Augmented Reality and Natural Language Processing-Driven Intelligent Learning Platform for Interactive Education Systems

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Article Info

Article History:

Received Apr 11, 2026
Revised May 09, 2026
Accepted Jun 10, 2026

Keywords:

Augmented Reality,
Natural Language Processing,
Intelligent Tutoring System,
Interactive Learning,
Personalized Education

ABSTRACT

Traditional teaching practices mostly rely on passive learning tool which leads to concern about how engaged students are and how deeply students understand the material. Generally, students have trouble visualizing their ideas and concepts and digital learning tends to be boring. However, the challenges create possibilities for developing better and adaptive educational technologies. Thanks to the development of AR and NLP technologies new learning environments with graphic components and communication options arise. AR technology helps in putting digital objects in the real world while NLP allows people to talk to machines naturally. A smart educational platform using augmented reality and natural language processing technology has been developed for improved learning experience. The platform gives users access to 3D visual representations of various academic models which learners can explore with their augmented reality devices. The NLP component enables students to pose questions and acquire answers in natural language that follow the context. The content is tailored to the needs of students by means of a recommendation engine based on machine learning. According to the tests, the new system provides more effective learning because of higher levels of retention, engagement, and understanding compared to existing online education platforms.

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1. INTRODUCTION

Modern technologies have revolutionized the entire education sector, providing various opportunities for teaching and learning outside traditional educational institutions. Wider usage of the Internet-based educational instruments, learning applications, and computer-aided instruction has contributed to greater access to information about studies and enhanced the freedom of learning [1]. However, many educational institutions continue using static learning materials including books, slides, videos, and images. While this particular method is good at conveying information, it fails in interaction and engagement necessary for cognitive learning in complex subjects.

Modern education faces one major issue, the challenge that students encounter while trying to understand complicated ideas that they cannot see directly. Areas of study like anatomy, molecular chemistry, engineering design, astronomy and higher math often utilize complex forms and movement that create difficulty in representing them with classical materials. This may lead to lower motivation and retention levels and poor understanding of concepts. In addition, typical e-learning systems typically provide the same instructional approach for everyone regardless of differences in learning preferences and abilities [2].

Augmented Reality (AR) is the new technology that helps to overcome these shortcomings. It combines the real world and digital information that applies in any form: 3D models, animation, any kind of relevant data. While VR technology immerses people in a different world, AR gives people the possibility to stay in the real world and add a new layer to the existing reality. This technology allows making learning practical [3].

Many studies show that augmented reality (AR) adds significantly to the enhancement of engagement and success of students in different fields of study. With the help of AR technologies, medical students are able to see the human body component parts in real life. AR-based systems in engineering and science education aid students in understanding complex systems, processes, and performing lab exercises without having to use expensive apparatuses. Nevertheless, most AR educational systems currently available are focused only on visualization and interaction and do not promote smart communication and personalized learning support [4][5][6].

Natural Language Processing (NLP) is an enhancing field of artificial intelligence that brings a lot of possibilities for improving the communication between learners and programs. NLP allows the machines to comprehend, understand, and generate human language, which allows learners to communicate with educational facilities naturally, without resorting to any predefined commands [7][8]. In recent years, improvement of transformer based models and conversational AI helped to enhance efficient educational assistants in their accuracy and contextual understanding capabilities. Natural language processing makes it possible for learners to ask questions and get answers and explanations to their problems [9][10].

While AR and NLP technologies have proved themselves to hold significant educational advantages individually, their combined application in a single intelligent learning platform has yet to be adequately researched. Most AR-based learning systems do not employ the conversational abilities of cognitive communication systems, while NLP-based tutoring systems rely on the text-based format and fail to deliver a visually immersive experience. Hence, the absence of the synergy between the visual immersion and intelligence has made current educational technologies less effective. In addition to this, there are many educational technologies where the effective learning mechanism of adaptive teaching is not employed.

