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Teachers and Technology: A Comprehensive Study on Augmented Reality Awareness Among School Educators in India

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Abstract: The teaching-learning process in the modern era heavily relies on digital pedagogy, with Augmented Reality (AR) applications emerging as a suitable approach to advance it. This study assessed the awareness of AR applications among school educators in India, analyzing demographic factors such as age, gender, teaching experience, and subject specialization. A descriptive survey design with a quantitative approach was employed, involving 730 educators from urban and rural schools across India. Using a combination of random and stratified sampling, participants were selected from all 28 states and 8 union territories, covering 10% of districts per region. Data collection utilized online (email, WhatsApp, social media) and offline (pen-and-paper) methods via standardized questionnaires. Results showed that female teachers exhibited higher awareness and gain scores in AR applications compared to male teachers. However, no statistically significant difference was found in AR awareness based on gender (t=1.75, $p > \alpha$), urban-rural location (t=1.004, $p > \alpha$), age groups [$F(2, 727) = 0.689$, $p > 0.05$], teaching experience [$F(3, 726) = 0.9936$, $p > 0.05$], school type (t=0.500, $p > \alpha$), or subject specialization (t=0.240, $p > \alpha$). These findings indicate that AR awareness among Indian educators is consistent across various demographic factors, suggesting equitable exposure and understanding of AR applications among diverse teaching populations. The study highlights the potential for AR integration in education irrespective of demographic differences.

Keywords: augmented reality; awareness; school educators; teachers; technology

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1. Introduction

Technology is a powerful catalyst for enhancing education, offering unique opportunities for learning and collaboration. In today's world, smartphones, mobile gadgets, and digital devices are increasingly popular among students, making it essential for teachers to harness these tools to improve classroom teaching. The integration of technology into education dates back to the 1950s, with early examples such as the Sensorama Simulator (1957) and the first augmented reality (AR) headset, the "Sword of Damocles" in 1966, designed to assist helicopter pilots. By 1999, Hirokazu Kato developed ARToolKit, an open-source library that further advanced AR technology (Arena et al., 2022). As the use of digital devices grows, teachers must adopt innovative teaching methods to create engaging learning experiences. One such technological innovation is AR, which overlays virtual objects, audio, video, or simulations onto real-world settings (Dunleavy et al., 2009). AR integrates two- and three-dimensional digital content into real environments, engaging sensory modalities like visual, auditory, and tactile experiences (Cipresso et al., 2011). This multi-sensory approach enhances traditional teaching methods, fostering critical thinking and increasing student engagement. Currently, three types of AR are used in education: marker-based AR, which relies on target images or markers to overlay 3D content; marker-less AR, which uses sensors and algorithms to map real-world spaces; and location-based AR, which overlays digital objects based on geographical data (Softtek, 2021). These AR technologies are applied across disciplines, such as arts, science, social studies, and mathematics, making abstract or complex concepts easier to grasp. AR also benefits subjects like language education, history, vocational training, and special education, as well as higher education research, where realistic simulations enable safe practice environments. AR enhances teaching and learning outcomes by improving access to learning materials, increasing motivation and attention, enabling safer hands-on practice, and fostering creativity, imagination, and abstract thinking. It also helps in presenting complex concepts that are challenging to teach through traditional methods. By blending virtual elements with real-world settings through mobile devices and tablets, AR provides immersive and interactive educational opportunities (Pasalidou et al., 2023). Studies have shown that AR enhances student engagement, motivation, confidence, and overall satisfaction (Akcayir, 2017; Weng et al., 2020). However, successful AR integration depends on teachers' attitudes, perceptions, and behaviors. Educators' willingness to adopt AR is influenced by factors such as perceived ease of use, enjoyment, and the relative advantage of AR over traditional teaching. Positive perceptions lead to positive attitudes, which encourage teachers to integrate AR into their practices. This creates a feedback loop where consistent AR usage further reinforces favourable attitudes and perceptions (Wu et al., 2013). Teachers play a crucial role as guides, fostering discovery and self-exploration among students. AR supports this by making education more engaging and enjoyable, preparing students to become curious and empathetic global citizens (AlGerafi et al., 2023). As education continues to evolve, AR remains a valuable tool for creating dynamic, immersive, and effective learning environments.

1.1. Review of Literature

Research on teachers' awareness of Mobile Augmented Reality (MAR) consistently highlights positive awareness and a willingness to integrate this technology into educational practices. Studies show that educational mobile AR apps can significantly enhance teaching performance, effectiveness, and productivity (Pasalidou & Fachantidis, 2021). Teachers, especially in biology and language education, view MAR as a tool that makes their teaching more engaging and interactive (Ashley-Welbeck & Vlachopoulos, 2020; Schmidthaler et al., 2023). This positive perception extends to various applications, such as interactive learning, experiential learning, and the visualization of complex concepts (Perifanou et al., 2023). Despite these positive perceptions, challenges like technological errors, GPS issues, software lags, and students' unfamiliarity with AR can hinder its effective use (Mundy et al., 2019). However, teachers generally report feeling knowledgeable about AR technology and express a strong willingness to learn more to better integrate it into classrooms (Dsouza & Hemmige, 2023; Mohamad & Husnin, 2023). Factors such as perceived usefulness, attitude, and behavioral intention are significant drivers of AR adoption, while perceived ease of use plays a moderate role (Ibili et al., 2019; Salmee & Majid, 2022). There are also notable gender and geographical disparities, with female and urban teachers demonstrating more positive attitudes towards AR than their male and rural counterparts (Putiorn et al., 2018). Teachers also express concerns about institutional support, teacher training, and the availability of AR educational applications. Despite these concerns, they remain hopeful about AR's potential to enhance student motivation and bridge gaps between learners and educators (Manna, 2023). Overall, teachers are enthusiastic about the integration of AR, particularly when provided with adequate training and resources (Jamrus & Razali, 2021; Koutromanos et al., 2022). Research has shown that MAR significantly impacts teachers' knowledge acquisition and behavioral changes (Cheng & Tsai, 2014; Do et al., 2020). Several studies highlight that knowledge and subjective norms are key factors influencing MAR adoption in research and higher secondary education (Buchner et al., 2022; Cheon et al., 2012; Marín-Marin et al., 2023). Additionally, AR has been found to enhance cognitive processes like information collection and problem-solving (Georgiou & Kyza, 2017). Despite challenges in pinpointing specific effects on higher-order thinking, AR is generally seen as beneficial by both teachers and students (Wijnen et al., 2023; Ozdamli & Hursen, 2017). Factors such as perceived usefulness and ease of use strongly influence teachers' intention to adopt AR (Romano et al., 2020). Teachers in science education tend to favor smartphone applications and marker-based content, which are the most popular AR tools (Arici et al., 2021). Female teachers, in particular, show a more favourable perception of AR due to its role in enhancing classroom engagement and memorability (Alamaki et al., 2021). Age also plays a role in familiarity with technology, with younger educators typically being more aware of AR applications than older teachers (Staddon, 2022; Ventouris et al., 2021). Experienced educators tend to rely on traditional teaching methods, making them less likely to explore AR tools compared to their less experienced counterparts (Khukalenko et al., 2022). Additionally, STEM teachers exhibit higher awareness of AR due to its relevance to their fields, compared to educators in humanities or arts (da Silva et al., 2019; Sirakaya & Sirakaya, 2022). Societal and cultural factors in India also influence the exposure to and use of technology among male and female educators (Gomez-Trigueros & Aldecoa, 2021; Huang et al., 2019). However, while teachers are generally positive about MAR and its potential to enhance education, the successful integration of AR relies on adequate training, resources, and institutional support. Gender, geography, age, and subject specialization also play significant roles in shaping perceptions and adoption of this technology in educational settings.

