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Article

Middle School Science Teachers' Awareness of Augmented Reality in Teaching: Influence of Selected Variables

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Abstract

The research examined the effect of professional characteristics on the awareness among middle-school science educators regarding the teachable potential of augmented reality. 90 females working as educators at Al-Kharj, Saudi Arabia, were randomly selected from the sample pool of 120 participants to fill out a descriptive survey questionnaire. Awareness was gauged through the application of the researcher-created questionnaire measuring perceived affordances, curricular alignment, and intention to implement the technology. Reliability testing established strong internal consistency with Cronbach's alpha = 0.827 and split-half reliability coefficient = 0.885. One-sample t-tests, descriptive statistics, analysis of variations by one way analysis of variances (ANOVA) with post hoc comparisons and interpretations on the basis of the five-point Likert scale were adopted to examine the data. Results showed an indiscriminately high awareness level scale ($M = 4.06$, $SD = 1.09$) among educators and the absence of significance on the basis of scientific specialisation and previous involvement with technology course work. Nevertheless, experience worked out to be a discriminating force in that more experienced educators showed more variability within their perception. Seasoned practitioners reported strong interest in the application of augmented reality to teaching but with tenure corresponding to some doubt about its teaching appropriateness. Implications state professional development programmes stratified on the basis of experience severity ought to be developed by learning institutions. Such programmes ought to utilize the validated questionnaire to identify needs through diagnosis, to monitor development through progress monitoring and to regularly review participants through the application of implementation components linked to the curricula.

Keywords

Augmented Reality Technology, Science Teaching, Teacher Awareness, Intermediate Education.

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Introduction

During the last ten years, the use of open innovation has been witnessed globally on many fronts, including teaching. Technology has therefore been embedded indispensably within the learning process to conform to the increasing necessity by learners to be part and parcel of the digital revolution that includes universal coverage to digital information by different volumes and scales. Among the newest technological interventions adopted on the teaching scene is Augmented Reality (AR), which has the potential to translate the conventional teaching style to an interactive learning process.

AR is identified as one of the new innovations in virtual learning-centered teaching. It integrates real and virtual aspects through the application of virtual reality technology, thus bringing about the realization of an interactive three-dimensional sphere where learners can interactively interact with information and applications (Bassyouni & Elhajj, 2021). Technically framed by educational tools supported by AR can be improved to facilitate the learning encounter. With its characterization as an interactive learning mechanism, not only is there an introduction to an attractive and eye-friendly method of delivery but also relevance to learners' interest and needs. Such technology is supportive to other innovative learning strategies and brings to learning an improved new way to handle the instructional challenges and remarkably enhance the effectiveness and quality of the learning process (Himawan, Budiyanto, & Budianto, 2024).

The study by Chang, Wu and Tarng (2025) pointed out the effectiveness of the AR technology within the realm of learning, specifically the promotion of learning outcomes and student engagement. Incorporation of technology within the realm of learning has increased substantially to represent the nationwide transformations towards the technological and visually inclined culture. Likewise, research by Amores-Valencia, Burgos and Branch-Bedoya (2023) pointed out the learning potential of AR to provoke learners' curiosity and elicit excitement and hence induce them to acquire further knowledge and implement scientific principles through legitimate and authentic learning by experience. A few studies examined the adoption potential of the AR technology within the realm of teaching. Research by Álvarez-Marín et al. (2023), for example, suggested that science educators be provided with special and targeted professional development to acquire the required competences to teach and learn through the AR-based approaches. Furthermore, professional development interventions could also redesign the perception towards the AR held by the educators and facilitate its integration within the learning frameworks.

Statement of the Problem

By Saudi Vision 2030, digital transformation is expected to be one driver of instructional quality and workforce preparation across K–12 schooling within the Kingdom. Despite the national emphasis, middle school science achievement has been spotted to be uneven through international assessments and therefore suggests that these technological efforts by themselves do not always produce measurable learning gains. AR has been highlighted to unify the digital and physical spaces within the learning environment through real-time interactivity and found to enhance conceptual knowledge, the ability to inquire and visualisation among learners within the field of science. Saudi and other international studies correlated improved student performance along with increased learning pleasure through the application of AR. However, awareness and comprehension among teachers through and through and not technological accessibility by any other name is what strongly determines the effective integration among educators and the application used within the classrooms. Therefore, an intensive examination among the awareness among teachers is critical.

Research is proposed to fill the gap within the extant literature because few studies examined middle school science teachers' comprehension of the purpose and learning value of the adoption of AR in the teaching of science. Awareness is conceptualized within the study as the perception of teaching affordances, perceived alignment with the curriculum standard, and intention to adopt AR within daily teaching. Academic specialisation, professional experience, and technology-oriented professional development are the explanatory variables. Higher awareness is hypothesized to be correlated with greater strong curricular alignment and intention to adopt AR. Though research on the application of AR within education is on the increase, limited studies have operated an analysis on the awareness structure guided by these specific characteristics of the teacher within Saudi middle school settings. A systematic awareness mapping is therefore called for.

This study is especially consequential because awareness profiling among teachers can help professional learning programme design, resource allocation strategy direction, and vendor-neutral technology integration supportive of Saudi Arabian national reform agendas. Research tractability is possible due to aid by legitimate measures and stratified sampling processes permitting examination of inter-determination among main variables. Results should enhance standards-driven AR adoption and theory-knowledge about determinants of adoption among science teaching professionals. Because awareness has never been studied prospectively as an independent construct accounting for inter-adoption variations, through this quantitative fill-in study there is an attempt to satisfy an especially institutionally important gap. Beyond this attempt to fill the gap, it is also seeking to know the middle school science teachable possessing the perception that the utilisation of teachable through the bases of AR-based teachable on teaching sciences matters. How these perceptions compare across specialisation bases, and experience bases is also an additional endeavour.

