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XR Technologies, Benefits and Challenges Faced in Education Sector: A Critical Analysis with reference to Urban Bengaluru

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Abstract

Purpose: The preeminent intention of the present research is to know how far the demographics impact on the study of XR Technologies, or Extended Reality or Cross Reality. Further, the study probed about the benefits of XR technology and challenges faced in higher education. The immediate developments in the domain of education is compelling and in certain cases forcing to consider and implement latest technologies, methods and practices in order to attain higher quality of education. Higher education institutions have started using XR technologies which consist of virtual, augmented and mixed reality. XR technologies has intensify the way people experience the physical and virtual environments from observations to immersions (Stephanic Hai - Wan Chauah, 2019). XR technologies has the potential to help faculty and students transcend the boundaries of classroom by providing new variety of environments for presenting, delivering instrumental content and learned experience (Cindy Ziker *et al*., 2021). XR is intensively developing technology that provides useful tools for displaying and interacting with various information (Gupta *et al*, 2023). One of the key areas of application is education and training (Wang *et al*., 2024).

Approach: A well drafted previously tested questionnaire was administered as schedule in order to avoid delay, incompleteness and rejection. Primary data gathered by visiting different colleges of different streams. x^2, Contingency Co-efficient, Weighted Arithmetic mean and Summated Score quantitative techniques were performed to measure the variation and weightage of opinions of students.

Findings: The study found that all demographic profiles showing significant variation in the data with high degree of relationship. The study found benefits of XR Technologies like widens student participation, engages all students and enhances learning activity. The study also found challenges of XR technology that includes lack of trained personnel, finding discomfort while learning immersive VR and limited availability of ready-to-use XR content.

Keywords: Immersive, challenge, benefits, eye strain, discomfort, technology, multi-sensory, implement, relationship, higher education, immersion

Introduction

The concepts of Extended Reality (XR) technologies (XRs) such as Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) today is very promising technological tools for education (Ahmed Alnagrat *et al*. 2022) [1]. XR technologies is becoming more common in every day working life (Vasaraimen *et al*., 2021) [22]. These technologies are user friendly and availabilities of these technologies grow and invest in 3 technologies are often expected to widen both work and efficiency and productivity (Du *et al*., 2018; Stanton *et al*. 2020) [8, 20] and adequately research on these technologies also increased (Radianti, *et al*. 2020) [17]. These technologies are not just important from individuals point of view, but they often transform ways of organising work and working together (Orlikowski, 2007) [14]. The upcoming 5G allows the users to transfer big data instantly and each successful Computed Radiography (CR) content means a huge technical leap. AR and VR can dramatically improve the educational experience of providing a computer generated 3D

environment that can be explored and interacted with the students. Educators should be looking for ways to leverage existing tools to create meaningful interactions using XR technologies while continuing to explore new opportunities that have not yet been invented (Ziker *et al*., 2021) [6]. They create new opportunities for students and teachers and assist in the presentation of contents in the class room at low cost (Ahmed Alnagrat, 2022) [1]. XR technologies are transforming various fields including aviation, maritime transport logistic, autonomous vehicles (AVs), pedestrian safety and Intelligent Transport System (ITS). Now XR technologies are used in the areas like pilot and driver training, real time navigation assistance and complex simulations offering solutions to longstanding challenges in transportation safety, efficiency and decision making. With sufficient support XR has the potential to help faculty and students transcend the limits of classroom by providing new type of environment for presenting and delivering instrumental content and creating learned experience (Cindy Zukier *et al*., 2021) [26]. Universities can generate more income when compare to primary and secondary schools and many private managements are developing and adopting target curriculum that follows XR technologies in specific domains like health, engineering and commerce which helps to prepare the next generation of the market. XR technologies describe all real and virtual considered environments between human and computer input (Ahmed Jannah Ahmed Alphagrant, 2022) [18].

Statement of the problem

XR technologies are better for enhancing instructions and learning experiences in out of classes and a better system them traditional education system based on remembrance and board reaching which is largely followed in +2 grade, degrees and post graduation. Some of the best institutions in Bengaluru attempted to adopt technology based teaching at the university level. VR Simulations have been shown to provide effective instructions and tools that can transfer soft skills to the classroom and workplace (Souza, V. *et al*. 2020) [19]. XR helps to reduce the overall cost and whereas the cognate learning experience was expensive in different respects. XR technologies touches wider audience of learners and offer newer opportunities for the students. Researchers conducted previously reveal that the usage of XR technologies have link with improvement in student academic performance and motivation, XR technologies improves the students performance and hence many private institutions are implementing the XR technologies laboratory.