1.2. Rationale of the Study

The integration of Augmented Reality (AR) technology into education holds transformative potential, especially in Indian schools where traditional teaching methods still dominate. This study aims to explore how Indian school teachers perceive, approach, and engage with AR applications in the classroom. While global research indicates positive awareness of AR and its potential to enhance learning, challenges such as technological limitations and insufficient training often hinder its widespread adoption. In India, where educational resources and access to technology vary significantly, understanding these dynamics is crucial (Shivani & Chander, 2023). This study seeks to bridge the gap in existing literature by examining teachers' perceptions of AR across various dimensions. It aims to assess teachers' readiness to embrace digital transformation, as well as their views on the usefulness and impact of AR on teaching and learning. The study would also explore how gender, age, teaching experience, and subject specialization influence AR adoption, as well as the factors contributing to these differences. Additionally, it would investigate the role of technological readiness, professional development, and institutional support in the adoption of AR, and asked to know what primary factors shaping Indian school teachers' awareness of augmented reality (AR) applications in education along with to what extent external elements, such as curriculum guidelines, peer collaboration, or student engagement, influence the integration of augmented reality in Indian classrooms. The findings would offer valuable insights into the barriers and enablers of AR integration, providing recommendations for policymakers and educators to enhance the adoption of AR in Indian schools.

1.3. Statement of the Study

The study titled "Teachers and Technology: A Comprehensive Study on Augmented Reality Awareness Among School Educators in India" aims to explore Indian educators' awareness of Augmented Reality (AR) in the classroom. AR technology, which integrates digital elements like sounds or images into the physical world through devices such as smartphones or AR glasses, offers significant potential in education. This research examines key issues, including teachers' perceptions of AR—whether they find it useful, their thoughts on implementing it, and their emotional responses (e.g., apprehension, interest, excitement). The study also investigates how frequently teachers use AR, and how awareness of AR varies across factors like age, teaching experience, and subject specialization. Additionally, it explores gender differences in AR awareness and the influence of school-related factors on AR adoption. By employing a descriptive survey research method, the study aims to provide a comprehensive understanding of the current state of AR awareness among Indian educators.

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Objectives

1. To assess the level of awareness of Augmented Reality (AR) applications among school educators in India.
2. To investigate the demographic factors such as age, gender, teaching experience, and subject specialization in shaping AR awareness among educators.

Hypotheses

1. A majority of school educators in India are anticipated to have limited awareness of Augmented Reality (AR) applications in education.
2. Male educators are expected to demonstrate a significantly higher level of awareness of AR applications compared to female educators.
3. Educators teaching in urban schools are expected to have a significantly higher level of awareness of AR applications compared to their counterparts in rural schools.
4. The level of awareness of AR applications among school educators in India is likely to vary significantly across different age groups.
5. Awareness of AR applications among educators is likely to differ significantly based on their teaching experience.
6. Educators in private schools are expected to exhibit significantly higher awareness of AR applications compared to those in government schools.
7. Awareness of AR applications among school educators in India is likely to vary significantly based on their subject specializations.

2. Methodology

2.1. Design

This study employed a descriptive survey design, utilizing a quantitative research approach to provide a comprehensive understanding of the research problem. The quantitative methodology involved collecting and analyzing numerical data to identify patterns, trends, and correlations, enabling the extrapolation of findings to a larger population (Creswell & Clark, 2023; Schoonenboom & Johnson, 2017). Closed-ended survey methods were used to gather detailed insights into participants' experiences and perspectives, facilitating a structured analysis. The descriptive design allowed for effective data tabulation and calculation, enhancing the validity and coherence of the study's findings. By offering a thorough and nuanced perspective, this approach ensures that the research addresses the full scope of the topic, informing actionable recommendations and conclusions.

2.2. Sample

This study employed a robust sampling process, selecting 730 teachers from urban and rural schools across India. A combination of random and stratified sampling techniques was used, with participants drawn from all 28 states and 8 union territories by selecting 10% of districts in each region (Makwana et al., 2023; Tipton, 2013). Data collection was conducted through both online methods (email, WhatsApp, social media) and offline approaches (pen-and-paper), ensuring a diverse and representative sample of educators.

2.3. Tools

In this study, we created standardized questionnaires with 20 multiple-choice questions to measure educators' awareness of using Augmented Reality (AR) in schools. Each question had four answer options, with 5 points given for a correct answer and 0 points for an incorrect one (Garratt et al., 2011; Zaidi et al., 2021). The total scores ranged from 0 to 100. Based on these scores, awareness levels were divided into three categories—Low, Moderate, and High—using equal intervals, as

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described by Ascher-Svanum et al. (2013). To ensure the reliability and validity of the questionnaire, we carried out a detailed validation process, focusing on content and face validity, with feedback from nine experts in the field. The questionnaire was tested on a group of 30 participants, and the Kuder-Richardson reliability coefficient was calculated at 0.79, showing good reliability.

