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Teacher-Mediated Augmented Reality and AI-Assisted Materials in a Moroccan Middle School: Vocabulary, Reading, and Writing Gains among Grade 8 EFL Learners

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ABSTRACT

The integration of emerging technologies into English as a Foreign Language (EFL) instruction has received growing attention, yet evidence from lower secondary schools remains limited, particularly on teacher-mediated augmented reality (AR) supported by AI-assisted material development. This study examined whether participation in a teacher-mediated, AR-supported instructional environment was associated with differences in vocabulary, reading comprehension, and writing performance among Grade 8 EFL learners in a Moroccan middle school. A quasi-experimental pre-test/post-test design was used with 60 learners aged 12–16 in two intact classes. The control class received textbook-based instruction aligned with the national curriculum; the experimental class followed the same curriculum supplemented with AR-enhanced materials. AI tools assisted only with scripting and content preparation, the teacher reviewed all materials, and no AI feedback, grading, or instructional decisions were used in class. Curriculum-aligned tests were administered before and after a four-week intervention and analyzed with paired-samples *t*-tests and with Welch independent-samples *t*-tests on gain scores. Both groups improved significantly in all three domains ($p < .001$). The experimental group showed larger mean gains in vocabulary (2.22 vs. 0.76), reading comprehension (2.19 vs. 0.59), and writing (1.63 vs. 0.64), with significant between-group differences in each domain ($p < .001$; Hedges' $g = 1.67$, 1.97, and 1.26). Because the study relied on intact classes, teacher-developed assessments, a single school, and a short intervention, the findings are interpreted as associative rather than causal. They underline the importance of pedagogical design and teacher mediation when emerging technologies enter EFL classrooms.

KEYWORDS

EFL

Augmented Reality

Artificial Intelligence

Vocabulary

Reading Comprehension

Writing

Introduction

The introduction of digital technologies in the teaching of English as a foreign language (EFL) has increasingly been associated with efforts to improve learner interaction, increase their exposure to purposeful language input, and facilitate varied learning experiences in school settings. In computer-assisted language learning (CALL) research there has been an increasing focus on the shift from isolated tools to pedagogically integrated learning environments that

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incorporate technology into the practices and curricular objectives of the classroom (Stockwell 1).

Augmented reality (AR) is one of the new technologies that have gained increased interest because of its ability to place digital information over physical learning environments, thereby facilitating contextualized and situated learning. AR environments enable learners to interact with linguistically relevant material that is visually and spatially embedded, which may support meaning-making processes (Lee and Park 936). Such contextualization is particularly crucial in school-based EFL settings, where learners often benefit from concrete and task-supported learning experiences.

Empirical research on the topic in the secondary school setting indicates that AR-based teaching can potentially enhance learner motivation and help them develop vocabulary provided that it is incorporated into well-structured classroom tasks. When AR resources are aligned with instructional goals and learners are guided by the teacher, they are more likely to show increased engagement and better retention of lexical items (Fan et al. 1093). Nevertheless, studies have also warned that AR does not automatically yield learning benefits; its usefulness is determined by pedagogical scaffolds, task design, and instructional mediation rather than by technological novelty (Dunleavy and Dede 741).

In addition to AR, artificial intelligence (AI) has become an additional technology in language education, especially in terms of content preparation, adaptive feedback, and linguistic support. Recent school-focused studies have investigated the use of AI-assisted tools for language practice and instructional design, noting that it may increase the coherence and responsiveness of learning materials when the tool is used under teacher supervision (Mohebbi). Recent discussions of AI integration in TESOL similarly emphasize that AI tools should be considered in relation to pedagogy, teacher knowledge, and instructional purpose rather than treated as autonomous replacements for teachers (Kohnke and Zou).

This view is pedagogically grounded and concurs with the widely recognized importance of teacher agency in technology integration. Instead of positioning emerging technologies as replacements for instruction, researchers claim that teachers must remain at its center as its designers, mediators, and evaluators (Spector 25). This is especially essential in lower secondary school contexts in which the cognitive, linguistic, and self-regulatory abilities of the learners are still in developmental stages (Dörrenbächer-Ulrich et al.).