Study Questions

1. Are there statistically significant differences in awareness regarding the importance of using AR in science instruction when cognitive variables are examined in relation to scientific specialisation?
2. Do teachers' years of professional experience result in statistically significant variations in their awareness of the significance of employing AR in science instruction?
3. Does awareness of the importance of utilising AR in science teaching significantly vary based on participation in technology-oriented professional development courses?

Study Objectives

1. Determine the level of awareness among middle school science teachers in the Al-Kharj region concerning the necessity of using AR in science instruction.
2. Examine the hypothesis that there are statistically significant differences in awareness levels based on scientific specialisation.
3. Identify whether statistically significant differences exist in awareness levels according to years of teaching experience.
4. Evaluate the presence or absence of statistically significant differences in awareness with respect to participation in technology-oriented professional development programmes or courses.

Study Significance

This research is an important theoretical contribution because it conceptualises awareness of AR among teachers as a multifaceted construct consisting of perceived teaching affordances, curricular relevance, and adoption intention. It also fine-tunes previous models of readiness and adoption in educational technology by considering specialisation among academics, teaching experience grounded on data evidence, and professional development on technology-oriented areas. Beyond this, the development and validation of a psychometrically adequate, curriculum-informed awareness tool enhance methodological rigor and facilitate accurate measurement among educational research. This step empowers awareness profiling where cross-regional and longitudinal comparisons are possible, an aspect not hitherto examined extensively among studies on science teaching. All these theoretical breakthroughs serve as a basis on which future studies can be conducted and also supplies educators with information on the crucial onthsames determining technological acceptance among educational settings.

Practically, the research provides the policy makers and leaders in schooling with empirically informed direction on ordered implementation, professional development priorities setting, and resource investment aligned with Vision 2030 objectives. The awareness profiles developed through the research reinforce evidence-informed coaching strategies and the building of progressive steps between instructional planning and standards-centered practices to maintain student engagement with science learning. Contextualized within the province of Al-Kharj, the results can be duplicated by other schooling systems seeking to implement successful digital transformation. Readiness indicators identified can be further used by ministries, school districts, and teacher education programs to assess the success of scalable, equitable, and accountable AR integration within the teaching of science. Such practical applications nab the significance of the study to fill the disconnect between schooling policy and classroom enactment.

Study Scopes and Limitations

- **Objective Scope:** The research questions clearly identify the constructs and hypothesised relationships that form the basis of the investigation. The analytical procedures are confined to variables operationalised through validated instruments within the established theoretical framework, ensuring coherence and precision in measurement.
- **Time Scope:** The study is bounded by a predetermined timeframe aligned with data availability and methodological design. This temporal limitation guarantees consistency in measurement processes, thereby enhancing the comparability and reliability of the results.
- **Spatial Scope:** The research is restricted to specific educational environments within a defined jurisdiction to preserve contextual coherence. Interpretations of the findings are made in accordance with these boundaries, and recommendations are formulated with careful consideration of their transferability to comparable contexts.
- **Human Scope:** The sample comprises participants who meet the explicit criteria set by the study's objectives. Ethical and sampling procedures are implemented to ensure that generalisations are appropriately limited to populations sharing similar characteristics and engagement conditions.

Key Concepts

Operational Definition of AR: AR is an interative technology that can project and superimpose on the real world in real time the computer-generated two- or three-dimensional digital information to facilitate perception and interaction. Herein, the term AR is used to refer to the new notion of spatial integration, where the computer-generated visual information or elements are superimposed on the environmental settings to facilitate learning of science (Desai, 2024). For the purpose of this research work, the operational meaning of AR is the combination and fusion of the virtual and real aspects by casting the related figures and animations of science, texts, and 2D or 3D segments of videos through advanced technology tools to enhance learners' perception awareness and overall cognition and information gain.

Theoretical Framework

Concept of Augmented Reality Technology

AR is an immersive technology that blends software-created two- or three-dimensional computer-generated digital content and the real world to enhance perception and engagement. In the realm of learning spaces, the value of AR lies in its potential to combine learners' real-world environs with the virtual and hence conceptualize the learning basis, facilitate inquiry learning, and enhance learning outcomes. While different nomenclatures, added reality, enhanced reality, and blended reality among others are adopted within the literature thereof, they are all synonymous to the same essence thereof. Use hereof thus lends to the latter study to ensure consistency. Herein, the term AR is used to refer to the real-time fusion during the computer-generated imagery and the real-world environs to facilitate the learning process and enhance learning effectiveness thereof (AlNajdi, Alrashidi, & Almohamadi, 2020; Dutta et al., 2023).

Social Learning Theory

AR is consistent with constructivist learning theory by establishing realistic and dynamic settings where learners build knowledge through investigation and reflection. The manipulation of virtual entities within everyday settings allows learners to experiment with hypotheses, receive instant feedback, and adjust mental models to enhance meaning-making and knowledge transfer. Leverage on aspects like the speed, direction, and perspective within the AR settings can also enhance learner control, which is the hallmark of constructivist teaching. By this effect, the AR provides the spark to facilitate further and more conceptual learning (Hallmann, Stechert, & Ahmed, 2023).