2.4. Procedure of Data Collection

In this study, survey questionnaire was distributed to educators from private and government schools across India, including rural and urban areas, regardless of age, gender, qualifications, or the educational board of their institutions. To ensure a diverse sample, we used both physical and digital methods for distribution. In-person sessions were followed by sharing the questionnaire via email and WhatsApp. For online responses, we used Google Forms, providing clear instructions and timelines to ensure timely submissions (Regmi et al., 2016). Before participation, all educators received detailed information about the study's purpose, the survey's nature, and the time required to complete it, allowing them to make an informed choice. We received 730 responses: 237 from male and 493 from female participants, with 531 from urban areas and 199 from rural areas. Participants provided informed consent before participating. While formal ethical approval was not sought, we emphasized ethical practices by ensuring all participants voluntarily joined with a clear understanding of their rights and the study's objectives.

3. Result

3.1. Hypothesis 1

The result of Hypothesis1 examined the level of awareness among school educators in India about Augmented Reality (AR) applications. This was done by calculating the range, frequency, and percentage of respondents based on their scores.

The table 1 illustrates the level of awareness among teachers regarding augmented reality (AR) applications, categorized into high, moderate, and low levels, along with corresponding gain scores and percentages. A higher proportion of female teachers (54) demonstrated a high awareness level compared to males (12), with gain scores of 3910 and 900, respectively, contributing 5.36% and 1.23% to the total percentage of gain scores (6.59%). In the moderate awareness category, the majority of both male (202) and female (400) teachers were represented, with gain scores of 10,550 and 20,905, contributing significantly to the overall gain scores at 14.45% and 28.64%, respectively, accounting for a combined 43.09%. Conversely, a smaller number of teachers exhibited low awareness, with 23 males and 39 females, whose gain scores (580 for males and 1085 for females) resulted in a minor contribution of 0.79% and 1.49% to the total, respectively, summing to 2.28%. Overall, female teachers had a higher awareness level and contributed more significantly to the total percentage of gain scores, which collectively reached 51.96%.

Table 1. Level of awareness on augmented reality applications (AR) among the teachers.

Teachers' Awareness Level on AR	*Range of Scores*	*Frequencies*		*Gain Scores*		*Percentage of Gain Scores*		*Total Percentage of Gain Scores*
		Male	*Female*	*Male*	*Female*	*Male*	*Female*	
High	67-100	12	54	900	3910	1.23%	5.36%	6.59%
Moderate	34-66	202	400	10550	20905	14.45%	28.64%	43.09%
Low	< 33	23	39	580	1085	0.79%	1.49%	2.28%
Total		730		12030	25900	16.48%	35.49%	51.96%

In this figure 1, the line graph shows the percentage of gain scores for males and females based on their teachers' awareness of AR. Male scores rise from 1.23% to 14.45% before dropping to 0.79%, while female scores increase from 5.36% to a peak of 28.64% before declining to 1.49%. Females exhibit a more pronounced peak, indicating greater sensitivity to teachers' awareness levels.

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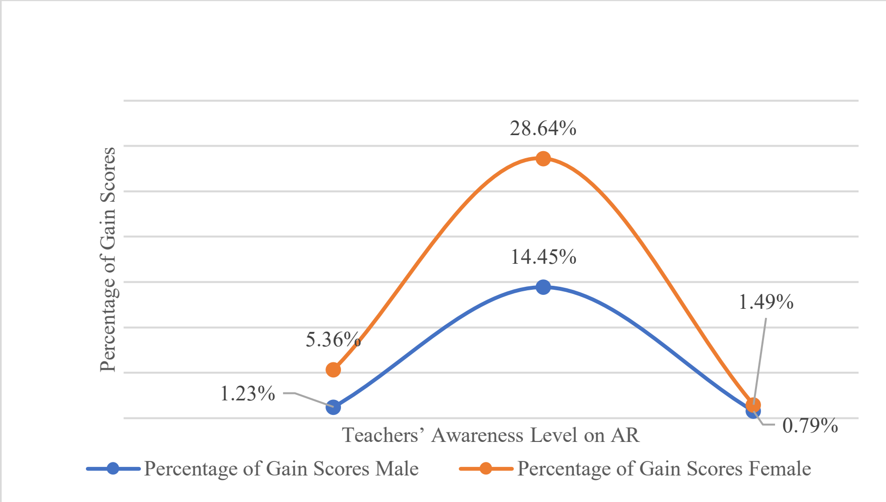

Figure 1. Teachers' understanding and familiarity with augmented reality (AR) applications.

3.2. Hypothesis 2

The second hypothesis looked at whether male educators have a significantly higher awareness of Augmented Reality (AR) applications compared to female educators. This hypothesis was tested by calculating the awareness levels of male and female school educators in India using *t*-tests. The calculation included various statistical measures such as Mean (M), Standard Deviation (SD), Standard Error of the Mean (SE_M), Number of Participants (N), Standard Error of the Difference (SE_D), Degrees of Freedom (*df*), and *p*-values from the gain scores of these variables.

Table 2 presents the significant differences in awareness levels of Augmented Reality applications between male and female school educators. The mean awareness score for female educators (M_1 = 52.54, SD_1 = 12.86, SE_{M1} = 0.58) is slightly higher than that of male educators (M_2 = 50.76, SD_2 = 12.67, SE_{M2} = 0.82). The total number of participants is 730 (N_1 = 493 for females, N_2 = 237 for males), with degrees of freedom (*df*) at 728. The Standard Error of the Difference (SE_D) is 1.012, and the calculated *t*-value is 1.755, with a *p*-value of 0.0796, indicating no statistically significant difference in awareness levels between the two groups.

Table 2. Significant level of awareness among male and female school educators on AR application.