In order to tackle these difficulties, this research proposes an Intelligent Learning Platform for Interactive Training Systems based on Augmented Reality and Natural Language Processing. The proposed platform integrates cutting-edge AR visualization and context-oriented chat helping capabilities along with recommendation system based on machine learning. The AR application allows students to engage in real-time interaction with educational objects that have 3D features on their AR devices. The NLP application provides interaction in the form of the interacting language. Besides, the recommendation engine works constantly in analyzing the learning behavior of the students and improves the educational material and educational path accordingly.

The proposed platform intends to enhance student participation, understanding of concepts, ability to remember information, and effectiveness of learning across different domains. By combining immersive visualization, smart communication tools, and adaptive learning capabilities, it helps both classroom education and distance learning methods and raises the potential of next generation intelligent educational systems.

1. The most important elements of this research are summarized in the following points:

2. Creation of AR-based educational environment for immediate visualization and interaction with difficult academic ideas.

3. Integration of a conversational learning assistant based on the principles of natural language processing that can understand and act appropriately to any questions of students.

4. Development of the recommendation system that provides students with personalized educational materials.

5. Application of the learning analytics systems for controlling the students' leaning process and their academic performance.

6. Extensive evaluation of the implemented system in terms of learning retention, comprehension, engagement, and satisfaction.

The remainder of this paper is organized as follows. Section 2 presents a review of related literature on AR-based learning, NLP-enabled educational systems, and adaptive learning technologies. Section 3 describes the architecture of the proposed intelligent learning platform. Section 4 discusses the methodology and implementation details. Section 5 presents the experimental setup and evaluation metrics. Section 6 analyzes the obtained results and comparative performance. Finally, Section 7 concludes the paper and outlines future research directions.

2. LITERATURE REVIEW

[11] Proposed the notion of an intelligent tutoring system (ITS) that employs adaptive metacognitive guidance to optimize the learning outcome of students. The framework used in this system consists of changing pedagogical strategies depending on the condition of the learner and his/her cognitive state. Experiments using such a system lead to positive results in knowledge acquisition and assimilation. The results also suggest that the adaptive learning mechanism enhances student engagement and problem-solving abilities. Nevertheless, the proposed system could not include AR visualization and/or NLP-based communication interaction.

According to [12], the Augmented Reality-enabled Intelligent Tutoring System was created to improve teaching and learning in science education through immersive learning. The system utilized a combination of interactive three-dimensional visualization and adaptive instruction. The experimental evaluation showed that teaching and learning were improved when students used the system. The students were able to understand complicated concepts in science. On the downside, the system was limited to science and was not able to communicate intelligently using NLP as well as analyze the learning process.

According to [13], an AI-based visualization system was developed to observe learner interaction in intelligent tutoring systems. The framework converted learner activity data into visuals that aid in instructional decision-making. Experimental results showed that monitoring learners and teaching effectiveness have improved with the help of visual data. The framework helped teachers track their students' progress and behavior, however, it did not incorporate elements like augmented reality or conversational NLP and personalized recommendation techniques.

[14] Presented a new AI tutoring solution in the area of software engineering education that would provide intelligent conversation. The results of the experiments showed the effectiveness of the system in terms of the learners' engagement and performance. Despite all the benefits of the introduction of the proposed solution in the higher education system, which can be linked to further developments in the field of education, it still lacks approaches that are specific to other disciplines as well as AR-based visualization and efficient learning analytics.

3. PROPOSED INTELLIGENT LEARNING PLATFORM ARCHITECTURE

The suggested Intelligent Learning Platform based on Augmented Reality and Natural Language Processing is aimed at implementing visionary learning access, interacting with the learning process, and analyzing performance in order to improve teaching. The system has five principal components that can be seen on Figure 1.

3.1 Input and Knowledge Repository

First, the system accumulates different types of educational resources such as text materials, three-dimensional models, videos, animations, and assessment data sets. All these resources are kept at a centralized knowledge repository acting as the primary knowledge source for the system.

3.2 Augmented Reality Visualization Module

The AR module gives a three-dimensional perspective of learning concepts by using AR devices like smartphones and tablets. It identifies the surroundings, draws 3D shapes, and let students manipulate them via touch gestures like rotating, moving, or scaling the objects.

This module enhances student learning by making understanding difficult concepts easier through visual learning.