Key Features of Augmented Reality Technology

AR is also aligned with social learning theories emphasizing observation, modelling, and participating as key mechanisms of learning. Shared AR applications, like shared visualizing of phenomena or shared manipulating virtual objects, are developed to facilitate formalized dialogue, guided practising, and distributed problem-solving. Such interactive interactions facilitate shared efficacy growth, reinforce the explicit procedures of experts through peer and tutor modelling, and quicken the learning of skills. AR therefore operates as an inter-disciplinal socio-technical scaffold bringing together experiential involvement and social brokerage to sustain the development of knowledge. It has unique properties that render it highly effective to enrich learning processes and outcomes inter-disciplinarily, including the arts.

Characteristics of AR involve the merging of real and virtual worlds to place learning materials within real-world settings and the employment of interactive 3D models that allow the examination and manipulation of intangibles. AR also supports systematic collaboration, inviting shared discovery and intentional practice to reinforce the building of communication and problem-solving proficiencies. Also, it accommodates differentiated teaching strategies, providing learners with chances for paced guidance and repetition that reinforce comprehension and long-term retention. Systematic evidence supports many of these benefits, revealing that contextualized tasks with instant feedback enhance problem-solving skills, that interactivity builds motivation and engagement, and that manipulable models enhance scientific concepts comprehension. Other results include high long-term retention rates, mobility to accommodate variable learner requirements, and increased knowledge esteem due to prolonged multimodal interactions. All these results together indicate that when used to support curricular objectives and systems of assessment, the AR can be an effective scaffold to support consequential, equitable, and long-lasting learning (Kosch et al., 2022).

Literature Review

Following this section, prior research will be discussed through a critical literature review approach that systematically analyses existing studies, organises them thematically, and evaluates them through interpretive assessment. This review identifies key methodological trends, underlying theoretical foundations, and areas of both alignment and divergence within the literature. It also highlights existing research gaps, thereby establishing a comprehensive and insightful foundation for the present study.

Comprehensive Overview

Existing research investigates the effective application of AR on various subjects, grade levels, and fields and its effect on behavioural and rational learning outcomes, motivation, and classroom interactions. Research methodological designs range from experimental and quasiexperimental research to mixed-method studies, pilot studies, observational research, interviews, and journal reflections. Informal theory commonly utilised is constructivist and socio-cultural and places the scaffold provided by AR on the basis of abstraction and group exploration (Lyrath, Stechert, & Ahmed, 2023). Samples used range from preschool kids to secondary learners and educators and can be compared across various developmental phases. Central questions include whether AR is more effective compared to the traditional end-of-course post-tests in augmenting knowledge gain, motivation, and long-term learning outcomes and also studies the moderating effect of subject specialisation and professional development. Data gathering techniques usually involve achievement tests, motivation questionnaire, structured observation, and qualitative examination to decrypt the mechanisms by which the educational effect of AR is mediated (Pasalidou et al., 2025).

Thematic Analysis

The examined literature identifies three common themes. Firstly, the cognitive affordances of AR—i.e., the making transparent of invisible processes, the minimisation of abstraction, and the framing of inquiry—are always linked to increased knowledge gain and improved performance. Secondly, motivational aspects standout since AR fosters interactivity, contextual engagement, and long-period sustenance of collaborative and experience-based learning activity involvement (Sandoval Pérez et al., 2022). Thirdly, adoption success hinges mainly on the preparedness and perception of the teacher regarding curricular convergence and the effectiveness by which the classroom integration is undertaken. Research on short-period outcomes usually utilises experimental study approaches reinforced by mixed-method and qualitative explanatory analysis to detail mechanisms and contextual determinants. Some examination ventures beyond the academic outcome to study socio-cognitive capabilities and especially where achievement-outcome centricity is deliberately pursued. At large, the success of utilisation of AR to facilitate learning is an outcome of the quality of the designtypically spoken by the competency of the teacher and the level of convergence that is curricular (Mahamad et al., 2024).

Comparative Analysis

The analysed studies exhibit various points of convergence and divergence. Points of convergence are short-term gains in learning and overall positive attitudes towards the application of AR during selected teaching activity. Points of divergence are the time and size of these effects. Experiment and quasi-experiment studies report higher post-test performance, although the degree of improvement is contingent on the character of scaffolding and the sophistication of the learning subject. Learner motivation is always improved by the application of interactive AR app, but this usually fades during the progress of prolonged teaching units. Rigour of sampling varies across studies from randomized class sample to convenience sampling, thus influencing the external validity. Comparative synthesis is challenged further by the MASCA framework due to the application of custom-made assessments and different measurement scales. Results on adoption are also polarized mainly on whether professional training to the teacher is included, with further variations within specialisation and experience levels. Such emergent trend highlights the necessity to study awareness among the teachers and to scrutinize the difference characterising specialisation, experience, and acquaintance with professional training (Muskhir et al., 2025).

Advanced Integration

The amalgamation of different research designs and contextual circumstances reflects the presence of a causal order. AR enables the concretization of abstract constructs and the ability to test hypotheses, obtain feedback, and reconstruct conceptual knowledge. Interaction also serves to magnify these effects where learning tasks are socially shared and participative. Professional preparation enhances awareness on the part of the teacher, and perceived curricular relevance to AR enhances acceptability. Differences between grade levels and subjects reflect disparities in cognitive requirements and challenges associated with classroom management. Reconciliation is proposed through the approach of recognising the proximal outcomes awareness and quality of design—in interlinked determinants of effectiveness. Withholding the study to validated instruments and stratified sampling will be used to analyse variations in awareness on the basis of specialisation, teaching experience, and input from training. Standards-aligned tasks and observation will be included by the research to mark the paths between awareness and its linkage to adoption and corresponding commitment and learning outcomes.