Awareness Levels of Augmented Reality Applications	Female Educators				Male Educators				*N*	*(df)*	SE_D	*t-value*	*p -value*
	M_1	N_1	SD_1	SE_{M1}	M_2	N_2	SD_2	SE_{M2}					
	52.54	493	12.86	0.58	50.76	237	12.67	0.82	730	728	1.012	1.755	0.0796

This figure 2 represents a T-distribution, highlighting the rejection and acceptance regions for a hypothesis test. The green area indicates the acceptance region (where the null hypothesis is retained), while the red areas represent the rejection regions (where the null hypothesis is rejected). The black curve shows the T-distribution, and the blue marker represents the calculated *t*-value, which lies in the acceptance region, suggesting insufficient evidence to reject the null hypothesis.

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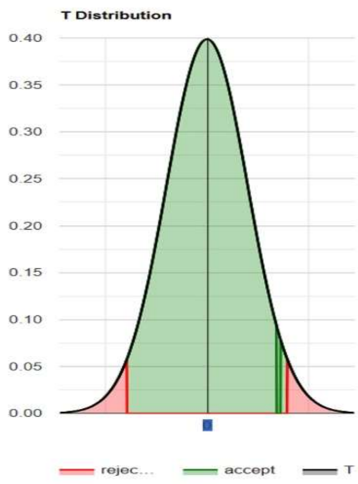

Figure 2. Comparative analysis of the level of awareness about AR applications between male and female school educators.

3.3. Hypothesis 3

In this Hypothesis3, the educators in urban schools are expected to have significantly higher awareness of AR applications compared to those in rural schools. This was tested using t-tests to scrutinize the awareness levels of urban and rural male and female school educators in India. The scrutiny included statistical measures such as Mean (M), Standard Deviation (SD), Standard Error of the Mean (SE_M), Number of Participants (N), Standard Error of the Difference (SE_D), Degrees of Freedom (*df*), and *p*-values.

The table 3 compares the awareness levels of augmented reality (AR) applications among urban and rural school educators. Urban educators have a slightly higher mean awareness score (52.25) than rural educators (51.18), with respective sample sizes of 531 and 199. The standard deviations are similar (12.90 and 12.59), and the standard error of the difference (SE_D) is 1.065. A *t*-test shows a *t*-value of 1.004 and a *p*-value of 0.316, which is greater than the conventional significance threshold of 0.05. This indicates that the difference in awareness levels is not statistically significant, suggesting that urban and rural educators have comparable levels of familiarity with AR applications.

Table 3. Significant level of awareness among urban and rural school educators on AR application.

Awareness Levels of Augmented Reality Applications	Urban Educators				Rural Educators				*N*	*(df)*	SE_D	*t-value*	*p - value*
	M_1	N_1	SD_1	SE_{M1}	M_2	N_2	SD_2	SE_{M2}					
	52.25	531	12.90	0.56	51.18	199	12.59	0.89	730	728	1.065	1.004	0.316

This graph in figure 3 illustrates a T-distribution used in hypothesis testing, showing rejection regions (red) and the acceptance region (green). The rejection regions, located in the tails, represent extreme *t*-values where the null hypothesis is rejected. The green area in the centre indicates the range of *t*-values where the null hypothesis is accepted. The black curve represents the T-distribution, and the vertical green line marks the calculated *t*-value, which falls within the acceptance region, indicating that the null hypothesis is not rejected.

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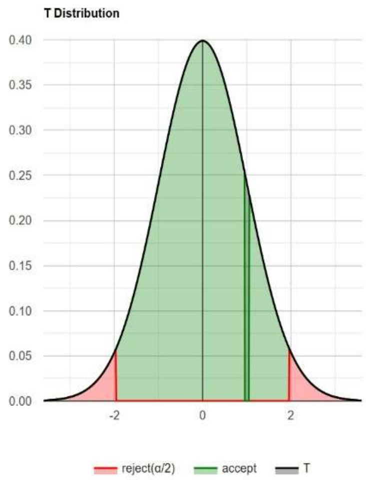

Figure 3. Comparative analysis of awareness levels regarding AR applications among urban and rural school educators.

3.4. Hypothesis 4

Hypothesis$_4$ advocates that school educators from different age groups exhibit significantly different levels of awareness regarding AR applications. To test this hypothesis, the gain scores of school educators, categorized by age group, were analyzed using a one-way analysis of variance (ANOVA). The results are presented in table 4, where the Sum of Squares (SS), Degrees of Freedom (*df*), Mean Square (MS), and *F*-values represent the ANOVA output.

Table 4 presents the results of a one-way analysis of variance (ANOVA) conducted to compare teachers' awareness of AR across different age groups. The analysis revealed that the between-groups variation for the 20–33 years age group had a Sum of Squares (SS) of 226.71, with 2 degrees of freedom (*df*), resulting in a Mean Square (MS) of 113.35 and an *F*-value of 0.689 ($p = 0.502$). For the 34–47 years age group, the within-groups variation had an SS of 119,572.06 with 727 *df* and an MS of 164.47. The corrected total for the 48–60+ years age group was 119,798.77, with 729 *df* and an MS of 164.33. These results indicate no statistically significant differences in AR awareness among teachers across the age groups, as the *p*-value exceeds the 0.05 threshold.

Table 4. One-Way Analysis of Variance (ANOVA) results regarding the comparison of the total scores of the teachers' awareness of AR based on age group.

Teachers' Awareness of AR based on Age Group	Source of Variation	*SS*	*df*	*MS*	*F value*	*p value*
20-33 Years	Between Groups	226.71	2	113.35	0.689	0.502
34-47 Years	Within Groups	119572.06	727	164.47		
48-60> Years	Corrected Total	119798.77	729	164.33		

This graph in figure 4 depicts the right-skewed *F*-distribution used in hypothesis testing, with the x-axis showing *F*-statistic values and the y-axis showing probability density. It highlights the rejection region (red, significance level *α*) and acceptance region (green), separated by critical *F* values, with the black curve representing the distribution.