3.3 Natural Language Processing Module

The NLP module serves as an intelligent learning aide for students who make inquiries about their learning content through natural language. The learner's questions are subjected to the processes of preprocessing, intent identification, and context interpretation before relevant information from the knowledge repository is retrieved.

Then the assistant provides suitable answers in the form of text explanations and AR-supported display.

3.4 Personalized Recommendation Engine

The learner activity of the recommendation engine is assessed in terms of assessment scores, engagement, learning history and interaction. The recommendation engine utilizes this information in order to recommend appropriate study materials and modify the content based on the learner's progress.

3.5 Learning Analytics and Feedback Module

The learning analytics module keeps track of the learner's performance and engagement during the learning process constantly. It gathers data on assessment scores, learning time, and the number of interactions.

The information collected through the learning analytics module is used to produce reports, charts, and dashboards to keep track of students' progress and pinpoint the areas where the learning process needs improvement.

3.6 Output Layer

The resulting outputs of the suggested platform consist of:

- The possibilities for AR-assisted learning actions.
- The smart dialogue support.
- The personalized learning advice.
- The ongoing assessment and feedback.
- The clarified perception and retention of information.

In conclusion, many advantages arise from the combination of AR, NLP, recommendation systems, and learning analytics.

4. METHODOLOGY

4.1 Overview of the Proposed Methodology

The proposed Intelligent Learning Platform driven by Augmented Reality and Natural Language Processing (AR-NLP-ILP) combines immersive visuals, intelligent interaction, personalized recommendations, and learning analytics to improve the educational experience. The method includes six key steps:

1. Education Content Acquisition
2. Augmented Reality Visualization
3. Natural Language Processing
4. Personalized Recommendations
5. Learning Analytics and Feedback
6. Adaptive Learning Output

Figure 1 shows the complete working process of the proposed AR-NLP model.

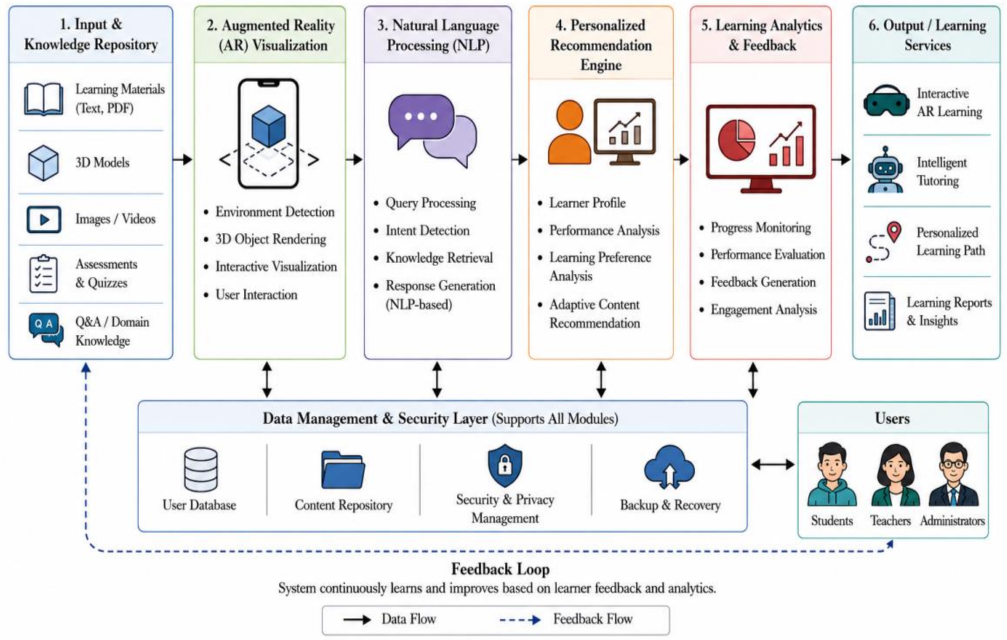

Figure 1. Proposed AR-NLP Intelligent Learning Platform Architecture

4.2 Educational Content Acquisition

In the beginning, different learning resources like written texts, three-dimensional models, movies, recordings, and evaluations are gathered and preserved in a unified knowledge bank. These resources represent the knowledge support for the AR and the NLP modules.

