



## Reimagining Virtual Education: The Role of Augmented Reality in Enhancing Learning Outcomes and Satisfaction through Personalized and Interactive

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### ABSTRACT

Through the seamless integration of virtual components into the actual environment, augmented reality (AR) is a new technology that offers people true immersion. Its use is widespread in many sectors, notably education because it has great potential to improve student performance. Learning results, inspiration, and participation among pupils have all been demonstrated in this study to increase when augmented reality is used in the classroom. It has been utilised to improve learning in a range of educational settings, from universities to basic schools, including science, literary works, and politics. In order to conduct an in-depth analysis, a close-ended survey questionnaire is designed including all of the variables, to collect data from 357 students involved in the top 15 schools in Zhengzhou. The findings of this also represent a good reliability of all items with the research purpose.

**Keywords:** E-learning experience, Virtual learning environment, Perceived ease of use, digital knowledge

### 1. INTRODUCTION

Augmented reality offers a multimodal learning environment that incorporates visual, aural, and kinaesthetic learners. Augmented Reality (AR) enhances the understanding and memory of intricate ideas by merging virtual and physical world encounters [1] [2]. Since AR-based educational games are naturally dynamic and captivating, they inspire students' interest and active engagement. As the application is realistic, it promotes discovery and investigation. It



raises curiosity and drive in the subject matter. Additionally, AR can create dynamic and interesting experiences out of conventional instructional resources [4]. Learners can browse 3D models, control objects, and see mysterious ideas in real time with augmented reality (AR) applications. Thus, it helps them retain and recognise complicated concepts better [5]. Additionally, augmented reality (AR) enables tailored and flexible lessons that accommodate different learning needs and styles. The investigators have recognised some factors such as *user Engagement, technical quality of AR tools, learning content design, and AR features* for this research project to investigate how these factors have a significant impact on virtual higher education environments including the mediation role of perceived ease of use [7]. Irrespective of the possibility it holds, obstacles like financial constraints and technology constraints prevent AR from being widely used in education. Working together, educators, technology professionals, and policymakers can create scalable, long-lasting augmented reality alternatives that put educational fairness and affordability first [12]. Augmented Reality (AR) presents chances to improve learning outcomes in classrooms by providing individualised, enveloping, and engaging environments. Through the use of augmented reality (AR) technology, educators may establish interactive learning spaces that stimulate innovation, analytical thinking, and teamwork in students, equipping them with the skills needed for flourishing in the digital age [2].

## **A. Aim**

This study aims to assess the impact of augmented reality on student learning outcomes and satisfaction in virtual higher education environments. Along with measuring satisfaction, the project intends to investigate how the engagement characteristics under investigation affect students' and educators' observed levels of contentment.

## **B. Objectives**

RO1: Analyse the significant impact of user engagement on student's learning outcomes and satisfaction

RO2: Assess the significant effect of the technical quality of AR tools on students' learning outcomes and satisfaction

RO3: Investigate the significant influence of learning content design on students' learning outcomes and satisfaction

RO4: Examine the significant impact of AR features on students' learning outcomes and satisfaction

RO5: Evaluate the mediating role of perceived ease of use and its significant impact on the relationships between the AR features and students' learning outcomes and satisfaction.



RO6: Explore the significant impact of perceived ease of use on students' learning outcomes and satisfaction.

### C. Research questions

RQ1: What is the significant impact of user engagement on student's learning outcomes and satisfaction?

RQ2: What is the significant effect of the technical quality of AR tools on students' learning outcomes and satisfaction?

RQ3: What is the significant influence of learning content design on students' learning outcomes and satisfaction?

RQ4: What is the significant impact of AR features on students' learning outcomes and satisfaction?

RQ5: What is the mediating role of perceived ease of use and its significant impact on the relationships between the AR features and students' learning outcomes and satisfaction?

RQ6: What is the significant impact of perceived ease of use on students' learning outcomes and satisfaction?

### D: Research Hypotheses

**DV: *Student Learning Outcomes and Satisfaction:*** Student learning outcomes and satisfaction are declarations of what learners will know, understand, or be capable of showing after finishing or engaging with an educational material or program [9].

**IV: *User Engagement:*** Gamifying learning with AR (augmented reality) applications will increase learner enthusiasm and participation while fostering logical thinking in the classroom [11]. On the other hand, using augmented reality in the learning environment allows instructors to more courteously and simply convey complex concepts and subjects [14]. Furthermore, by enabling students to engage with the content at their speed and in their preferred manner, augmented reality (AR) could give them a significantly personalised educational experience.