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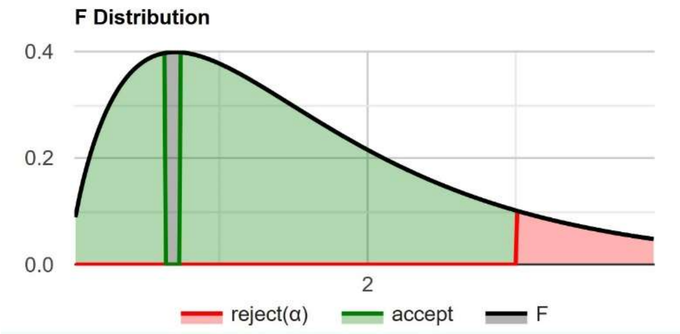

Figure 4. One-Way ANOVA results comparing teachers' total awareness scores of AR across different age groups.

3.5. Hypothesis 5

Hypothesis5 indicates that school educators with varying levels of teaching experience show significant differences in their awareness of AR applications. To examine this, the gain scores of educators, grouped by their teaching experience, were evaluated using a one-way analysis of variance (ANOVA). The findings are summarized in table 4, which includes the Sum of Squares (SS), Degrees of Freedom (*df*), Mean Square (MS), and *F*-values as part of the ANOVA results.

Table 5 displays the results of a one-way analysis of variance (ANOVA) conducted to compare teachers' awareness of AR across different levels of teaching experience. For educators with less than 10 years of experience, the between-groups variation had a Sum of Squares (SS) of 489.85, with 3 degrees of freedom (*df*), resulting in a Mean Square (MS) of 163.28 and an *F*-value of 0.9936 (p = 0.3952). For educators with 11–20 years of experience, the within-groups variation had an SS of 119,308.92 with 726 *df*, and the corrected total for those with 21–30 years and 31–40+ years of experience was 119,798.77 with 729 *df* and an MS of 164.33. These results indicate no statistically significant differences in AR awareness based on teaching experience, as the p-value is greater than 0.05.

Table 5. One-Way Analysis of Variance (ANOVA) results regarding the comparison of the total scores of the teachers' awareness of AR based on teaching experience.

Teachers' Awareness of AR based on Teaching Experience	Source of Variation	*SS*	*df*	*MS*	*F value*	*p value*
< 10 Years	Between Groups	489.85	3	163.28		
11-20 Years	Within Groups	119308.92	726	164.34	0.9936	0.3952
21-30 Years	Corrected Total	119798.77	729	164.33		
31-40 > Years						

In figure 5, this graph illustrates a right-skewed *F*-distribution with probability density on the y-axis and *F*-statistic values on the x-axis. It divides the area into the rejection region (red, for significance level α) and the acceptance region (green), separated by critical *F* values. The black curve represents the *F*-distribution.

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Figure 5. One-Way ANOVA results comparing teachers' total awareness scores of AR across varying levels of teaching experience.

3.6. Hypothesis 6

This hypothesis looked at whether private schools' educators have a significantly higher awareness of Augmented Reality (AR) applications compared to government schools' educators. This hypothesis was tested by calculating the awareness levels of private and government school educators in India using *t*-tests. The calculation included various statistical measures such as Mean (M), Standard Deviation (SD), Standard Error of the Mean (SE_M), Number of Participants (N), Standard Error of the Difference (SE_D), Degrees of Freedom (*df*), and *p*-values from the gain scores of these variables.

Table 6 presents the comparison of awareness levels of augmented reality (AR) applications between educators from private and government schools. Private school educators have a mean awareness score (M_1) of 51.76 (SD_1 = 13.24, SE_{M1} = 0.64) based on 424 participants, while government school educators have a mean score (M_2) of 52.24 (SD_2 = 12.23, SE_{M2} = 0.70) based on 306 participants. With a total sample size of 730 and degrees of freedom (*df*) of 728, the standard error of difference (SE_D) is 0.962. The *t*-value of 0.500 and *p*-value of 0.617 indicate no significant difference in AR awareness levels between private and government school educators.

Table 6. Significant level of awareness among private and government school educators on AR application.

Awareness Levels of Augmented Reality Applications	Educators' of Private Schools				Educators' of Government Schools				*N*	*(df)*	SE_D	*t-value*	*p - value*
	M_1	N_1	SD_1	SE_{M1}	M_2	N_2	SD_2	SE_{M2}					
	51.76	424	13.24	0.64	52.24	306	12.23	0.70	730	728	0.962	0.500	0.617

This curve in figure 6 represents a symmetric T-distribution with probability density on the y-axis and *t*-statistic values on the x-axis. It shows two rejection regions (red, for significance level $\alpha/2$) on the tails and an acceptance region (green) in the centre, separated by critical *t* values. The black curve represents the T-distribution.

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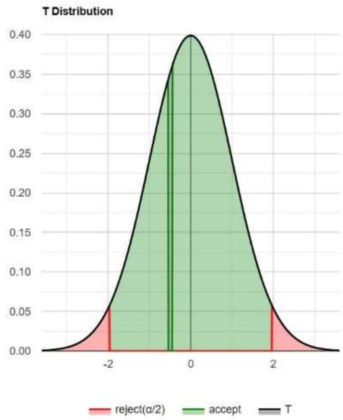

Figure 6. Comparative analysis of awareness levels regarding AR applications between private and government school educators.

3.7. Hypothesis 7

Hypothesis7 examines whether school educators teaching science-based subjects have significantly higher awareness of Augmented Reality (AR) applications compared to educators teaching social science or art-based subjects. To test this, the awareness levels of educators in India were calculated using *t*-tests. The calculation incorporated various statistical measures, including the Mean (M), Standard Deviation (SD), Standard Error of the Mean (SE_M), Number of Participants (N), Standard Error of the Difference (SE_D), Degrees of Freedom (*df*), and *p*-values, derived from the gain scores of these variables.

Table 7 compares the awareness levels of Augmented Reality (AR) applications between school educators teaching science-based subjects and those teaching social science or art-based subjects. Educators in science subjects have a mean score (M_1) of 52.09 (SD_1 = 13.55, SE_{M1} = 0.75) based on 326 participants, while educators in social science or art subjects have a mean score (M_2) of 51.86 (SD_2 = 12.21, SE_{M2} = 0.61) based on 404 participants. With a total sample size of 730 and degrees of freedom (*df*) of 728, the standard error of difference (SE_D) is 0.955. The *t*-value of 0.240 and *p*-value of 0.8102 indicate no significant difference in AR awareness levels between the two groups of educators.