In the Moroccan EFL setting, there are few studies on emerging technologies in education, particularly in middle school (Jebbour). The national curriculum introduces English as a foreign language, and its implementation takes place within a context in which efforts and national strategies have been undertaken to improve educational infrastructure and reduce class size (Jebbour). These contextual factors raise important questions in terms of the practicality and pedagogical compatibility of AI- and AR-based teaching within the context of a public-school environment. Findings from well-resourced or tertiary-level settings cannot be easily generalized to these contexts.

The present study addresses these gaps by examining a pedagogically structured teacher-mediated AI-facilitated AR instructional setting for Grade 8 Moroccan middle school learners. Instead of treating the effects of AI or AR as independent variables, the study conceptualizes an integrated instructional environment, where technological tools are actively subordinated to the curricular goals and classroom activities.

This study is located in a lower secondary EFL context in Morocco, thus adding context-specific evidence to a body of literature that is skewed towards higher education and Global North contexts. Concurrently, the research assumes a cautiously conservative position and

recognizes methodological limitations involved in quasi-experimental school-based research such as the use of intact classes and curriculum-congruent assessment tools.

The research aims to contribute to the debate on AI- and AR-mediated EFL teaching by prioritizing pedagogical design, contextual realism, and methodological caution. Instead of making claims of technological change, it provides empirically grounded observations that may guide future research on the emerging technologies in secondary-level language education.

The following research questions guided the investigation. Because the study was exploratory and conducted in a real middle school setting, the questions were formulated in associative terms:

RQ1. Does participation in a teacher-mediated AR-supported instructional environment with AI-assisted material development relate to differences in vocabulary performance in Grade 8 EFL students as compared to traditional teaching?

RQ2. Does enrollment in an AI-assisted augmented reality instructional setting relate to variation in Grade 8 EFL learner reading comprehension performance versus that in traditional instruction?

RQ3. Are Grade 8 EFL learners involved in an AR-supported instructional environment using AI-assisted material development likely to show differences in writing performance as compared to traditional instruction?

These research questions were designed to be associative and not causal in nature, as it was a quasi-experimental research design, and intact classes were used. No causal claims are made beyond the observed patterns in the data.

Based on the theoretical rationale and the comparative pre-test/post-test design, the study formulated the following directional hypotheses:

H1: Learners who participate in the teacher-mediated AR-supported instructional condition will demonstrate greater pre-test-to-post-test gains in vocabulary performance than learners receiving textbook-based instruction.

H2: Learners who participate in the teacher-mediated AR-supported instructional condition will demonstrate greater pre-test-to-post-test gains in reading comprehension than learners receiving textbook-based instruction.

H3: Learners who participate in the teacher-mediated AR-supported instructional condition will demonstrate greater pre-test-to-post-test gains in writing performance than learners receiving textbook-based instruction.

These hypotheses concern expected differences in observed learning gains between the two intact classes and are not intended to imply causal attribution beyond what can be supported by the quasi-experimental design.

Literature Review

Research on technology-based English as a Foreign Language (EFL) instruction in school settings has consistently highlighted the potential of digital technologies to promote engagement, interaction, and access to meaningful language input when these technologies are properly aligned with pedagogical goals. In lower secondary education, where students are moving from basic language exposure to more cognitively demanding tasks, technology-mediated instruction has been identified as a way to provide contextualized and individualized support that is often hard to secure through textbook-based instruction (Abd El-Gawad). Nevertheless, researchers warn that the power of these technologies is determined not so much by their technical complexity but by how well they fit into the instructional and classroom practices (Kim et al.).

Mobile-assisted and multimedia-supported learning environments have been the focus of much interest within the school-based EFL research on the basis of their accessibility and suitability to classroom limitations. Research involving learners in digital reading environments has examined how visual and interactive features can influence reading performance and learner engagement. Such results indicate that the multimodal environments can be especially helpful in the context of adolescent learning, where visually rich and interactive learning experiences are generally well received when linked to the aim of instruction in a meaningful manner (Andrei).