The educational dataset can be represented as:

$$D = \{T, M, V, A, Q\} \quad (1)$$

where:
- T – text-based learning materials,
- M - 3D learning objects,
- V – interactive multimedia content,
- A – assessment components,
- Q - knowledge resources.

4.3 Augmented Reality Visualization Module

The Augmented Reality module creates three-dimensional interactive designs that are placed over the real life with the help of AR-enabled devices.

The process of placing virtual objects in the actual environment can be seen as:

$$P_{AR} = T \times R \times S \times P \quad (2)$$

where:
- P represents original object coordinates,
- S denotes scaling transformation,
- R represents rotation transformation,
- T denotes translation transformation,
- P_{AR} denotes the final AR object position.

The AR module allows learners to perform operations such as Rotation, Zooming, Object manipulation, Multi-view exploration.

These relations substantially boost conceptual thinking and spatial learning capacities.

4.4 Natural Language Processing Module

The NLP module allows learners to interact with the educational platform using natural language queries.

A learner query is represented as:

$$Q = \{w_1, w_2, w_3, \dots, w_N\} \quad (3)$$

where w_i denotes the input query words.

The inputquery undergoes preprocessing tasks including Tokenization, Stop-word removal, Lemmatization, Normalization. The intent classification process is formulated as:

$$I = \arg\max_{c \in C} P(c|Q) \quad (4)$$

where:
- I represents predicted user intent,
- C denotes the set of probable intent classes,
- $P(c|Q)$ represents the probability of class c given query Q.

The system retrieves relevant educational learning resources and generates context-aware answers.

4.5 Personalized Recommendation Engine

The recommendation system constantly evaluates learner activities and academic results to personalize educational content.

The learner profile vector is represented as:

$$L = [s, t, e, c, q] \tag{5}$$

where:
s - assessment score,
t – learning time,
e - engagement level,
c - concept mastery,
q - query frequency.

The recommendation score for learning content is computed as:

$$Rec_i = \sum_{j=1}^{m} w_j x_j \tag{6}$$

where:

- Rec_i denotes recommendation score,
- w_j denotes feature weights,
- x_j represents learner characteristics.

The content with the maximum recommendation score is chosen as:

$$Content^* = \arg\max_i (Rec_i) \tag{7}$$

This allows for personalized and flexible learning guides for each learner.

4.6 Learning Analytics and Feedback Module

The learning analytics component regularly tracks learner interfaces and educational performance.

The engagement score is computed as:

$$E = \alpha T + \beta I + \gamma Q + \delta S \tag{8}$$

where:

- T represents learning duration,
- I denotes interaction count,
- Q represents number of learner queries,
- S denotes assessment score,
- α,β,γ,δ are weighting coefficients.

subject to:

$$\alpha + \beta + \gamma + \delta = 1 \tag{9}$$

The learner mastery score is calculated as:

$$M = \frac{\sum_{i=1}^{N} S_i}{N} \tag{10}$$

where:

- S_i refers to assessment score,
- N denotes total valuations.

The feedback generated from learning analytics is utilized to improve recommendation quality and learning personalization.

4.7 Adaptive Learning Strategy

The model actively alters academic content effort according to learner development.

The efficient difficulty level is calculated as:

$$D_{new} = D_{old} + \eta(M - M_{th}) \tag{11}$$

where:

- D_{old} reveals current difficulty level,
- D_{new} denotes updated difficulty level,
- M is the learner mastery score,
- M_{th} represents threshold mastery value,
- η is the learning adjustment factor.

If:

$$M > M_{th}$$
the learner receives advanced content.
Otherwise,
$$M < M_{th}$$
the system recommends additional tutorials and revision materials.

4.8 Objective Function of the Proposed Framework

The key objective of the suggested framework is to enhance learning efficiency while reducing cognitive overload.