Table 7. Significant level of awareness among Science and Social Science or Art subject based school educators on AR application.

Awareness Levels of Augmented Reality Applications	Educators' belong to Science Subjects				Educators' belong to Social Science/ Art Subjects				*N*	*(df)*	SE_D	*t-value*	*p - value*
	M_1	N_1	SD_1	SE_{M1}	M_2	N_2	SD_2	SE_{M2}					
	52.09	326	13.55	0.75	51.86	404	12.21	0.61	730	728	0.955	0.240	0.8102

In the figure 7 graph represents a T-distribution, showing the acceptance region (green) where the null hypothesis is retained, and the rejection regions (red) on both sides, determined by the significance level (*α*).

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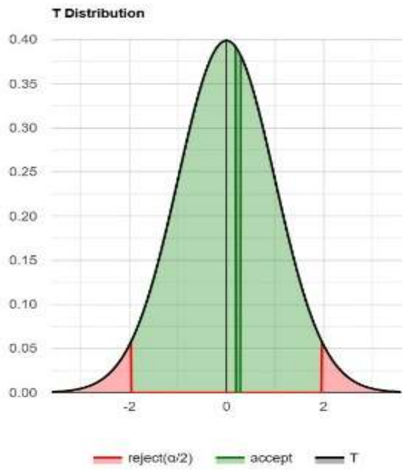

Figure 7. Comparative analysis of AR application awareness between Science educators and Social Science/ Arts educators.

4. Analysis and Interpretation

The data in table 1 provides a comprehensive analysis of teachers' awareness levels regarding augmented reality (AR) applications, categorized as high, moderate, and low, along with corresponding gain scores and percentages. The findings reveal differences in awareness levels between male and female educators (Karthick & Shanmugam, 2024). So far this analysis is concerned a higher proportion of female teachers (54) demonstrated a high level of awareness compared to male teachers (12). The gain scores for females and males in this category were 3,910 and 900, respectively. These scores contributed 5.36% (females) and 1.23% (males) to the total gain score percentage, making a combined contribution of 6.59%. This indicates that female educators are more likely to exhibit high awareness of AR applications than their male counterparts. On the other hand, the moderate awareness category accounted for the majority of teachers from both genders. Among male teachers, 202 fell into this category, contributing a gain score of 10,550, equivalent to 14.45% of the total. Female teachers represented 400 individuals in this category, with a gain score of 20,905, contributing 28.64%. Together, this category made up 43.09% of the total percentage of gain scores, reflecting its dominance in the overall awareness landscape. Similarly, a smaller proportion of teachers exhibited low awareness of AR applications. This included 23 male teachers with a gain score of 580 (0.79%) and 39 female teachers with a gain score of 1,085 (1.49%). The combined contribution of this category was minimal, totalling 2.28% of the overall gain scores. However, the analysis highlights those female educators not only displayed higher levels of awareness across categories but also made a more substantial contribution to the total percentage of gain scores. Collectively, female teachers accounted for 51.96% of the total gain scores, underscoring their prominent role in AR awareness within the teaching profession. These findings suggest targeted interventions may be needed to elevate AR awareness among male teachers and those in lower awareness categories, thereby fostering a more uniform understanding of AR applications across the teaching community (Tripathy & Panda, 2021).

The analysis of table 2 evaluates the awareness levels of AR applications among male and female school educators, revealing that female educators have a slightly higher mean score than their male counterparts. However, the calculated t-value (1.755) and corresponding two-tailed p-value (0.0796) exceed the conventional significance threshold (p>0.05), indicating no statistically significant difference between the two groups. The 95% confidence interval for the mean difference (-0.21 to 3.76) includes zero, further supporting the lack of meaningful disparity. With degrees of freedom (df = 728), the critical t-values for both the 0.05 (1.96) and 0.01 (2.58) significance levels are greater than the observed t-value, placing the results firmly in the region of acceptance for both 95% and 99% confidence levels. These findings suggest that the observed mean difference is too small to reject the null hypothesis (H_0), which posits that the awareness levels of male and female educators are equal (Amores-Valencia et al., 2023). Moreover, the *p*-value (0.0796) indicates a 7.96% probability of committing a Type I error (wrongly rejecting H_0), which exceeds the acceptable threshold for statistical significance. Thus, the evidence strongly suggests that gender does not significantly influence educators' awareness of AR applications in this sample (Ghobadi et al., 2023).

Table 3 compares the awareness levels of Augmented Reality (AR) applications among urban and rural school educators. Urban educators have a slightly higher mean awareness score compared to rural educators, and similar standard deviations for urban and rural educators. *t*-test yields a *t*-value of 1.004 and a two-tailed *p*-value of 0.316, which is greater than the conventional significance threshold (p>0.05), indicating that the difference in awareness levels is not statistically significant. The 95% confidence interval for the mean difference (-1.02 to 3.16) includes zero, further supporting the conclusion that there is no meaningful disparity. With 728 degrees of freedom, the critical *t*-values for the 0.05 (1.96) and 0.01 (2.58) significance levels exceed the observed *t*-value, placing the result within the region of acceptance. The *p*-value of 0.316 suggests a 31.6% probability of committing a Type I error (incorrectly rejecting the null hypothesis), which is too high to justify rejection. Therefore, the analysis concludes that urban and rural educators have comparable levels of awareness of AR applications, with no significant difference between the groups (Liao et al., 2024; Perifanou et al., 2023).

Table 4 summarizes the results of a one-way ANOVA conducted to evaluate differences in teachers' awareness of AR across age groups. The analysis produced an *F*-value of 0.689 with degrees of freedom (2, 727) and a *p*-value of 0.502. As the *p*-value exceeds the standard significance thresholds of 0.05 and 0.01, the results indicate no statistically significant differences in AR awareness between the age groups. The null hypothesis (H_0), which assumes equal group averages, is accepted since the difference between the group means is too small to be meaningful. The test statistic [$F(2, 727) = 0.689$] lies within the 95% region of acceptance [0, 3.0081] and does not approach the critical values (19.50 at 95% and 99.50 at 99% confidence levels). Additionally, the *p*-value (0.502) suggests that rejecting the null hypothesis would entail a high risk (50.2%) of committing a Type I error. A larger *p*-value strengthens support for H_0, confirming no significant differences between group means. Thus, teachers’ AR awareness is statistically consistent across all age groups (Cyril et al., 2022; Radu et al., 2022).