***Technical Quality of AR Tools:*** A Software Development Kit, or SDK for short, is a collection of tools and applications used to create additional software. It is a type of augmented reality technology. An **SDK** that is accessible to download and install and freely available for creating augmented reality applications for many platforms' gadgets is called **ARToolKit** [18] [14]. ARToolKit has received many improvements. The most recent release has some features, such as quick camera setup, instantaneous fashion speed assistance, characteristic marker creation, monitoring of geometric pictures, and simple black boxes [9] [11]. Additionally, ARToolKit includes several optional modules for **OpenSceneGraph** and **Unity construction**.



**Learning Content Design:** ‘Content’ in the broad sense of *user experience (UX)* and *user interface (UI)* design often encompasses data, pictures, videos, or writing that are incorporated into digital knowledge, such as a web page, software, or business[13]. Making well-informed decisions on the many components of learning, including activities, techniques, examinations, framework, satisfaction, and further, is known as learning layout.

**AR Features:** Using little to no involvement, augmented reality (AR) overlays digital components on top of real-world images. In-depth interaction between the user and the envisioned items is possible due to augmented reality (AR) implementation [16]. User actions directly impact the way that reality is reproduced on screen. AR glasses and handheld gadgets like tablets or smartphones could be used to project visuals through augmented reality.

**MV: Perceived Ease of Use:** The perceived ease of use is a subjective component that refers to the individualised beliefs and perceptions of the ease involved in integrating and using technology [19]. The degree to which a person thinks utilising a specific technology would be effortless can be described as perceived ease of use [20]. It refers to an individual's understanding of the straightforwardness of technology, its ease of understanding without using more effort, and is yet informative and user-friendly.

## **E. Scope of the project**

Future research can focus on how AR is integrated across different pedagogical frameworks, exploring its applicability concerning various teaching methodologies such as flipped classrooms, problem-based learning, experiential learning, and so on. In addition to this, the effectiveness of AR in specific disciplines could be explored such as STEM subjects and contemporary competitive arts, including how the integration of AR helps in enhancing the learning process or facilitates engagement among the students. Furthermore, one interesting area of exploration could be how different demographics of students exhibit different approaches towards or behavioural exhibits to AR where their propensity to indulge with the technology could be evaluated based on their prior experience with technology, age factors, educational backgrounds, and so on. Simultaneously, given the increasing digitalisation of educational processes future research might delve into exploring how AR is integrated across existing learning management systems (LMS) in institutions. In addition to this, future studies might concentrate on carrying out comparative studies assessing the benefits of AR with that of other immersive technologies such as Virtual Reality (VR) or Mixed Reality (MR) which can be beneficial for the higher education system to identify and opt for the best technology that shall be able to extract optimal educational outcomes and garner student satisfaction in various educational contexts.



## 2. LITERATURE REVIEW

Many philosophical views have been advanced in recent years to help explain the factors that influence the use and acceptance of various technologies that assist in the processes of instructing, learning, and assessing. The most important model for predicting how people will behave in connection with whether they embrace or dismiss technology is the **Technology Acceptance Model (TAM)** [3] [6]. Additionally, the usefulness of TAM to multiple helpful enabling technologies in education, from social media networks to technology that helps in learning using instructional robots. Furthermore, it has been examined in several acceptability studies [3]. According to the educational paradigm known as constructivism, students acquire new knowledge by elaborating on the knowledge they have already acquired. Constructivism is just one educational theory, but it can encourage students to participate more actively in their education by helping them make connections between new ideas and their experiences to improve their knowledge of previously learned material and to gain an improved understanding of newly presented concepts [10]. The foundation of **constructivism learning theory (CLT)** is the idea that learners actively engage in inquiry-based learning, expanding on prior knowledge to acquire new ideas. Classroom teachers may make the most of this strategy by assisting students gain a sense of previously taught topics by connecting them to real-world situations, which will help new teachings remain in place [10].

### **Student's learning outcomes and satisfaction**

The student's learning outcomes and satisfaction refer to the degree of fulfilment experienced by the students in the context of using AR technology in virtual higher education environments [21]. The learning outcomes are the precise information, skills, aptitudes, or dispositions that students should possess after a course or program of study [22]. Through immersive and engaging interactions with digital information, augmented reality (AR) encourages student participation and inquiry-based learning which in turn elevates their academic performance and adds to their level of engagement and satisfaction [23].

### **User Engagement**

Augmented reality (AR) improves the learning environment in education by raising student engagement and proficiency in using the technology as well as the subjects being taught [24]. User engagement in this context is enhanced through the incorporation of AR where features like realistic simulations, and 3-D modelling, amongst others provide real-life experiences in the virtual world thus fostering active participation and instilling critical thinking abilities among the students [25] [26]. The availability of these unique experiences in learning with AR helps in increasing the engagement of the students and also facilitates their competence with AR [27].