The optimization objective is defined as:
$$max\, J = \lambda_1 E + \lambda_2 m + \lambda_3 R - \lambda_4 C \qquad (12)$$
subject to:
$$\sum_{i=1}^{4} \lambda_i = 1$$
where:
- E denotes engagement score,
- R denotes retention score,
- C denotes cognitive overload,
- λ_i are weighting coefficients.

5. EXPERIMENTAL SETUP AND EVALUATION METRICS

5.1 Experimental Setup

An assessment of the proposed AR-NLP Intelligent Learning Platform was conducted through the implementation of a prototype using Augmented Reality and Natural Language Processing. The prototype contains educational material in the form of written content, 3D models, videos, as well as the evaluation component of questions.

The expedition was executed with the use of an AR mobile device and a standard computing tool for simulations of the learning environment, both in a classroom and a remote setting. The pupils of the experimental group interacted with the learning platform in terms of AR-based learning objects and through sending queries to be processed by the Intelligent Tutoring System.

The framework was analyzed based on the learning results before and after the use of the platform, in terms of engagement, learning conceptual knowledge, knowledge retention, and satisfaction with the learning process.

5.2 Evaluation Metrics

The effectiveness of the proposed platform was evaluated using the following performance metrics.

5.2.1 Learning Accuracy

Learning accuracy measures the proportion of correctly answered assessment questions after using the proposed platform.

$$Accuracy = \frac{N_{Correct}}{N_{Total}} \times 100$$
where:
- $N_{Correct}$ represents the number of correctly answered questions.
- N_{Total} represents the total number of assessment questions.

5.2.2 Knowledge Retention Rate

Knowledge retention evaluates the learner's ability to recall concepts after the learning session.

$$Retention = \frac{C_{Recalled}}{C_{Learned}} \times 100$$

where:

- $C_{Recalled}$ denotes correctly recalled concepts.
- $C_{Learned}$ denotes the total concepts studied.

5.2.3 Learner Engagement Score

Learner engagement is calculated based on interaction frequency, learning duration, and participation level.

$$Engagement = \frac{I + T + P}{3}$$

where:

- I represents interaction frequency.
- T represents time spent on learning activities.
- P represents participation level.

5.2.4 Response Time

Response time measures the average duration required by the system to generate answers for learner queries.

$$Response\ Time = \frac{\sum_{i=1}^{n} t_i}{n}$$

where:

- t_i denotes the response time for query iii.
- n denotes the total number of queries.

5.2.5 User Satisfaction Score

User satisfaction is measured through learner feedback questionnaires using a five-point Likert scale.

$$Satisfaction = \frac{\sum_{i=1}^{n} S_i}{n}$$

where:

- S_i represents the satisfaction score given by learner iii.
- n represents the total number of participants.

5.3 Comparative Evaluation

The proposed AR-NLP Intelligent Learning Platform was compared with conventional e-learning systems and AR-only educational platforms. The comparison focused on:

- Learning accuracy
- Knowledge retention
- Student engagement
- User satisfaction
- Response time

The integration of immersive AR visualization and intelligent NLP interaction is expected to improve learning effectiveness and provide a more personalized educational experience compared to traditional educational systems.

6. RESULTS AND DISCUSSION

6.1 Performance Evaluation of the Proposed Platform

The performance of the proposed Augmented Reality Natural Language Processing-Based Intelligent Learning Platform (AR-NLP-ILP) was assessed through the use of learning accuracy, knowledge retention, learner engagement, response time, and user satisfaction metrics. The results obtained show that using augmented reality visualization combined with intelligent NLP interaction has considerable advantages over traditional e-learning technologies as far as learning experience is concerned. The comparative performance evaluation of the proposed AR-NLP learning platform is listed in Table 1.

Table 1. Comparative Performance Analysis of the Proposed AR-NLP Intelligent Learning Platform

Performance Metric	**Traditional E-learning**	**AR-based Learning**	**Proposed AR-NLP Platform**
Learning Accuracy (%)	82.5	88.7	**94.2**
Knowledge Retention (%)	78.4	86.1	**92.8**
Learner Engagement (%)	75.2	87.3	**95.1**
Response Time (s)	2.45	1.82	**1.28**
User Satisfaction (1-5 Scale)	3.85	4.31	**4.82**

6.2 Learning Accuracy Analysis

The learning accuracy evaluates the learner's ability to accurately understand and response to the assessment questions following a learning session. As shown in Figure 2, the suggested AR-NLP system attained 94.2% accuracy, while traditional e-learning systems and AR-exclusive learning platforms recorded 82.5% and 88.7% respectively.