Table 5 presents the results of a one-way ANOVA comparing teachers' awareness of AR across different levels of teaching experience. For educators with less than 10 years of experience, the analysis showed between-groups variation with 3 degrees of freedom (*df*) and within-groups variation with 726 *df*. The *F*-value was 0.9936, with a *p*-value of 0.3952. Since the *p*-value exceeds the significance level ($\alpha = 0.05$), the null hypothesis (H_0), which assumes the group means are equal, is not rejected. This indicates that the differences in sample averages among the groups are not statistically significant (De Lima et al., 2022; Nikou, 2024). Additionally, the *p*-value of 0.3952 corresponds to a 39.52% probability of a Type I error if H_0 were rejected, which is too high to justify rejecting it. The test statistic falls within the 95% acceptance region [0, 2.6172], and does not exceed the critical values at either the 95% (8.53) or 99% (26.12) confidence levels. These findings confirm there is no significant difference in AR awareness based on teaching experience. Thus, the analysis concludes that teaching experience of less than 10 years does not significantly affect teachers' awareness of AR (Stoner et al., 2024).

Table 6 compares the awareness levels of augmented reality (AR) applications between educators from private and government schools, based on a total sample size of 730 and 728 degrees of freedom (*df*), the analysis yielded a *t*-value of -0.5005 and a *p*-value of 0.617. Since the *p*-value is greater than the significance level ($\alpha = 0.05$, $p > \alpha$), the null hypothesis (H_0), which assumes no difference in AR awareness levels between the two groups, is not rejected (Chang et al., 2022; Oueida et al., 2023). This indicates that the observed difference in sample averages between private and government school educators is not statistically significant. The *p*-value of 0.617 corresponds to a 61.7% chance of a Type I error (rejecting a correct H_0), which is too high to justify rejection. The test

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statistic falls within the 95% acceptance region [-1.9632, 1.9632], further supporting the acceptance of H_0. Similarly, the difference in sample means ($x_1 - x_2 = -0.48$) lies within the 95% confidence interval [-1.8887, 1.8887]. These results confirm that the average AR awareness levels of educators from private and government schools are statistically equivalent, as the *p*-value strongly supports the null hypothesis.

Table 7 compares the awareness levels of AR applications among school educators teaching science-based subjects and those teaching social science or art-based subjects. The analysis is based on responses from 326 educators teaching science subjects and 404 educators teaching social science or art subjects. Both groups exhibited nearly identical mean scores, indicating similar levels of AR awareness. With 728 degrees of freedom, the critical *t*-values for significance at the 0.05 (1.96) and 0.01 (2.58) levels exceed the calculated *t*-value of 0.240, demonstrating no statistically significant difference between the two groups. The calculated test statistic ($t = 0.240$) falls well within the 95% region of acceptance [-1.9632, 1.9632], supporting the null hypothesis (H_0). Additionally, the difference in mean scores between the two groups ($x_1 - x_2 = 0.23$) lies within the 95% confidence interval [-1.8749, 1.8749], further reinforcing the conclusion that the observed differences are not statistically significant. The *p*-value associated with the *t*-test is 0.8102, which is considerably greater than the typical significance level of $\alpha = 0.05$. This *p*-value indicates an 81.02% probability of a Type I error (incorrectly rejecting a true null hypothesis), making the risk of rejecting H_0 excessively high. Consequently, H_0 cannot be rejected, meaning there is insufficient evidence to conclude that the mean AR awareness levels differ between educators teaching science-based subjects and those teaching social science or art-based subjects (Singh et al., 2024). However, the analysis validates that educators teaching science-based subjects and those teaching social science or art-based subjects have statistically equivalent levels of AR awareness. The high *p*-value of 0.8102 strongly supports the null hypothesis, and the test statistic, along with the confidence interval, confirms that the small observed difference in mean scores between the groups is not significant. These findings suggest that subject specialization does not significantly influence AR awareness among school educators (Castano-Calle et al., 2022; Tzima et al., 2019).

5. Major Findings

1. Female teachers demonstrated a higher level of awareness and contributed more significantly to the overall percentage of gain scores compared to male teachers regarding Augmented Reality (AR) applications. This advocates that female teachers exhibited a more pronounced peak in sensitivity to awareness levels.
2. No statistically significant difference was found in awareness levels between male and female school educators regarding AR applications, indicating that gender did not have a notable impact on educators' awareness of AR applications.
3. The difference in awareness levels between urban and rural educators was not statistically significant, implying that both groups had comparable levels of familiarity with AR applications.
4. There was no statistically significant difference in AR awareness among teachers across different age groups, confirming that AR awareness levels were consistent regardless of age.
5. The findings also revealed no significant differences in AR awareness among school educators with varying levels of teaching experience. Thus, having less than 10 years of teaching experience did not significantly influence educators' awareness of AR applications.
6. No significant difference was observed in AR awareness levels between private and government school educators, confirming that both groups had statistically equivalent levels of awareness.
7. There was no significant difference in AR awareness levels between educators teaching science subjects and those teaching social science or arts. This indicates that subject specialization does not significantly affect educators' awareness of AR applications.