Research Gap and Current Study Objectives

While past research is highly positive, all the limitations are still pertained to population scope, construct clarity, and depth of analysis. Teacher considerations are not effectively modelled to portray awareness profiles relating instruction, specialisation, and teaching practice to each other. Data tend to be condensed in particular grade band or subjects, and lack of follow-up procedures or appraisal measures attenuate validity. Heavy dependence on small convenience-centred samplings also minimises the scope for generalising and clouds the effect of moderating considerations. Redresses the deficiencies are met by the current study by operationalising teacher awareness as being multi-dimensional and by modelling the variations across specialisation, teaching experience, and professional exposure. The main goal is to gauge awareness level and determine group differences and relate them to the curricular alignment and casual adoption. Reliability check and transparent reporting are included in the research layout to facilitate the replicate-ability within different educational settings (Borgen, Ropp, & Weldon, 2021).

This review undertakes an integrative analysis of the published studies on the learning effects, underlying processes, and adoption settings of AR, and covers results from experimental, mixed-method, and questionnaire studies. In its analysis, it detected flaws on the modelling of the awareness of the teacher and on the contextual uses on the instructional level. The goals of the current research directly address the latter and uses research methodologies and measures that correspond to the main theoretical and empirical bases developed in the prior literature.

Methodology

Research Design

The current research is consistent with the method adopted by Criollo-C et al. (2021) to employ descriptive survey research to determine signs of abnormal states and awareness. However, it departs from this by embracing quasi-experimental models to check the results of intervention. This research orientation thus reflects the study's focus on the ranking of awareness more than on the prediction of causal relations. Consistent with this consideration, the research design brings together the following considerations to maximise the coverage scope, ecological validity, and the scope of generalisability within the contextual scope delimited:

Sample

The study will focus on teachers as the target population, as it aims to investigate teacher-related factors influencing levels of technology adoption. This contrasts with studies such as Chu and Lee (2025), which examined student populations. Concentrating on teachers allows for a more direct assessment of professional influences and contextual constraints that affect classroom integration. This approach also centres on the key decision-makers who play a primary role in the adoption process.

Instruments

Data will be gathered through the help of a structured questionnaire that is set to be reliable and aided by validity evidence following the work by Di Pasquale et al. (2024). Whilst the research by Zhang et al. (2023) uses achievement tests, critical-thinking tests, and motivation scales, the study does not exploit any of these measures due to the emphasis on awareness and not performance by the students. Instrument items are set to elicit perceived pedagogical affordance, curricular relevance, and adoption intention. The selected format will allow for consistent administration and standardised marking.

Study Procedures

Research Method

To achieve its research objectives and address the research questions, the study employed the descriptive survey method. This approach, as noted by Papadopoulos and Katsanos (2023), enables researchers to gather comprehensive and accurate information that reflects social reality, influences cultural, political, and scientific domains, and facilitates the analysis of related phenomena.

Population and Sample

Population consists of all the female middle school science teachers working within the government schools under the jurisdiction of the Al-Kharj Governorate, Kingdom of Saudi Arabia, during the second semester of the academic year 1446 AH. By official records, the total population is equal to 120 teachers. A random sample size of 90 teachers has been chosen to amplify representativeness and reduce the effect of selection bias. Table 1 displays the demographic information on sampled participants.

Table 1: *Sample Description: Specialisation, Experience, and Technology Training Courses.*

Variables	Frequency	Percentage
1 – Years of Experience		
5 Years or Less	48	53.33%
6–10 Years	29	32.22%
More than 10 Years	13	14.44%
Total	90	100%
2 – Scientific Specialisation		
Biology	42	46.67%
Physics	23	25.56%
Chemistry	25	27.78%
Total	90	100%
3 – Training Courses in Technology		
5 Courses or Less	52	57.78%
6–10 Courses	28	31.11%
More than 10 Courses	10	11.11%
Total	90	100%

Research Instrument

The questionnaire used here is the one developed by the researcher himself to gauge the awareness among middle school science teachers about the need to implement AR technology to teach science, keeping in view some demographic variables. Questionnaire construction was the result of guidance provided by what has been learned about the implementation of AR from previous research on the application of AR to teach. The questionnaire included 25 declarative statements sent to middle school science teachers working in the Al-Kharj Governorate to gauge their awareness and perception about the learning outcomes and benefits of teaching through AR. The questionnaire was framed along the lines of two broad sections.

Demographic Data

It covers factors such as the years of experience, scientific expertise and the number of completed technology trainings.

Awareness of AR Technology

It measures intended to deliver the perceived importance and utility of AR in science education.

Validity and Reliability of the Study Instrument

Face Validity

Expert judgment was used to determine the face validity of the instrument. The pilot version of the questionnaire, consisting of 25 items, was piloted with the help of a committee consisting of 10 experts consisting of faculty members teaching the curriculum and science teaching methods along with senior science supervisors and teachers. All items were tested by the panel on the grounds of relevance, clarity, and suitability and recommendations towards further improvement. Depending on these recommendations, some items were edited, merged, or deleted and the final version of the questionnaire consisting of 20 items were developed.

Internal Consistency Validity

For internal consistency testing, piloting the questionnaire was undertaken on 30 educators who filled out the new questionnaire. IBM SPSS data analysis examined Pearson correlation coefficients between individual items and the overall sum of the corresponding dimension's corresponding items. It has been used to test the construct validity of the survey questionnaire and is represented on Table 2.