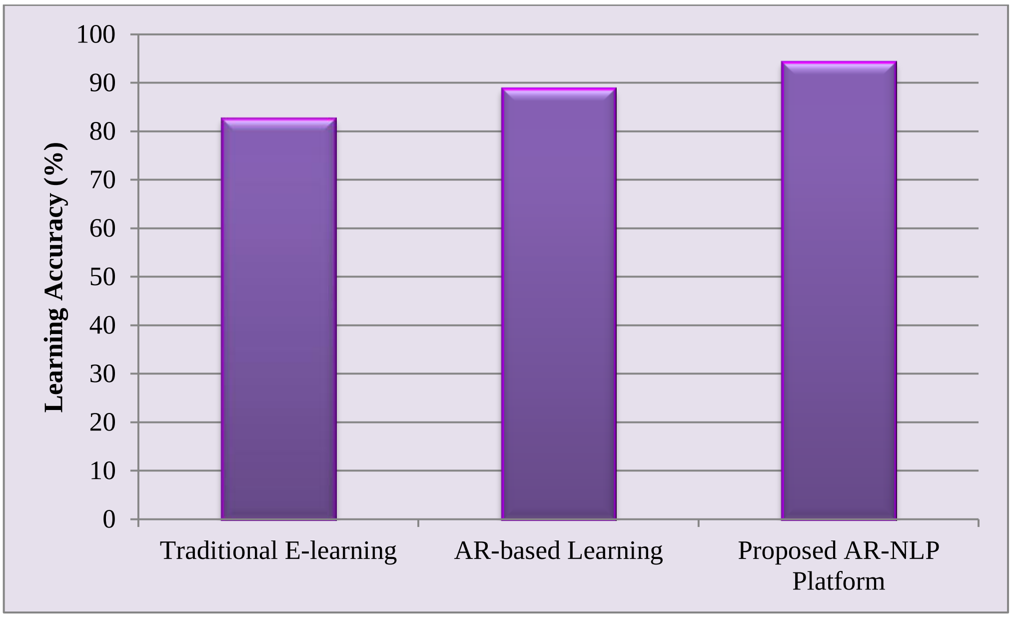

Figure 2. Learning Accuracy Comparison

The integration of smart conversational support and 3D visualization leads to enhanced accuracy, which aids learners understand difficult ideas effectually.

6.3 Knowledge Retention Analysis

Knowledge retention is defined as the ability of a learner to recall what has been learned. The developed system displayed a retention rate of 92.8% which is higher than that of conventional learning techniques which is given in Figure 3. The immersive characteristics of augmented reality visuals elevated the process of memorization to new heights.