## **Technical quality**

Emphasising the technical quality of the AR is significant as it contributes to the seamless experience of the user along with eliminating undesirable interruptions such as lag, incorrect tracking, glitches, and others [28]. Technical quality is important since it helps in increasing user engagement with the technology as well as adds to user satisfaction [29]. Furthermore, technical quality ensures all the features work correctly as intended and offer optimal functionality. Applications for AR can be resource-intensive and demand a lot of computing power thus focussing on the technical aspect of it capacitates smooth and efficient usability through identifying and resolving performance concerns, such as sluggish frame rates that otherwise would undermine its efficacy and experience [30].

## **Learning content design**

The learning content refers to the computer-generated input that could comprise interactive 3D models, and simulations, distributed through visually appealing interface design for intuitive interaction [31]. In addition to clickable objects and draggable components, it can consist of gamification features as well as the overlaying aspect which enhances the visualisation and offers immersive and realistic learning environments [32]. Furthermore, the learning content design that focuses on contextualisation further enhances the attractiveness of the technology.

## **AR features**

The AR features comprise various factors such as modelling and animation, visual overlays, spatial mapping, anchoring, tracking, navigation, and so on. In the virtual learning environment using augmented reality, ARKit creates a coarse point cloud that roughly depicts its perception of the user's surroundings in 3D [33]. This also includes specific feature points that are a representation of real-world surfaces facilitated by the incorporation of existing web development technologies, including CSS, HTML, and JavaScript [34]. Furthermore, the collaborative experiences provided by these technologies allow multiple users to interact with the same AR content simultaneously which adds to its desirability among the students [35].

## **Perceived ease**

The degree to which a person believes that using a particular system would be free of effort is an expression of perceived ease of use. The term "perceived ease of use" refers to how simple an individual believes a technology to be wherein the fundamental ideas behind this concept were adapted from TAM [36]. It can be estimated that under homogeneous circumstances, users are more likely to adopt an application that they find easier to use than another.



## Hypotheses Development

### **H1: User engagement has a significant impact on student's learning outcomes and satisfaction**

AR uses gamification and multimedia instruction to keep students interested throughout the course. This facilitates easy and enjoyable learning. Virtual worlds and other absorption strategies allow students to delve deeper into the course topics [8]. Lessons seem more engaging, applicable, and authentic as a result. Through a variety of access points and interactive learning opportunities, augmented reality (AR) may improve education. AR, for instance, can assist students in visualising difficult subjects like geographical location, science, or physiology by presenting them with 3-dimensional models [17].

### **H2: Technical quality of AR tools has a significant impact on student's learning outcomes and satisfaction**

The impressive features of augmented reality technology could inspire students to participate in recreated learning tasks and make the connection between virtual and real-world learning settings [12][14][16]. A favourable mindset towards studying is developed with this, and educational motivation also increases. Distance barriers are removed from communication between students and instructors globally thanks to technology [1][7]. Students are being prepared for a globalised future through the use of virtual classes, online assignments, and interactive platforms. It introduces varied viewpoints into the learning atmosphere.

### **H3: Learning content design has a significant impact on student's learning outcomes and satisfaction**

The capacity of students to implement what they have learnt in real-world situations outside of the classroom or training space is one of the key results of learning that are prioritised in effective instructional design [15][16][18]. It adds learners' participation and information retention. Consequently, this optimises operational effectiveness and may lower expenses for institutions [16].

### **H4: AR features has a significant impact on student's learning outcomes and satisfaction**

Present-day investigation of simulated settings, virtual item manipulation, and virtual experimentation are all made possible for students by AR [4][6][15]. This practical method promotes active attention and helps in the growth of students' ability to think critically and solve problems skills. Learners with a range of learning challenges may find it easier to attend college using the help of augmented reality (AR) [17][18].

### **H5: Perceived ease of use has a mediating impact on user engagement**

According to the TAM model, a person's attitude about technology is the primary determinant of whether or not they utilise it. Two presumptions (reported ease of use and perceived



usefulness) support this tendency [8]. It clarifies that the degree to which an individual thinks utilising technology should be simple is known as perceived ease of use [4][8]. The argument leads to the conclusion that the belief about the action that will result in a choice is the element responsible for perceived ease of use [8].

### **H6: Perceived ease of use has a mediating impact on the relationships between AR features and students' learning outcomes and satisfaction**

The perceived ease of use is a determinant of the users' intention of indulging and using the technology [37]. In the context of this study, it can be mentioned that the perception of the students regarding the usability of the AR technology can determine their attitude toward using AR and benefiting from it which is then reflected in the learning outcomes. The satisfaction derived from the interaction with AR further propels their frequency and engagement with the technology.