Augmented reality (AR) has become a promising approach to multimodal learning as it allows the digital material to be integrated into the real classroom environment. Recent EFL research has examined AR-supported vocabulary learning and reading comprehension, including work on AR-enhanced vocabulary instruction and AR-supported reading comprehension (Khan et al.; Asadi and Ebadi; Salehi). Khan et al. examined AR-supported vocabulary learning among 95 university-level EFL learners and reported improved vocabulary development and positive learner perceptions of AR. Asadi and Ebadi investigated AR applications for EFL reading comprehension and reported that thoughtfully designed AR applications could support reading comprehension while also being positively perceived by teachers. Salehi examined the perspectives of junior-high-school English teachers concerning AR-supported vocabulary instruction, including its potential benefits, teacher readiness, and implementation challenges. Contextual grounding of this kind has been linked to better recall and retention in that learners can also tie new forms of language to perceptually salient information instead of definitions in isolation. Notably, these benefits appear to be strongest when AR activities are used within integrated activities rather than solely as an exploratory tool.

In addition to learning vocabulary, AR has also been studied as an aid in the process of reading comprehension among school-age learners. Research on EFL reading comprehension has shown that AR applications can provide additional visual and contextual support during reading tasks (Asadi and Ebadi). Such findings can be interpreted in relation to Mayer's Cognitive Theory of Multimedia Learning (CTML), which proposes that multimedia learning involves visual/pictorial and auditory/verbal processing channels, each with limited processing capacity, and that meaningful learning requires active coordination of these representations (Mayer). A recent review by Morfidi and Iatraki examined the use of AR in reading instruction and highlighted the potential of AR to support reading through interactive and adaptable learning experiences.

Although AR has been associated with potential learning benefits, research also indicates that its educational value depends on instructional design, teacher mediation, and the way learners are guided in using the technology (Dunleavy and Dede; Salehi). Research on teacher competencies in AR-supported educational settings similarly emphasizes the importance of teachers' ability to use AR purposefully rather than simply introducing the technology into instruction (Freese et al.). This finding highlights the fact that AR is not a substitute for instruction; rather, it serves as an enhancement to the learning process conducted by the teacher.

In line with the progress in AR research, AI-supported tools have begun to emerge in school-level language education, especially as adaptive learning systems, automated feedback tools, and intelligent tutoring elements. In a recent systematic review, Kundu and Bej ("AI in School") examined empirical evidence concerning AI in school-based EFL learning and identified engagement, achievement, and satisfaction as important areas of investigation. Unlike higher education research, school-based studies increasingly consider AI as a supportive instructional tool within classroom learning rather than simply as a means of autonomous learning (Kundu and Bej, "AI in School").

Recent research has examined AI-driven adaptive language-learning platforms in relation to learners' needs, proficiency, learning preferences, and engagement (Qu). It seems that these systems are especially applicable to situations in which a teacher works with large classes in which learners have diverse needs.

The use of AI-based feedback aids has also been explored in relation to writing development in lower secondary EFL settings. Recent research on secondary EFL learners has examined AI-assisted writing feedback as a supplement to conventional instruction and teacher feedback (Ekizoğlu and Demir). In these situations, AI is used as a supportive tool, which enhances the frequency of feedback and not as a replacement of teacher assessment. This blended model can provide learners with additional opportunities for revision while retaining an important role for teacher guidance.

Studies also indicate that AI-enhanced environments have a potential contribution to language development via increased engagement, confidence, and motivation in learners. For example, Shadiev et al. examined speech-enabled corrective feedback technology in EFL learning and reported effects concerning learners' speaking development, anxiety, and confidence. Similarly, recent research on AI-supported EFL learning has examined motivation and engagement as important dimensions of technology-mediated language learning (Shadiev et al.; Kundu and Bej, "AI in School"). These affective benefits may be particularly relevant to middle school EFL classrooms where anxiety and hesitation to use the target language may prevent participation.

Recent research has begun to investigate the integrated use of various technologies in integrated learning settings. Garg et al., in a systematic review of AR, AI, and emerging technologies in education, emphasized the potential of combining AR with adaptive and personalized technological support while also identifying teacher readiness, accessibility, cost, and pedagogical alignment as important implementation considerations. Instead of justifying the gains of learning by one technological property, these studies emphasize the significance of coherence among technological affordances and pedagogical objectives (Garg et al.).