Table 2: *Pearson Correlation Coefficients Between Each Item and the Total Score.*

Item	Statement	Pearson's r
1	Using AR helps science teachers create scientific and technical content for teaching.	0.622**
2	Simplifies scientific concepts and facts for students.	0.575**
3	Promotes deep understanding of scientific knowledge among students.	0.640**
4	Develops principles and skills of self-learning in science.	0.511**
5	Enhances students' critical, creative, and scientific thinking skills.	0.705**
6	Improves students' academic achievement in science.	0.734**
7	Provides diverse learning methods suitable to science content.	0.672**
8	Supports instructional activities based on students' individual differences.	0.719**
9	Develops interactive and participatory learning skills.	0.563**
10	Creates an engaging and motivating learning environment.	0.655**
11	Promotes principles of effective learning in science teaching.	0.596**
12	Saves time and effort in delivering scientific knowledge.	0.641**
13	Provides flexible and diverse assessment methods.	0.560**
14	Intellectually supports students with enrichment scientific topics.	0.529**
15	Designs learning activities related to science content.	0.519**
16	Employs AR-based applications in science teaching.	0.515**
17	Increases students' self-efficacy in science learning.	0.663**
18	Promotes meaningful learning in science.	0.524**
19	Generates new and creative ideas among students.	0.612**
20	Enhances the principle of enjoyment in science learning.	0.681**

Study Instrument Reliability

The reliability of the questionnaire was assessed using Cronbach's Alpha and the Spearman-Brown split-half coefficient. The instrument was pretested with a randomly selected pilot group of 30 teachers, representing the study population. Reliability coefficients were calculated to determine the internal consistency of the questionnaire. A summary of these results is presented in Table 3.

Table 3: *Reliability Coefficients of the Study Instrument using Cronbach's Alpha and Spearman-Brown Split-Half.*

Dimension	No. of Items	Cronbach's Alpha	Split-Half Reliability
Overall Instrument	20	0.827	0.885

Reliability Coefficients of the Study Instrument

As indicated in Table 3, the overall consistency coefficient of the instrument was 0.827 based on Cronbach's Alpha, while the split-half coefficient calculated using the Spearman-Brown method yielded a value of 0.885. Both values surpass the widely accepted reliability threshold of 0.70 (Villanueva et al., 2021), signifying a high degree of internal consistency and confirming that the questionnaire is a reliable tool for data collection within this study's context.

Procedure of the Study

The research process was carried out in a systematic manner, following these sequential steps:

- Conducting an extensive review of theoretical and empirical literature relevant to the research area.
- Developing a reliable research instrument (questionnaire) and establishing its face validity through expert evaluation.
- Defining the study population and determining an appropriate representative sample.
- Testing the accuracy and internal consistency of the questionnaire.
- Administering the questionnaire to the selected sample.
- Collecting responses from the participants.
- Coding and entering the collected data into IBM SPSS for statistical analysis.
- Analysing the data, deriving conclusions, formulating recommendations, and compiling the final research report.

Statistical Methods

To address the research questions and evaluate the instrument, multiple statistical analyses were conducted using IBM SPSS. These included the following procedures:

- Calculation of Pearson correlation coefficients and Cronbach's Alpha to determine the reliability and internal consistency of the instrument.
- Application of descriptive statistics, including frequencies and percentages, to summarise the demographic characteristics of the study sample.
- Computation of means and standard deviations to evaluate participants' responses to the questionnaire items.
- Use of ANOVA to identify statistically significant differences in mean scores based on the number of training courses attended, years of teaching experience, and scientific specialisation.
- Application of Scheffé's post hoc test to further examine intergroup differences where significant variations were detected.
- Execution of a one-sample t-test to determine whether the participants' mean scores significantly deviated from the theoretical mean value of 3 on a five-point Likert scale.

Scoring of the Questionnaire and Response Criteria

Middle school science teachers were assessed regarding their awareness of the importance of integrating AR into science instruction. Responses were categorised under five levels: Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree, each corresponding to a weighted value on a five-point Likert scale. To interpret the response levels, the interval used for classification was determined based on the standard formula:

$$Class\ interval = \frac{Range}{Number\ of\ response\ options} = \frac{4}{5} = 0.80$$

Accordingly, the mean scores were interpreted as follows:
Strongly Disagree = **1.00 – 1.80**
Disagree = **1.81 – 2.60**
Neutral = **2.61 – 3.40**
Agree = **3.41 – 4.20**
Strongly Agree = **4.21 – 5.00**

Results

The findings of this study will be organised to address the research objectives and evaluate the extent to which each aim has been fulfilled. The data analyses are presented to clarify the principal outcomes, highlight trends across the key variables, and provide empirical evidence in support of the research questions. Accordingly, this section of the study will be structured as follows:

Results Related to the First Research Question

What is the awareness of middle school science teachers on the relevance of applying AR in the teaching of science?

In order to answer this research question, all questionnaire items were examined through arithmetic mean, standard deviation, percentage, and t-value. And the items themselves ranked by mean scores, as shown in Table 4. Table 4 illustrates that middle school science teachers report high awareness about the worth of embedding AR within the teaching of science ($M = 4.06$, $SD = 1.09$; $t = 9.17$, $p < 0.01$). Overall mean scores range from an average of 3.29 (on the Neutral scale) to 4.37 on the Strongly Agree scale and indicate a strong awareness about the teaching potential of AR, especially the potential to create interactive and engaging learning and to cater to heterogeneous learners. Nevertheless, slightly lower mean scores on items related to self-efficacy and adaptive evaluation suggest potential areas where extra professional development or hands-on experience would be helpful. This pattern is consistent with the results from Czok et al. (2023), who described how the application of AR technologies can effectively improve conceptual knowledge and interest in the learning of science. Grodotzki, Müller and Tekkaya (2023), on the other hand, signaled limited adoption by educators and suggested that the difference could be due to institutional readiness, resource availability, and professional development. Such an optimistic outlook that is observed within the study is likely due to an increasing openness to technological advances and the availability of initiatives within the last few years to enhance the competency of the teaching profession and to combine innovative instructional materials and procedures. All these results imply that sustained supports mechanisms, namely professional development, balanced distribution of resources and collaborative practicing policies and entities are necessary to ensure that educators can fully capitalize on the possibility augmented by AR to teach to heterogeneous learners. Long-term investment is very much critical to translate strong awareness to long-standing quality teaching practice and to help bridge the gap within the modern teaching and learning of science.