### **Literature gap**

There is a prominent lag in data regarding the development of learning interventions that have been designed as an aftereffect of the integration of Augmented Reality in virtual educational environments along with its associated learning outcomes.

## **3. PROPOSED METHODOLOGY**

This chapter provides an overview of the various techniques and methods that have been incorporated to execute this research. The research philosophy is primarily associated with guiding the research through making assumptions and figuring out pathways for reflecting on the research topic. Three basic research philosophies are widely implemented in research studies that are positivism philosophy, realism philosophy, and interpretivism philosophy [38]. In this research, the positivism philosophy is deemed to be relevant owing to the simplicity of its application as well as the accessibility of factual information acquired from observations that can be measured [39]. This quantifiable approach makes the findings more reliable and trustworthy along with subjective interpretation.

The research approach includes the plans and procedures that go into the identification of the processes that are applied in research to derive factual data from broader assumptions. In research, two widely prevailing research approaches are the deductive and the inductive approach. In this research, the deductive approach has been chosen to be the most ideal one as it helps in drawing valid inferences where the process begins with the development of the research hypothesis from the foundation of theoretical frameworks [40]. A deductive approach is more scientific as a theory or hypothesis can be put to the test to procure results through observations and empirical evidence.



The research design refers to the comprehensive strategy and analytical technique that have been selected in the research to coherently integrate the various components of the study and ensure a thorough exploration of the research topic. There are three types of design widely implemented in research that are descriptive, explanatory, and exploratory research design. This research shall therefore employ the descriptive research design as it affords a detailed exploration of the subjects being studied. In order to gather information that can help define a research topic precisely, a variety of qualitative and quantitative research techniques are used in the descriptive research design [41]. In addition to this, this descriptive research design enables researchers to comprehensively examine the background of a research topic. This design is also beneficial in exploring the interaction of the different variables chosen in the study along with the accessibility of the responses of different demographics to the different variables [42].

A primary data collection method is to be employed in the research since it affords reliable, objective, and generalisable results along with the applicability of statistical methods to acquire reliable research results. According to reports published by “EON Reality,” the government of China has taken initiatives to introduce Augmented Reality (AR) in as many as 100 schools in Zhengzhou, in Henan province, China [44]. Therefore, from the top 15 schools in Zhengzhou, a total of 357 students are selected as the sample for this research from whom primary data is to be collected. The primary data can be collected from the sample by surveying with the application of a questionnaire.

The data analysis can be carried out with the help of the IBM SPSS software where inferential statistics are employed to decode the interconnection of the variables as well as the implication of one on the other. Moreover, the SmartPLS another software is also used in this study to check the reliability and validity of proposed study. It shall include regression analysis for the independent variables to explore their impact on the dependent variable along with hypothesis testing, analysing the demographic information, and so on.

In addition to this, a self-administered questionnaire is to be employed to procure data from the respondents and shall comprise close-ended questions that are developed with the help of the Five-point Likert scale. The inclusion of the scale adds to the simplicity of the survey format thus encouraging response rates and procurement of more reliable data, making the entire process easily comprehensible for the researcher and the responders.

Reliability and validity are among the most fundamental domains in the assessment of any measuring methodology for data collection [43]. Therefore, attention shall be employed to ensure the consistency of information that has been gathered from the respondents with the help of Cronbach Alpha, where values achieved in the range of 0.7 to 0.9 can be beneficial in establishing the reliability of the instrument. In addition to this, validity refers to what an



instrument measures and how well it does so, wherein the validity of research can be assured by testing the multicollinearity between variables.

It is pertinent in research to ensure that transparency is retained at all times along with adherence to ethical norms to eliminate any scope of falsification, misrepresentation, or fabrication of the information collected from the respondents. Therefore, this research shall comply with the Personal Information Protection Law (PIPL), 2021 to maintain the anonymity and confidentiality of the respondents along with prioritising autonomy, protection of the data, and more.

## 4. RESULTS

### Demographic results

The demographic information or results for a quantitative study is a collection of all the data which is related to the demographic characteristics about the respondents of the study. These different characteristics can involve aspects such as age, gender, highest qualification and more. The demographic information table below is the one related to the demographic characteristics and the numerical count data related to the same about the respondents of the current study. These characteristics include gender of the respondents, ethnicity, year of education of each of the respondents and the age of the respondents. As per the following table, the count of female respondents is greater than that of the male respondents. According to the table of demographic information below, it is also evident that the majority of the respondents of the current study are Tujia by their ethnicity with a count of 176 total respondents. The data below also shows that 175 of total respondents have a year of education in the 2nd year as their highest degree year. Lastly, the demographic profile detail below shows that 175 total participants out of all the respondents of the study are in the age group of 21-22 years.