Review of Literature

Maryam Biognah *et al*. (2025) [13] stated that agricultural sector confronts critical challenges like climate change, over population and resource shortage compelling urgent innovate solutions. The researchers further, clarified that XR technologies emerged as a transformative technology offering ground breaking approaches to latest farm practices. The study conducts a thorough literature review to explore the integration of XR technologies in agriculture, livestock farming and aquaculture. The analysis is revealed a significant increase in XR technology adoption over the previous two years. The findings suggest that XR technology can enhance productivity, improve training methods and facilitate remote collaboration.

The study by Baichuan Zeng (2025) [3] examine the current state of XR technology, its applications across various domains, and explores future directions, with a particular focus on AI powered spatial intelligence might address existing limitations and enable new capabilities. The analysis of framework components and showcasing commercial products, this study intends to provide a comprehensive review of where XR stands today and where it might be headed in the future. Further, the researcher expressed that XR's application span industries from workforce development and healthcare to entertainment and design, demonstrating their versatility in solving the real world problem and creating a new opportunities for innovative experiences.

Research paper delve into the potential advantages and difficulties of suing XR technology in engineering education. The paper also examines the factors influencing the acceptance and intention to continue using XR in teaching practice from instructors' view points. The study identified 5 themes that affect the use of XR in teaching practice. As per the research, professional development, technical support, XR and infrastructures are crucial contextual factors that positively influence the use XR in teaching practice. The paper stress on the need for addressing technical and infrastructure difficulties and providing adequate professional development and social support to facilitate.

Senthil Kumar Jagatheesa Perumal *et al*. (2022) [18] conducted a survey of review of XR solutions and associated challenges in education, training and skill enhancement in different fields through Internet of Everything (IoE) applications from the Metaverse prospective. The study highlighted the important ideas involved in XR and 10E technology as well as vital features incorporated for obtaining and skill enhancement through Metaversa. The researchers contribution helps to know the state of art features of XR and 10E devices and their application capabilities.

Valentin Kuleto *et al*. (2021) [21] express that colleges, universities and other educational institutions like Ed Tech companies can gain competitive advantage over the rivals. These institutions will have to implement in order to meet the growing demand for adoptive and personalised education. Further, the researcher stated that Y&2 group of students are critical for higher education institutions and in order to address and sharing the values requires the use of XR technologies on their content.

Materils and Methods

Data Source: The current research work depends upon both primary and secondary data. Primary data gathered by proper administration of previously known questionnaire. Interviews held in a natural condition i.e., in the different college campuses. The secondary sources include e-journals, books and magazines.

Line of Analysis: The study is descriptive in nature. x^2, contingency co-efficient, weighted arithmetic mean and summated score were performed.

Participants: The participants of this present study belongs to Urban Bengaluru's areas like Yelahanka the upcoming education hub of Bengaluru, Basavanagudi, Indiranagar and Jayanagar area in each area 25 students of different streams and have met the necessary data was gathered. The students respondents belongs to the streams of general degree and PG, Medical, Engineering, Chartered Accountants and cost accountants.

Sample and sampling technique: The sample of the study is 100 and convenient sampling technique is followed. The sample respondents from different streams is shown below: Degree and PG 61, Engineering 15, Medical 13, chartered accountants 6, and cost accountants 5. All these students are studying in different semesters of their selected streams.

Survey Instrument: A well designed and pre-tested questionnaire was administered as schedule in addition to Google form questionnaire. Both are well administered and reminds were sent to the students to complete the questionnaire and to submit online and gathered questionnaire which was used a schedule keeping in mind the possible delay, incompleteness, rejection and time conscious of respondents.

Study variable: Independent and dependent variables

The selected demographics constitute the independent variable and XR technologies becomes depended variable. All the benefits and challenges and their drivers becomes independent variable in this study.

Objectives

1. To study the impact of demographics profile of the respondents.
2. To analyse the benefits of XR technology.
3. To analyse the challenges faced by respondents students of higher education.

Hypotheses

1. There exist no significant variation in the demographics of student respondents and hence do not impact on the study.
2. There are no benefits from XR technologies.
3. Students of higher education is not facing any challenges.

Research questions

1. What are the reasons behind demographics not impacting on the study?
2. What are the benefits of XR technology?
3. What are the challenges faced by higher education students at Bengaluru?

Limitation

1. The study is very limited to select colleges of Bengaluru Urban.
2. The sample is small.
3. Any dependency on the study needs further study.