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6. Discussion

In today's digital age, the teaching-learning process is inseparable from technology. Regarding Augmented Reality (AR), findings revealed that female teachers demonstrated higher awareness and contributed more significantly to overall gain scores in AR applications, underscoring notable gender dynamics in educational technology adoption. This observation suggests that female educators may exhibit heightened receptiveness to technological innovations and their pedagogical applications (Mercader & Duran-Bellonch, 2021). Factors such as a proactive engagement in professional development, an inclination toward adopting innovative classroom practices, and a strong commitment to fostering collaborative, inclusive learning environments may account for this trend (Peikos & Sofianidis, 2024; George-Reyes et al., 2024). Their greater awareness might also reflect a learner-centered approach aligned with contemporary pedagogical frameworks. However, this does not imply that male educators lack awareness or engagement but highlights nuanced gender-based differences in perceiving and responding to emerging technologies. To further explore this dynamic, future research could examine factors such as access to training, motivational drivers, or resource availability, which may contribute to these disparities. Identifying such determinants is crucial for developing equitable strategies to support all educators and enhance AR integration into teaching practices. Similarly, findings indicated no statistically significant difference in AR awareness between male and female educators, suggesting that gender does not critically influence educators' familiarity with AR technologies. This uniformity could result from equal access to educational resources and training across genders and points to a shared level of interest and engagement with AR tools within the teaching community (Al-Shahrani & Asir, 2023; Turan et al., 2018). Yet, the overall low awareness among both groups reveals systemic gaps in professional development and highlights that AR integration in educational settings remains underemphasized. Despite AR's potential to revolutionize education through interactive and immersive experiences, its limited adoption stems from insufficient awareness (Wu et al., 2013). Addressing this gap requires targeted initiatives, including workshops, training sessions, and practical demonstrations, to enhance AR literacy regardless of gender (Zhang, 2024). Equal access to such resources is vital to modernizing education and improving teaching effectiveness. Furthermore, the study found no significant difference in AR awareness between urban and rural educators, indicating comparable familiarity with AR technologies across geographic boundaries. This parity likely reflects uniform challenges, such as limited training opportunities, inadequate technological infrastructure, and insufficient emphasis on AR in professional development programs, which are common to both urban and rural settings (Wang et al., 2024). Although urban educators are presumed to have better access to resources (Nikou et al., 2024), this advantage does not translate into higher AR awareness compared to their rural counterparts, who face notable technological constraints. The findings emphasize a widespread gap in AR literacy, calling for inclusive training initiatives that address the needs of both urban and rural educators. Online platforms and localized workshops can provide equitable access to AR training, bridging the digital divide and improving education quality across diverse contexts (Sulisworo et al., 2021). Similarly, findings revealed no significant difference in AR awareness across different age groups, suggesting that age does not significantly impact educators' familiarity with AR technologies. This uniform lack of awareness across all age groups highlights systemic issues, such as the insufficient inclusion of AR in professional development programs and the lack of hands-on training (Kaminska et al., 2023). These results challenge assumptions that younger educators, being more digitally inclined, are more familiar with emerging technologies, and dispel stereotypes about older educators being less receptive to technological advancements (Diehl & Wahl, 2010; Schlomann et al., 2022). Addressing this requires age-inclusive strategies that provide accessible, tailored training programs for educators across all age groups. Professional development initiatives, including workshops and ongoing support, are critical to equipping educators of all ages with the skills to integrate AR effectively into teaching practices (Philipsen et al., 2019). Promoting AR literacy across all demographics is essential for ensuring technological integration in education. Additionally, the study found no significant difference in AR awareness levels among educators with varying teaching experience, including those with less than 10 years of experience. This suggests that teaching tenure does not substantially influence educators' familiarity with AR technologies. The consistently low awareness levels across experience groups reflect a broader gap in professional development programs, which fail to emphasize AR integration regardless of educators' tenure (Schwaiger et al., 2024). Experienced teachers may not have encountered AR during their training, while less experienced educators might lack exposure to comprehensive AR education in recent training programs (De-Lima et al., 2022). To bridge this gap, targeted interventions must focus on promoting AR awareness among both novice and seasoned teachers. Tailored workshops and professional development programs that integrate AR training as a core component can empower educators to utilize AR effectively, thereby enhancing teaching quality and interactivity (Alalwan et al., 2020; Wells & Miller, 2020). Moreover, findings indicated no significant difference in AR awareness levels between private and government school educators, showing that educators from both types of institutions are equally familiar with AR technologies. This equivalence suggests systemic factors, such as limited AR training and a lack of emphasis on AR in teaching practices, affect educators universally (Sirakaya & Cakmak, 2018). Despite the perceived advantages of private schools in terms of resources, these do not necessarily translate into higher AR awareness compared to government schools, which often face infrastructural and technological constraints. Addressing this cross-institutional gap in AR literacy requires collaborative efforts among policymakers, educational institutions, and technology providers to design and implement inclusive training programs. Equipping educators in both private and government schools with AR-related knowledge can facilitate broader adoption of innovative teaching tools and enhance educational outcomes for students universally (Dembe, 2024; Mena et al., 2023). Finally, findings indicated no significant difference in AR awareness levels between educators specializing in science subjects and those teaching social sciences or arts, suggesting that subject specialization does not influence educators' familiarity with AR technologies. This widespread gap in AR awareness across disciplines reflects the underutilization of AR in professional development and the absence of subject-specific training resources that align AR applications with teaching needs (Rahmat et al., 2023). Although AR has immense potential for enhancing subject-specific teaching, such as simulating scientific experiments or visualizing historical events, its integration into pedagogy remains inadequate (Marrahi-Gomez & Belda-Medina, 2022). Addressing this requires subject-specific training programs and the development of AR resources tailored to different disciplines (Bilawar, 2022; Papakostas et al., 2022). Providing educators with the tools to utilize AR effectively, irrespective of their specialization, can foster an interactive and engaging learning environment that benefits students across all subject areas.

7. Conclusions

In conclusion, technology has become an essential part of education, and digital pedagogy offers a powerful way for teachers to simplify complex concepts and make learning more engaging. Among the various digital tools, Augmented Reality (AR) stands out as an effective method to enhance both teaching and learning by improving content clarity. However, this study revealed that teachers in India are largely unfamiliar with AR and continue to rely on traditional teaching methods. Though the analysis showed no significant differences in AR awareness across various factors such as gender, location, age, teaching experience, institutional type (private or government schools), or subject specialization. Although female teachers displayed slightly higher sensitivity to AR applications, the overall awareness levels were consistently low across all groups. This highlights a systemic gap in exposure and training for educators, regardless of their background or professional role. Therefore, these findings emphasize the urgent need to prioritize digital pedagogy through tools like AR and Virtual Reality (VR) to better equip teachers for modern classrooms. By providing targeted training programs and resources, educators can be empowered to adopt these innovative technologies, transforming teaching methods and improving learning outcomes for students nationwide.

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