**Table 1: Demographic Detail**

		Count	Column N %
gender	Male	169	47.3%
	Female	188	52.7%
ethnicity	Manchu	101	28.3%
	Tujia	176	49.3%
	Hui	80	22.4%
Year of education	1st year	93	26.1%
	2nd year	175	49.0%
	Final year	89	24.9%
age	18-20 years	100	28.0%
	21-22 years	175	49.0%
	23-24 years	82	23.0%



## Reliability analysis

Reliability analysis mainly helps to process all of the data in a dataset to identify the significance of proposed research study. On the other hand, to check the reliability and validity of proposed study- reliability analysis is also very important. Here, in this study by using PLS software, and developing both initial and final model- the reliability for this study is figured out.

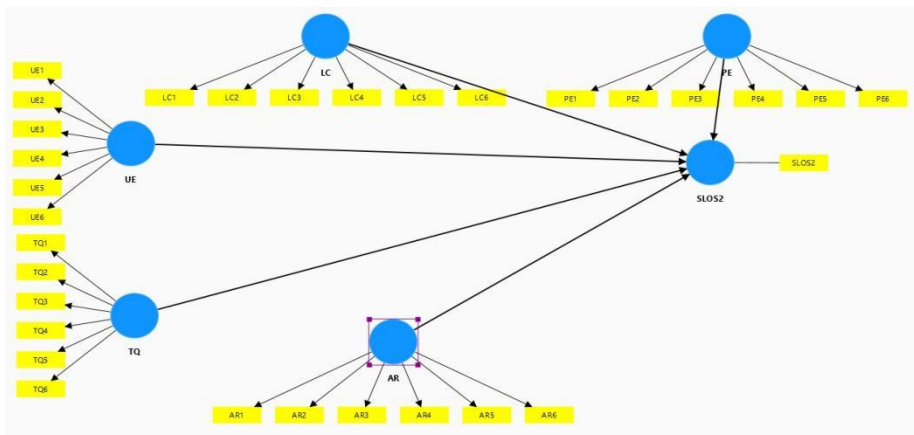


Figure 2: Initial Model

The above figure 2, is the initial model that is generated through PLS. Here, from the outcome of this model- the relationship between variables is clearly understood. Analyzing the above figure in reliability analysis, it is found that UE, TQ, LC, AR, and PE have a direct impact on SLOS. Based on that, the final model is generated that can help to check the reliability of this study.

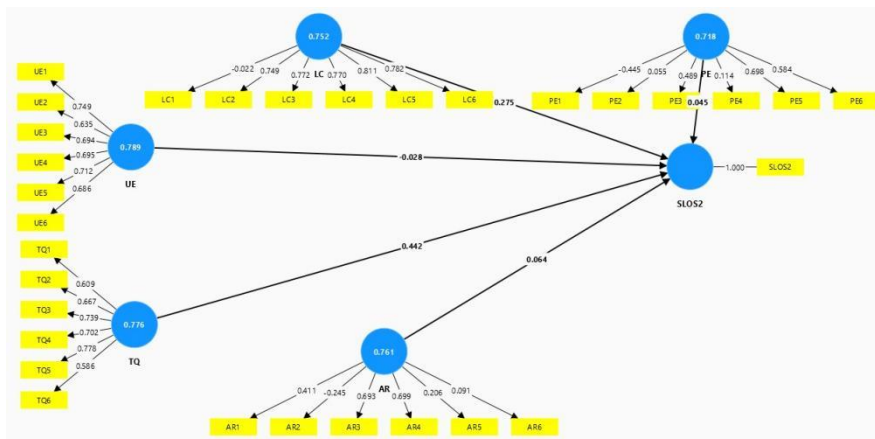


Figure 3: Final Model

Developing the final model through PLS, the reliability of all items are clearly understood. The Cronbach alpha value for all items is identified through the following figure 3- Final Model.



The Cronbach alpha value for “*User Engagement*” (*UE*) is figured out as less than .950. The Cronbach alpha values for UE1, UE2, UE3, UE4, UE5, and UE6 are determined as 0.749, 0.635, 0.694, 0.695, 0.712, and 0.686. It refers that UE has a good reliability with UE that supports this research purpose.

The *Technical Quality (TQ)* of AR tools is also considered as another predictor variable of this study, and the Cronbach alpha value for all of these items are figured out as 0.609, 0.667, 0.739, 0.702, 0.778, and 0.586. All of these values against this construct are less than .050, which refers to a significant reliability of this variable with the research outcome. The third construct of this study is *Learning Content design (LC)* that also has a good reliability with this study. The Cronbach alpha values for all of these items are as follows- 0.022, 0.749, 0.712, 0.770, 0.811, and 0.782. All of these values are at the level of less than .950. Therefore, it can be said that TQ and *Student’s Learning Outcome and Satisfaction (SLOS)* have significant reliability in this study.