Survey Findings

Table 1 - divulge the demographics of higher education students. There are 21 males and 79 female students and out of 100, 19 only married and 81 remained single. The age details reveal that 61 students belong to 22-26 years followed by 35 between 18-22 years and 4>26 years. The education status of student delve that 35 are studying degree, 26 PG 15 engineering, 13 medical, 6 chartered accountants and 5 cost accountants. The family income reveal that 38 family members fall in the range of 40K-50K per month followed by 22 in between 50K-60K, 18>60K, 15 in between 30K-40K, 4 between 20K-30K and 3 in between 10K-20K. 80 are visiting library, 81 are participating XR technology conferences and web seminars. All the demographics are highly significantly varying with high degree of relationship.

Table - 2 proclaim about benefits of XR technology. To measure the benefits weighted arithmetic mean was performed. Likert 3 point scale with corresponding weights were considered for the study. The opinions of students is defined as f and weights as "w". The sum of "fw" is divided by sum of "w" i.e., 3 + 2 + 1 = 6. To get "WA" the sum of "fw" is divided by sum of "W". Based on the highest "WA" ranking is performed. Accordingly the first rank was awarded to the benefit of widens student participation, followed by second rank i.e., engages all students and third rank enhances learning activity. The remaining benefits are ranked as per the strength of "WA".

Table - 3 discloses data about challenges faced in highest education application. To measure the challenges summated score (SS) was performed. In order to present bipolar opinions of the student respondents 5 point Likert scale was performed with varying from "strongly agree" to "strongly disagree". The multiplication of weights with the covered sum of bipolar has been performed and the summated score has been derived. 400 and above factors with summated score are better performed one and below 400 not performed well. All the SS > greater than 400 except resource limitation to buy equipment. Summate scale was developed by Renis Likert (1932) [25].

Summary & Discussion

The main motto of the present study is to know whether demographics impacts on the study or not. Further, the study also conducted to probe the benefits and challenges of XR technologies. The demographic profile of student respondents reveal significant variation in the data with high degree of relationship. The benefits of XR technologies include widens student participation, engages all students and enhances learning activity. The challenges of XR technologies measured by performing summated score that all the factors vary significantly except resource limitation to buy equipment. The survey technique was followed in the present study and the respondent students were interviewed in their respective colleges and collected the data required. Google form questionnaire was also circulated to the student. Concerned quantitative techniques were performed like x^2, contingency co-efficient, Kendall's co-efficient of concordance, summated score and weighted arithmetic mean was performed to analyse the data. The data collected was presented in proper tables and particular quantitative techniques were performed to analyse and present the data.

Table 1: Demographic profile of Respondents

Demographics	x^2	TV @ 0.05	df	Result of x^2	"c"	Result of c
Gender	33.64	3.841	1	Significant	0.50	High Degree
Marital status	38.44	3.841	1	Significant	0.52	High Degree
Age in years	48.86	5.991	2	Significant	0.57	High Degree
Education (Studying)	41.32	11.070	5	Significant	0.54	High Degree
Family Income (Rs)	50.07	11.070	5	Significant	0.57	High Degree
Visiting Library & Computer Laboratory	36.00	3.841	1	Significant	0.51	High Degree
Visiting XR Laboratory	38.44	3.841	1	Significant	0.52	High Degree
Participation in XR conferences and webinars	46.24	3.841	1	Significant	0.56	High Degree

Source: Field Survey
Note: x^2 = Chi-square
'c' = $\sqrt{(x2 / x2 + N)}$
Where 'c' = Contingency Co-efficient, N = Number of Observations
When the value 'c' is equal or nearer to 1, it means that there is high degree of association between attributes. Contingency co-efficient will always to be less than 1. High degree is considered here if 'c' is 0.50 and above.