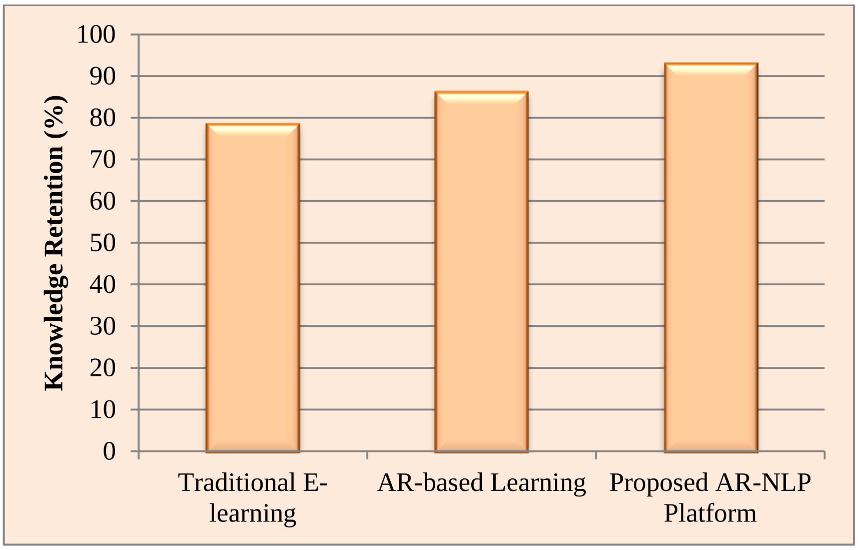

Figure 3. Knowledge Retention Comparison

6.4 Learner Engagement Analysis

The effectiveness of Learner engagement was assessed based on interaction frequency, learning duration, and participation levels as represented in Figure 4.

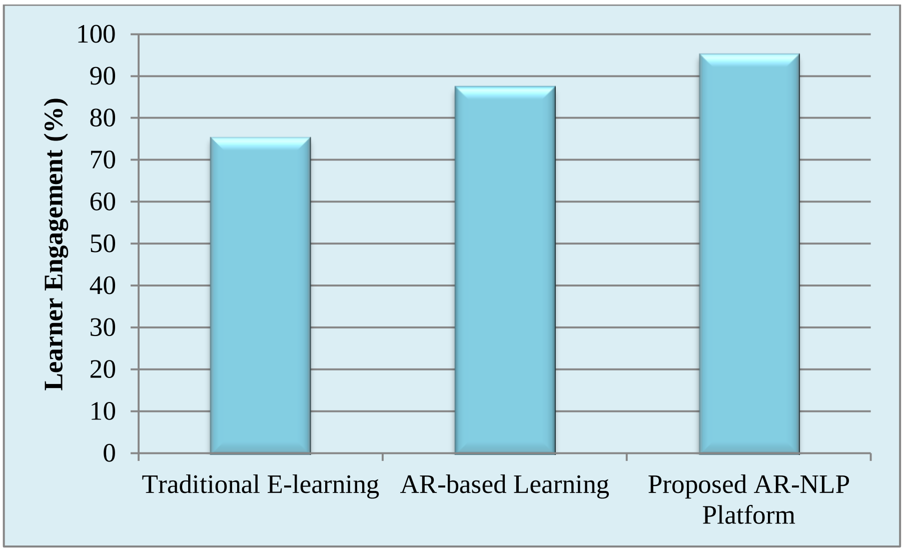

Figure 4. Learner Engagement Comparison

A learner participation score of 95.1% was achieved by the proposed platform, representing robust learner engagement and constant interface throughout the learning process.

6.5 Response Time Analysis

Response time means the average time taken by the system to produce a response to learner inquiries. The working system achieves an average response time rated 1.28 seconds which is satisfactory for educational apps in real-time situation. Figure 5 depicts the comparison of response time (s).