*AR features (AR)* are one of the crucial factors of this study that hold a good reliability with Student’s Learning Outcome and Satisfaction. The Cronbach alpha values of all items in AR are found from the final model, that are- 0.411, 0.245, 0.693, 0.699, 0.206, and 0.091. It indicates that AR also has a positive reliability and has a significant impact on Student’s Learning Outcome and Satisfaction. *Perceived Ease of Use (PE)* acts as a mediating variable of this study. The Cronbach alpha value for these constructs is- 0.445, 0.055, 0.489, 0.114, 0.698, and 0.584. It also denotes that PE and its related items have a significant impact on the Student’s Learning Outcome and Satisfaction.

### Pearson’s correlation

Pearson’s correlation is a common statistical measurement which is generally used for finding the degree of significant impact that any independent variable has on a dependent variable. This is an analysis which is also used for understanding the validity of the research methods used in a study. The significant value is calculated based on the relationships between each of the different variables as can be seen in the table below. For the very first variable being the dependent variable of the current study, the student’s learning outcomes have significance values below 0.05 for most of the variables. This means that this independent variable has significant relationships with those variables for which these values have been found. For the first independent variable, user engagement, the significance values are mostly less than 0.05 except for the mediating variable of Perceived ease. Furthermore, the significance values in the below table for the next independent variable technical quality are also mostly less than 0.05 which shows that this variable also has significant relationship with the other variables other than the mediating variable. For the next two variables learning content design and AI features, the following table shows the different significance values at a significant level of 0.05 being less than this significant value showing these variables again have significant relationships with



the other variables. In terms for the mediating variable, it is seen that this variable only has a significant relationship with AR features due to the significance value in the below table for the same being less than 0.05

**Table 2: Pearson’s correlation**

Correlations		SLOS	UE	TQ	LC	AR	PE
SLOS	Pearson Correlation	1	.681**	.749**	.672**	.044	.039
	Sig. (2-tailed)		.000	.000	.000	.409	.459
	N	357	357	357	357	357	357
UE	Pearson Correlation	.681**	1	.764**	.724**	.116*	.090
	Sig. (2-tailed)	.000		.000	.000	.028	.091
	N	357	357	357	357	357	357
TQ	Pearson Correlation	.749**	.764**	1	.690**	.040	.019
	Sig. (2-tailed)	.000	.000		.000	.447	.726
	N	357	357	357	357	357	357
LC	Pearson Correlation	.672**	.724**	.690**	1	.078	.036
	Sig. (2-tailed)	.000	.000	.000		.141	.493
	N	357	357	357	357	357	357
AR	Pearson Correlation	.044	.116*	.040	.078	1	.734**
	Sig. (2-tailed)	.409	.028	.447	.141		.000
	N	357	357	357	357	357	357
PE	Pearson Correlation	.039	.090	.019	.036	.734**	1
	Sig. (2-tailed)	.459	.091	.726	.493	.000	
	N	357	357	357	357	357	357

\*\* . Correlation is significant at the 0.01 level (2-tailed).  
 \* . Correlation is significant at the 0.05 level (2-tailed).

### Multiple regression analysis

The multiple regression analysis is the statistical test which is one of the most crucial tests used mainly for understanding the relationship impact of the different variables developed in a quantitative study. This is the same test, results of which are used for concluding the results of the hypothesis test for the different hypotheses that are based on the relationships between the same variables of a study. A significant value of 0.05 is considered to be the tolerable value for this statistical measure. This value being lower than 0.05 is what helps accept the hypothesis related to the relationship between the variables. For the first independent variable user engagement it can be seen that the significance value calculated is 0.011 which is less than 0.005. This means that user engagement has a significant impacting relationship with student’s



learning outcomes and satisfaction. Furthermore, the significance value for technical quality is also within the desirable range which ensures the impacting relationship this independent variable has with the dependent variable. The significance value for the next independent variable, learning content design is again less than 0.05. This means this independent variable has a significant relationship with the dependent variable as well. For the next two variables AR features and Perceived ease, the significance value calculated for the variables are not less than 0.05. This means that based on the multiple regression analysis model developed for this current study, these two variables do not have a significant relationship with the dependent variable.