Results Related to the Second Research Question

Do the levels of awareness of middle school science teachers about the necessity of using AR in teaching science significantly differ depending on an attribute of scientific Specialisation?

To answer this research question, ANOVA tested whether the awareness by middle school science teachers about the educational significance of AR in science teaching differes by scientific specialisation. As Table 5 reveals, there is no statistically significant difference among middle school science educators about the educational significance of AR by scientific specialisation. The results of the ANOVA provided an F-statistic of 0.408 with a corresponding significance value of 0.666, exceeding the 0.05 critical value. This suggests that educators teaching different scientific specialisations, including chemistry and biology and physics, exhibited similar awareness about the instructional potential of AR. Such results replicate those identified by Nadeem et al. (2022), who also detected insignificant difference among educators about technological awareness by subject specialisation. One viable explanation behind this finding is standardisation by academic preparation and professional development courses availed to science educators to ensure equal coverage by technological tools and novel teaching techniques regardless of specialisation. Complementary to this is the effort by the Ministry of Education at the national level to ensure the inclusion of technology by science educators in teaching to inspire uniform coverage by educators regardless of specialisation. Science teaching by its nature integrates pre-discipline and interdisciplinary aspects and hence systemic forces could be an explanation behind the high awareness by AR by educators regardless of specialisation identified by this study.

Table 4: *Middle School Science Teachers' Awareness of Augmented Reality Integration in Science Education.*

Item	Mean		SD	%	T-Value %	Significance	Response Level	Rank
1	AR helps the science teacher create scientific and technological content for teaching science.	4.25	1.23	85.00	9.74	Strongly Agree	6
2	Simplifies scientific concepts and facts in science learning for students.	3.91	1.58	78.20	5.46	Agree	16
3	Achieves deep understanding of scientific knowledge for students in learning science.	4.1	1.45	82.00	7.18	Agree	14
4	Develops students' principles and skills of self-directed learning in science.	4.12	1.36	82.40	7.8	Agree	13
5	Enhances students' critical, creative, and scientific thinking skills during science learning.	3.79	1.63	75.80	4.59	Agree	17
6	Increases academic achievement in science learning.	4.24	1.24	84.80	9.53	Strongly Agree	7
7	Diversifies learning methods in line with scientific content.	4.18	1.36	83.60	8.2	Agree	11
8	Enhances educational activities according to individual differences among students.	4.31	1.12	86.20	11.12	Strongly Agree	2
9	Develops students' skills in interaction and active participation in science learning.	4.19	1.32	83.80	8.53	Agree	10
10	Provides an attractive and engaging learning environment for students.	4.37	1.2	87.40	10.77	Strongly Agree	1
11	Achieves principles of effective learning in teaching science.	4.21	1.34	84.20	8.6	Strongly Agree	9
12	Saves time and effort in delivering scientific knowledge to students.	4.28	1.39	85.60	8.72	Strongly Agree	4
13	Provides diverse and flexible assessment methods suitable for students.	3.33	1.86	66.60	1.7	Neutral	19
14	Supports students intellectually through enriched scientific topics for performance tasks.	3.71	1.57	74.20	4.29	Agree	18
15	Designs educational activities related to the scientific content of the subject.	3.96	1.48	79.20	6.11	Agree	15
16	Utilizes AR-based technological applications in teaching science.	4.26	1.33	85.20	8.97	Strongly Agree	5
17	Increases students' self-efficacy in learning science.	3.29	1.79	65.80	1.41	Neutral	20
18	Facilitates meaningful learning in science.	4.23	1.37	84.60	8.51	Strongly Agree	8
19	Generates new and creative ideas among students in science learning.	4.14	1.4	82.80	7.74	Agree	12
20	Achieves the principle of enjoyment among students in science teaching.	4.29	1.31	85.80	9.34	Strongly Agree	3
Overall Score		4.06	1.09	81.20	9.17	Agree	

Table 5: *Significance of Differences in Science Teachers' Awareness of AR by Scientific Specialisation.*

Variable	Source of Variation	Sum of Squares	d.f	Mean Square	F-Value	Significance
Overall Score	Between Groups	0.991	2	0.496	0.408	0.666
	Within Groups (Error)	105.698	87	1.215		
	Total	106.69	89			

Results Related to the Third Research Question

Do science teachers in middle school statistically differ in their awareness levels of the importance of using AR in teacher science instruction by years of teaching experience?

To answer this research question, ANOVA analysis was performed to determine whether there is any difference between teachers' awareness regarding the value of AR in teaching sciences based on the years of teaching experience. Results of the analysis are listed in Table 6. Results shown by Table 6 indicate that there is a statistically significant difference at the .01 level between the awareness scores of the teachers considering the teaching experience. Calculated F-value = 5.867 and significance value = 0.004 ($p < 0.05$) further validate the fact that experience is measurable on influencing awareness about the value of AR among the educators. This finding further supports that differences between the teaching tenure are meaningfully adding to the divergences among the educators regarding the perception and worth to be covered by the application of AR during teachings.