Table 2: Benefits of XR Technology

Benefits	Weight	3	2	1	T	WA
	Likert Scale	SA	A	SWA		
Widens student participation	f	85	15	-	100	I
	fw	255	30	-	285	47.50
Improved and enhanced memory	f	75	18	7	100	X
	fw	225	36	7	268	44.67
Engages all students	f	82	13	5	100	II
	fw	246	26	5	277	46.17
No geographical limitation	f	71	11	18	100	XXI
	fw	213	22	18	253	42.17
All purpose and can be used to teach any topic	f	72	19	9	100	XV
	fw	216	38	9	263	43.83
Provides interactive lesson for students	f	75	10	15	100	XVII
	fw	225	20	15	260	43.33
Enhances learning activity	f	80	15	5	100	III
	fw	240	30	5	275	45.83
Universal apporach and ignores socio economic and geographical disputes	f	75	20	5	100	VII
	fw	225	40	5	270	45.00
Contextual learning	f	77	15	8	100	XIX
	fw	231	20	8	259	4317
Active autonomy	f	74	17	9	100	XIII
	fw	222	34	9	265	44.17
Multi sensory experiences	f	79	10	11	100	VII
	fw	239	20	11	270	45.00
Virtual rehearsal	f	80	14	6	100	IV
	fw	240	28	6	274	45.67
Focused immersion	f	81	8	11	100	VII
	fw	243	16	11	270	45.00
Influences emotion & self respect	f	75	15	10	100	XIV
	fw	225	30	10	265	44.16
Creates fun excitements for students, develops learning process	f	70	10	10	100	XVII
	fw	210	40	10	260	43.33
Breaks physical laws & do better in areas which cannot be done in real world	f	65	32	3	100	XVI
	fw	195	64	3	262	43.67
Visiting the past, present & future	f	65	16	19	100	XXII
	fw	195	32	19	246	41.00
AR in education improves and enhances sensory developments	f	78	12	10	100	XX
	fw	224	24	10	258	43.00
Do not required heavy resources as they do not get damage, lost or stolen	f	79	14	7	100	VI
	fw	237	28	7	272	45.33
Remote presence	f	81	11	8	100	V
	fw	243	22	8	273	45.50
Global teleportation visiting places above the means	f	76	14	10	100	XII
	fw	228	28	11	266	44.33
Forward world where students and teacher can go back in time interacting with objects, animals and human beings.	f	77	13	10	100	XI
	fw	231	26	10	267	44.50

Source: Field Survey
Likert scale: 3 Point - SA - Strongly Agree, A - Agree, SWA - Somewhat Agree
Weights = 3 + 2 + 1 = 6
WA = fw total / sum of weights, e.g. 262 / 6 = 43.67

Table 3: Challenges of XR Technologies Application

Different Challenges	SA	A	N	DA	SDA	SS
XR Technology can be pretty pricey	82	10	-	4	4	
	410	40	-	8	4	462
Learning to use it takes time	75	20	-	3	2	
	375	80	-	6	2	463
Ethical and health concerns	80	12	-	5	3	
	400	48	-	10	3	461
Technological failure	75	16	2	4	3	
	375	64	6	8	3	456
Need for specialised hardware	73	18	2	3	4	
	365	72	6	6	4	453
Lack of trained personnel	82	10	8	-	-	
	410	40	24	-	-	474
User resistance	76	14	2	3	5	
	380	56	6	6	5	448
Resource limitation to buy equipment	50	14	18	18	10	
	250	56	54	16	10	386
Increased teaching leads	73	12	5	6	4	
	365	48	15	12	4	444
Constraints towards availability of equipment	70	14	4	5	7	
	350	56	12	10	7	435
Internet Bandwidth	76	14	-	3	7	
	380	56	-	6	7	449
Dedicated campus space of XR lab	61	8	17	7	7	
	305	32	51	14	7	409
Difficulty to get XR learning content that fit their specific course	75	18	3	2	2	
	375	72	9	4	2	462
Finding discomfort while learning immersive VR	76	14	8	4	4	
	380	56	24	8	4	472
Limited availability of ready to take XR content	74	16	10	-	-	
	370	64	30	-	-	464
Female learners feel strangers harassing behaviours	70	15	10	3	2	
	350	60	30	6	2	448
Danger of eye strain simulator sickness and reality blurring	69	10	12	3	2	
	345	56	36	6	2	445
VR headsets might create some discomfort or danger for any learners	68	15	10	4	3	
	340	60	30	8	3	441

Source: Field Survey

Note: (1) In the case simulated Score (SS) statistics tool only the sum of multiplication is shown between the sum of observation in each case and multiplied by concerned "w".

(2) The weights are 5, 4, 3, 2, 1.

Conclusion of the study

One of the key areas of application is education and training (Wong *et al*., 2024) [16]. The other areas of XR application includes Transportation, Education, IoT, Robotics and Ind 4.0, Medical, Engineering. Higher Education at Bengaluru requires highly interactive, learning experiences belonging to structuring information and synthesizing information from different sources. VR can be used in the areas where it is difficult to reach physically and experience in education. Teaching faculty need to undergo experience to install XR strategies in the classroom. Innumerable challenges has to be faced at the time of leveraging the XR technologies application. XR technologies offering benefits to different students of national and international level. The study found that all the characteristics of student respondents are significantly varying with high degree of relationship. The benefits of XR technologies include widens student participation, engages all the students and enhances learning activity. The challenges of XR application includes all the challenges that crosses a Summated Score (SS) of 400 that and above and only one challenge fall below 400 is resource limitation to buy equipment. SS is used to simplify the representation of sums, especially dealing with money terms, enable calculations involving sequence of numbers and facilitate mathematical analysis and problem solving.

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