**Table 3: Multiple regression analysis**

Coefficients <sup>a</sup>								
Model	Unstandardized Coefficients		Standardized Coefficients	Sig.	95.0% Confidence Interval for B			
	B	Std. Error			Lower Bound	Upper Bound		
	(Constant)	-.029	.177	-.166	.868	-.377	.318	
1	UE	.170	.066	.146	2.552	.011	.039	.300
	TQ	.557	.064	.470	8.704	.000	.432	.683
	LC	.301	.062	.244	4.839	.000	.179	.424
	AR	-.042	.055	-.038	-.775	.439	-.150	.065
	PE	.046	.062	.036	.746	.056	-.076	.169

a. Dependent Variable: SLOS

### Sobel test

The Sobel Test is mainly utilised in this study in order to determine the mediating impact on the relationship between independent and dependent variables. Similarly, here in this study by help of Sobel test, the mediating impact of Perceived Ease of Use on the relationship between User Engagement and Student's Learning Outcome and Satisfaction is understood.

**Table 4: Relationship Between User Engagement and Perceived Ease of Use**

Coefficients <sup>a</sup>						
Model	Unstandardized Coefficients		Standardized Coefficients	Sig.	95.0% Confidence Interval for B	
	B	Std. Error			Beta	Lower Bound



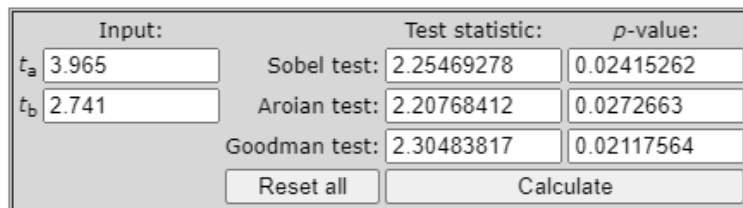
(Constant	2.642	.138		19.152	.000	2.371	2.914
1 )							
UE	.082	.048	.090	3.965	.091	-.013	.177

a. Dependent Variable: PE

**Table 5: Relationship Between Perceived Ease of Use and Student’s Learning Outcome and Satisfaction**

Coefficients <sup>a</sup>							
Model	Unstandardized Coefficients		Standardize d Coefficients	Sig.	95.0% Confidence Interval for B		
	B	Std. Error	Beta		Lower Bound	Upper Bound	
(Constant	2.781	.201		13.864	.000	2.386	3.175
1 )							
PE	.050	.068	.039	2.741	.059	-.083	.183

a. Dependent Variable: SLOS



**Figure 3: Sobel Test for User Engagement**

The t value for User Engagement is figured out as 3.965, and the t value for Perceived Ease of Use is figured out as 2.741. It is stated that the t value should be above 1.96, in order to make the mediating impact satisfied in this study. Considering both of these t values, the z-score for the sobel test is determined as 2.2546, that is also greater than 1.96. It refers that Perceived Ease of Use mediates on the relationship between User Engagement and Student’s Learning Outcome and Satisfaction in a significant way.

## 5. DISCUSSION

The study has identified the role of augmented reality influencing student learning outcomes and satisfaction as a result of the virtual higher education environments. Factors like user engagement, technical quality of AR tools, learning content design, AR features and perceived ease of use in order to determine its impact on student learning outcomes and fraction. It is



evidence from the study that all of these factors have a significant impact over the student satisfaction rate. Based on the reliability of the obtained methods it can be seen that consistent results can be generated when the test is reproduced in future under similar conditions.

The demographic information of the respondents in the study has revealed that the majority of the respondents belong from the second year of their education. Hence, it can be considered that a moderate range of information has been generated from such individuals regarding their conception on how augmented reality has improved student satisfaction and learning outcomes. It is evidence from these findings as well that the experiences students have had at this age group regarding the utilisation of augmented reality for educational purposes would provide concrete responses as to how technology is beneficial for student satisfaction and generating positive learning outcomes. The multiple regression analysis has proven that the variables like user engagement, technical quality and learning content design have a strong relationship with the dependent variable students' learning outcomes and satisfaction. This can be helpful in understanding the support of the different hypotheses for this study.

There was also the reliability analysis that has been conducted using the SMART Pls method based on which the reliability of the research methods of this study has been measured. It has been found in this test that the reliability of the research methods is good. This indicates that the research methods that have been used for the current study can also be used for other similar studies in the future for generating similar results much like the current study. Furthermore, the hypothesis related to the mediating variable perceived ease is also tested through the results of the same. It has been evident that variables such as user engagement has a definite impact on students' learning outcomes and satisfaction as was also seen in previous studies [45]. Other than this, there is also a significant impact of technical quality that the teachers can use in schools for helping improve the teaching quality as well as the learning experiences of the students as was seen in different studies which were reviewed for the current study as well [36]. As seen in studies before as well, it always depends on the perceived ease of using the different technological advancements which can help improve the student learning outcomes specifically for the students in virtual educational settings [23]. The mediating role has also been proved in the current study's data analysis as well.