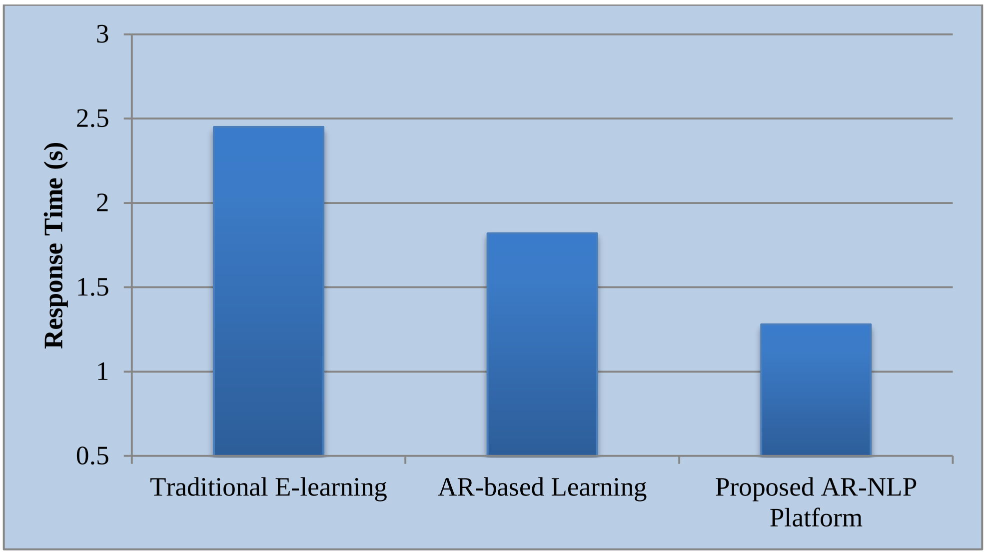

Figure 5. Response Time Comparison

6.6 User Satisfaction Analysis

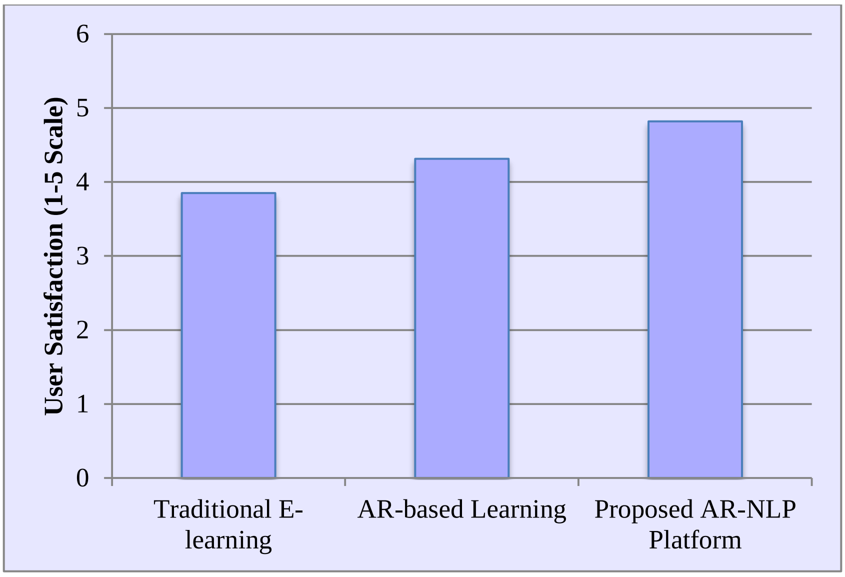

Figure 6. User Satisfaction Comparison

User satisfaction for the proposed system has been evaluated by learners' feedback collected using questionnaires based on a five-point Likert scale. According to the Figure 6, the system placed itself with an average score of 4.82/5, which means the system has high acceptance among its users.

6.7 Discussion

According to the results of the experiments, AR-NLP platform is better than the traditional education systems, which usually employ static learning materials and allow little interaction, limiting the engagement of learners. AR technologies improve visualization but usually do not provide intelligent support and personalization. The presented approach combines AR and NLP tutoring, recommendation, and learning analytics in one framework, allowing the system to adapt the offered learning content taking into account the behavior and progress of the learner. The possibility to integrate the approaches into one system increases the effectiveness of learning processes and shows the high potential of educational systems based on the approach in different educational settings.

7. CONCLUSION

The report investigates changes in consumer tastes and buying habits in the case of Generation Z in the area of sustainable fashion. Being called the first digital natives among the generations, Gen Z is becoming economically influential and possessing strong beliefs regarding environmental protection. It means Gen Z could change the retail landscape. This report summarizes the research on consumer drivers of sustainable behavior, such as the demand for transparency and authenticity in brands. The report also studies contradictions in Gen Z's behavior through the lens of the "value-action gap" concept, which points at the difference between attitudes and actual purchases of the representatives of this generation.

The recommendation system personalizes educational material according to student performance and engagement levels, while the analytics tool continually assesses learning success and gives feedback for optimization. According to experimental results, the developed system provides higher learning precision, knowledge retention, engagement of learners, and satisfaction of users compared to classic e-learning and AR-based educational systems. The developed model is appropriate for both in-class and distance learning environments and can be used in various educational fields. The further steps will address the incorporation of generative artificial intelligence technology, multilingual communication assistance, emotional learning analytics, as well as collaborative AR technologies into improving the personalization and efficiency of the next-gen intelligent education systems.

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