Table 6: *Science Teachers' Awareness of Augmented Reality: Impact of Years of Experience.*

Variable	Source of Variation	Sum of Squares	df	Mean Square	F-Value	Significance
Overall Score	Between Groups	12.68	2	6.34	5.867	0.004
	Within Groups (Error)	94.01	87	1.081		
	Total	106.69	89			

To establish which particular groups significantly differed from each other in awareness levels, the Scheffé post-hoc test was performed. Results from this analysis are shown in Table 7. The results shown in Table 7 indicate statistically significant differences at the 0.01 level between teachers with fewer than five years and those with between five and fewer than ten years of experience, in favour of the latter. Similarly, whereas also the former group with fewer than five years of experience differed from the latter group with ten or more years of experience, the difference was statistically significant at the 0.05 level, favouring the more experienced teachers. However, statistically significant difference did not arise between the group with five to fewer than ten years and the group with ten or more years. These results confirm that teaching experience is an important determinant of the proficiency and awareness among teachers about the application of AR to science learning. Contrary to the finding by Sriadhi et al. (2022) where they reported lack of significant differences through teaching experience, the results from the present study indicate the effect of contextual aspects like professional development opportunities. While the Ministry of Education through its management structure has extensive and relentless professional development plans that make the seasoned educators familiar to the teaching technologies and the digital learning tools, the observed enhanced awareness could be attributed to the effective professional support culture and the instititional encouragement that is rife within the Saudi learning system.

Table 7: *Scheffé Test Results: Teachers' Score Differences by Years of Experience.*

Group 1	Group 2	Mean Difference	Standard Error	Significance
Less than 5 Years	5–<10 Years	-0.82	0.244	0.003**
Less than 5 Years	10 Years or More	-0.525	0.325	0.025*
5–<10 Years	10 Years or More	0.296	0.347	0.672

Note: *Significant at 0.05, **Significant at 0.01.

Results Related to the Fourth Research Question

The fourth research question investigated whether statistically significant differences occurred in the awareness among science teachers of the significance of the application of AR in teaching science due to the number of technology courses they undertook. ANOVA was used to answer the question. Table 8 results reveal the association between the level of teachers' involvement in professional technical training and the perception about the significance of the application of AR in teaching science. Statistically significant differences occurred at the 0.01 level between the group consisting of tutors with fewer than five years of teaching experience and the group consisting of tutors with between five and fewer than ten years of teaching experience and the former group registered higher mean scores. Likewise, tutors with fewer than five years of teaching experience also significantly differed from tutors with ten years and more teaching experience, where the former group registered higher mean scores at the 0.05 level. Nonetheless, there occurred no statistically significant difference between tutors with between-five and fewer-than-ten years teaching and tutors with ten years and more teaching experience. This is in sharp contrast to the finding by Yoon and Kang (2021) where there occurred insignificant differences due to teaching experience. This difference is attributed to the professional development and the provision of technology courses undergone by the active tutors within the Kingdom of Saudi Arabia where the tutors are on a regular basis provided with new technological and digitized teaching techniques since the Ministry of Education ensures the constant provision and strong emphasis on the innovative teaching and learning of sciences.

Table 8. *Differences in Teachers' Mean Scores by Number of Technical Training Courses.*

Variable	Source of Variation	Sum of Squares	df	Mean Square	F-Value	Significance
Overall Score	Between Groups	4.434	2	2.217	1.886	0.158
	Within Groups (Error)	102.256	87	1.175		
	Total	106.69	89			

Discussion

Interpretation of Results

Quantitative results Verify the hypothesis that middle school educators from Al-Kharj demonstrate an extensive awareness about the significance of AR within the educational process (M = 4.06, SD = 1.09) (Hidayat & Wardat, 2024). Such awareness has been measured along various aspects, namely perceived affordances, alignment with the curriculum and intention to adopt. Therefore, the first research goal has been attained where educators provided positive assessments about AR and its instructional worth. Hypothesis testing also uncovered significant variations on the basis of teaching experience (F = 5.867, p = 0.004), thereby validating the proposition that professional experience has an effect on technological proficiency. Conversely, statistically significant variations proved unfindable on the basis of scientific specialisation (F = 0.408, p = 0.666), and thus the proposition about discipline-wise differences is negated (Saidani Neffati et al., 2021).

Theoretical and Practical Implications

These results confirm the diffusion of innovation theory where awareness is suggested to be an measurable antecedent to technology uptake in the field of education. Experience-related gradient observed seems to Favor professional development models emphasizing the incremental build-up of expertise over time. Practically, the results can serve the basis on which targeted intervention initiatives can be developed aligned with the Vision 2030 targets on the integration of educational technology. Policy policies should thus embrace experience-differentiated orientations to training where the more receptive more experienced educators are catered to but the full range of support is extended to the less experienced educators. The awareness profiles thus developed can serve to inform evidence-informed decisions on the distribution of resources and the organization of professional learning programs and thus the effectiveness improved in the implementation of the AR across the different teaching populations (Kamińska et al., 2023).

Comparison with Previous Literature

The current research reflects the awareness level among the middle school science teachers higher than that seen in comparable international studies that reviewed teachers' attitudes about the employment of technologies. Such results are aligned with new evidence reflecting optimistic educators' attitudes regarding the teaching employment of immersive technologies. Nevertheless, the experience difference witnessed within this study is not aligned with past research reporting that teaching tenure doesn't significantly relate to the adoption of technologies. However, the outcome seen among the scientific specialisation results is aligned with previous studies indicating the absence of disciplinary differences in technology acceptance. Such trends further indicate the dependency between technological awareness and demographic characteristics within educational venues on contextual aspects, namely professional development efforts sustained over time, support mechanisms at the institutional level and the integration strategies generated through policies.

