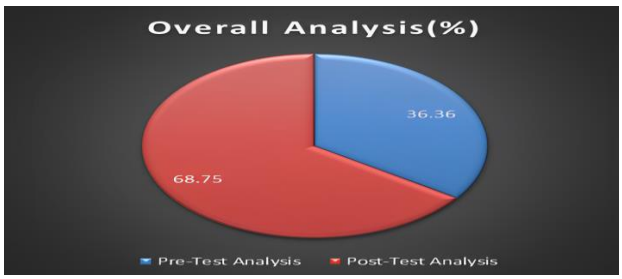

Fig. 14. Pre-Test and Post-Test results to enhance the spatial ability skills

Table 4 and Figure 13 show the proposed approach outperformed in the post-design utilization through studies conducted on students by demonstrating theframework's efficacy. In this way, the suggested framework may be extensively used to design, develop, and implement AI-AR based education for students and practitioners to implement their knowledge into practice via enhanced learning. Future work will concentrate on implementing a large-scale application to correlate various views of a map to define and evaluate geographical features.

5. Conclusion and Future Scope

This article exemplifies that Geographical studies require efficient spatial ability skills to interpret maps and verbal-based processes to assist the students. Research shows that AR and AI technologies are used to design and develop applications useful for students to improve their learning outcomes. This application is very helpful for middle-school students to understand the concepts of maps in the course of geography. The efficacy of the developed application would be checked by its implementation and analysis to find out its impact on spatial thinking skills on the Prominence of the Land Masses following Natural vegetation (Land, Soil, Natural Vegetation) and consequently in terms of learning outcomes.

Conflicts of interest

The authors declare no conflicts of interest.

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