The findings of this study clearly find that it can be concluded that these variables have the most significant influence over the and has mined of students learning outcome and satisfaction. Apart from that, AR and its related tools also help the students to get access to different learning content design. They can also prepare learning resources and materials through using several AR features. Therefore, it can be summarised that AR applications can help students to evaluate their learning strategies and techniques as well as deliver significant learning outcomes and satisfaction. During the same period, it is also found that Augmented Reality advanced the virtual higher education environment that encouraged and motivated



students toward their learning processes. Reviewing different kinds of previous studies, and applying quantitative tests, all of the formulated hypotheses also become supportive for this research purpose.

An additional Sobel test has further proven how the perceived ease of use of augmented reality influences user engagement and students learning outcomes and satisfaction. Based on this information it can be concluded that augmented reality can be utilised by educational institutes for enhancing the learning outcomes and satisfaction rate. It can however be recommended that a future study is conducted regarding similar concepts that collect qualitative interviews of educational institute authorities in order to generate a better understanding of the situation from a different perspective. Apart from Augmented Reality, the significance of Mixed Reality (MR) is also exposed throughout the discussion of this study. Following the aforementioned discussion, it also can be concluded that using AR applications, and features can help students to extract vast optimal educational outcomes that ensure a higher level of student's learning outcome and satisfaction.

### Instruments and Questionnaire

Variables	SI No	Questions	Source
Student's learning outcomes and satisfaction	SLOS 1	I think student's learning outcomes and satisfaction is effectively navigated through the course resources on the internet.	(Aldhahi et al., 2021)
	SLOS 2	I can successfully interact through email with my teacher.	
	SLOS 3	Through the technical process, I can overcome technical obstacles by myself.	
	SLOS 4	I believe that I can acquire the ability to utilise a new technology effectively.	
	SLOS 5	I can gain knowledge without having to share a room with the teacher.	
	SLOS 6	When I have a query about a course, I can look for the answer online.	
User Engagement	UE1	I take a lot of time to list all the good and bad things about myself.	(Jessen et al., 2020)
	UE2	Thoughts regarding how others could better themselves are not something I dwell on often.	
	UE3	I most likely emerged with a concept that no one else did.	



	UE4	I anticipate being happy with the design of the project decisions I make.	
	UE5	I hardly ever reflect on the discussions that I had with other people after they have ended.	
	UE6	Usually, I assess their performance based on many factors.	
Technical quality	TQ1	I believe that the AR group's test result has much improved.	(Gerup, Soerensen and Dieckmann, 2020)
	TQ2	In my opinion, it has fewer average placement mistakes of the precordial sensors.	
	TQ3	In my opinion, the AR group's test results are noticeably superior.	
	TQ4	Compared to a movie and note, I believe a significantly greater test result was acquired with the use of AR.	
	TQ5	No noticeable variation in insertion time, in my opinion.	
	TQ6	I believe that the system made people more motivated.	
Learning content design	LCD1	I think learning content design is important for student engagement in the virtual learning environment	(Keshavarz, Mirmoghtadaie & Nayyeri, 2022)
	LCD2	I believe emphasising learning content design can be beneficial in evoking critical thinking among the students.	
	LCD3	I feel learning content design is imperative to enhancing communication in the virtual environment	
	LCD4	I think the effectiveness of the learning content design is majorly affected by the instructor and the authorities	
	LCD5	I believe learning content design lays the foundation for the activities in virtual learning	



	LCD6	I feel learning content design is subject to the technological competence of the stakeholders	
AR features	ARF1	I believe playing mobile augmented reality games is simple.	(Cai et al., 2023)
	ARF2	I fear that smartphone augmented reality will gather much too much personal data about me.	
	ARF3	I like to compete with other people.	
	ARF4	I think mobile augmented reality users are seen as more respectable than non-users.	
	ARF5	Without any hesitation, I will be among the first to attempt to create an image in smartphone augmented reality.	
	ARF6	I feel AR features affords the 3D identification of virtual and real-life components	
Perceived ease of use	PEU1	I think perceived ease of use is subject to flexibility of interaction	(Pal & Vanijja, 2020)
	PEU2	I believe perceived ease of use is related with the acquisition of skillfulness	
	PEU3	I feel perceived ease of use of VR can enhance the effectiveness of the teachers in their job roles	
	PEU4	I think perceived ease of use is necessary for accomplishing tasks in a successful manner	
	PEU5	I believe perceived ease of use significantly helps in increasing the productivity of the students	
	PEU6	I feel perceived ease of use is important for the students to gain a notion of autonomy in learning	



## 6. COMPETING INTERESTS

The authors did not receive support from any organization for the submitted work. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

## 7. COMPLIANCE WITH ETHICAL STANDARDS

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

## 8. DATA AVAILABILITY

The data supporting this study's findings are available from the corresponding author upon reasonable request.

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