Methodological Insights

Using a descriptive survey research design allowed the profiling of awareness among the full target population and maintained ecological validity. Statistical power to the study sufficient to discern group differences due to the utilisation of ANOVA and sample size (N = 90) appropriateness. Research instrument showed satisfactory reliability ($\alpha = 0.827$), validating construct measurement accuracy. However, convenience sampling on its own used within Al-Kharj means the results do not generalise to wider populations. Also, the cross-sectional data gathering places constraints on inferring causal relations regarding awareness development over time. Future studies thus need to utilise longitudinal research designs and randomised sampling to enhance both internal and exterior validity and allow more secure theoretical explorations (Alhalabi et al., 2021).

Explanation of Similarities and Discrepancies

Seen effects of teaching experience are probably linked to Saudi Arabia's formal professional development system that avails seasoned educators with broad opportunities to be trained in technological areas. Institutionally sanctioned relentless learning and encouragement to innovate could be the reason behind the observed high awareness levels compared to international contexts. Lack of difference by scientific specialisation could be due to the common standardization of the pre-service preparation regardless of scientific specialisation. Awareness profiles that are positive could also be due to regional considerations such as availability of resources and supportive administration. Such contextual considerations imply that awareness patterns among educators are not merely an outcome of individual properties but also system properties of the teaching milieu (Hemme et al., 2023).

Integrative Conclusion

Both interpretations conform to the available frameworks within the extant research on educational technology and professional development to be quoted in the following updates. This research shows that awareness about AR in teaching is transmitted systematically by the professional experience among the teaching staff and is consistent across various specializations in the sciences. The results help the theory to understand the determinants of key antecedents to the adoption of technology and help to shape strategies leading to its efficient deployment. Future work should examine the association between awareness levels and the actual classroom practices of integrating the technology. The outcomes report provides the basis upon which evidence-informed policies can be developed to facilitate effective and practicable integration of the AR by the middle school science teaching arm (Jiang et al., 2025).

Conclusion

The research found that middle-school science teachers enjoy an elevated awareness of the teaching potential of AR in the teaching of science by an overall mean rating of 4.06. Awareness did not differ appreciably by scientific specialisation, but those with more experience showed an overwhelming advantage; undertaking training courses could hardly make any difference. Based on these results, the research contributes to the literature by operationalising teacher awareness as a multi-faceted construct consisting of perceived affordances, curricular consistency and adoption intention and operationalising the same through a validated instrument ($\alpha = 0.827$) and under main demographic moderators. This study supplies the whole-of-Saudi Arabia region with a sensitivity-informed profile of awareness across Saudi middle schools and provides a credible and transferable questionnaire to inform targeted professional learning and facilitate evidence-informed growth along the priorities laid out by Vision 2030. Practically, the results justify differentiated professional development, informed resource allocation commensurate with instructional demands and the framing of observation frameworks to connect the adoption readiness of AR to quantifiable learning outcomes and the optimal roll-out.

Recommendations

Regulators and institutions must insist upon stepwise templates consisting of numbered steps, mandatory input, and explicit acceptance criteria. Such templates must be executed via standardised checklists, pilot A/B testing on similar tasks, and failure-mode linkage audits counting against the number of template edits. Program managers must make tasks be decomposed to components wherein each component has an assigned sub-goal, input, systematic output and explicit ownership. This can be mediated via dependency maps, task-tracking gates and integration review mediated by sheets with explicit steps and variant-specified variants. We would advise spending more time on the platform-thinking time with stiff latency-bottlenecks and consistency checks. One can do this by adding draft and final state, permitting oneself-reflection prompts and rubric-based grading to release only after stipulate reliability thresholds are reached. Persona assignment along the lines of the role, audience, constraints and tone must be formalized via quality-assurance offices. Mandatory metadata labels, pre-execution checks and large-scale analytics datasets must be utilised to identify drift to start the retraining and boost high-performing personas to enterprise-wide repositories.

Study Limitations

Limitations of the study are the following: first, the study used a cross-sectional and self-reported study design and only captured perceived awareness and intention but not actual classroom adoption nor student learning outcomes. Such an approach is susceptible to common-method bias and constrain the determination of causal links between awareness and adoption. Second, the study only included a sample from Saudi middle-school science teachers, thus limiting the generalisability of the results to other subjects, grade levels, or educational systems and also could be biased to policy and structure against and by the professional development structure unique to the Saudi school system. Thirdly, the framework to measure simply entailed the aspects related to the dimensions of awareness perceived affordances, curricular alignment, and intention to adopt but without triangulating by indicators of the quality of implementation and fidelity and long-term consequences and hence did not accurately represent the overall quality of AR integration into the everyday teaching practice.

Study Implications and Future Directions

Research has some methodological and practical implications and future research directions. Methodologically, the validated instrument to assess awareness can be used to create diagnostic assessments of needs, to benchmark teacher readiness, and to inform targeted professional development commensurate with curricular expectations. Practically, the research lends support to the strategy of modular implementation by relating the purchase and selection of educational resources to instructional relevance, teacher proficiency, and professional coaching. At the system-architecture level, consistency and quality outcomes can be improved by integrating structured time for thinking and persona-cantered guidance within task instructions. Future research should take the form of longitudinal studies employing mixed methods and experimental study where survey diagnostics are used together with classroom observation and learning analytics. Such studies would make it possible to examine tiered professional development at the regional and grade-level system to determine the cost-effectiveness, implications on the distribution of equity, and the sustainability of the adoption of AR under the scrimping and saving conditions of real-world implementations.

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