Along with developing interest in integrated digital environments, there are also several challenges which are mentioned in the literature. Among the issues raised frequently is the potential threat of cognitive overload when learners are exposed to multimodal input without adequate coordination (Mayer). School settings, where students might lack much experience with complex digital interfaces, may hinder learning because of excessive visual information or poorly timed visual information. This observation confirms the importance of prudent sequencing of instructions and a gradual introduction of technological features.

Another issue identified in school-based research concerns equity and access. Research on technology integration in middle-school language classrooms has shown that the availability of technology does not necessarily lead to effective integration and that teachers may face limitations involving time, resources, training, and technical support (Andrei). Teachers need to become flexible and creative with digital interventions to meet local limitations in contexts where the devices are unavailable or dependent on unreliable internet connectivity, rather than focusing on technical sophistication.

Teacher beliefs and professional competence are also key factors that determine the use of technology in EFL middle school classrooms. Studies have indicated that teachers' beliefs and attitudes toward technology are closely related to their technology-integration practices (Kim et al.). Research involving middle-school ESL teachers likewise found that teacher attitudes, available resources, time, and professional support influence the ways technology is integrated into classroom practice (Andrei). Professional development in pedagogical technology integration and basic technological competence has proved to be helpful in maintaining effective and sustained use of technology in schools.

In EFL-related studies, researchers have emphasized the importance of aligning technology-enhanced instruction with the key principles of language learning like meaningful input, opportunities for language production, and interaction. Research on technology-supported language learning emphasizes the importance of using digital tools in ways that support authentic language use and meaningful learning activities rather than isolated technological practice (Kohnke et al.). This perspective reinforces the view that technologies such as AI and AR must be integrated into communicative activities that prompt learners to process and apply language meaningfully.

With the advances that have been made, the literature is still weak in a number of aspects. To begin with, the majority of studies concentrate on individual skill outcomes, especially vocabulary, and there are fewer studies which seek to study the integrated language outcome related to reading and writing as well as lexical knowledge in school settings. Second, there is a limited body of research on subject-specific AI-based instructional design in conjunction with AR-based learning at the lower secondary level. Third, research conducted in underrepresented settings such as North African public-school systems remains comparatively limited, although recent Moroccan research has begun to examine AI integration in secondary EFL contexts (Enaim et al.; Farhane). These limitations restrict the contextual diversity represented in the current research.

The studies indicate that the implementation of technology-based EFL learning in middle school is promising, provided that it is based on adequate pedagogy, teacher mediation, and sensitivity to the context (Andrei; Kundu and Bej, "AI in School"). AR may help provide contextualized input and interaction, whereas AI-assisted tools can be used to increase differentiation and feedback when wisely deployed (Kundu and Bej, "AI in School"; Kohnke et al.). Nevertheless, these environments should be integrated into logical instructional frameworks that place learning goals at the forefront instead of pursuing technological innovations (Kohnke et al.).

These findings provide a conceptual foundation for the present study, as it aims to investigate the relationships between involvement in a pedagogically grounded, AI-supported AR instructional environment and language learning among EFL learners in a Moroccan middle school.

Theoretical Framework

The present study is theoretically informed by the Cognitive Theory of Multimedia Learning (CTML), which explains learning from instructional materials that combine words, images, and other forms of multimedia representation. CTML proposes that learners process information through separate but interacting visual/pictorial and auditory/verbal channels, that each channel has limited processing capacity, and that meaningful learning requires active cognitive processing. In multimedia instruction, learners select relevant information, organize verbal and pictorial representations, and integrate these representations with prior knowledge (Mayer 57–72).

This framework is relevant to the present study because the experimental condition combined printed language materials with AR-triggered visual and video resources, contextualized vocabulary support, reading prompts, and guided writing activities. The AR component therefore functioned not simply as a technological addition but as a means of extending the forms through which instructional information was presented and revisited. The use of short visual and video explanations was intended to provide additional representations

of selected language input while maintaining teacher mediation and alignment with the curriculum.

The framework does not, however, imply that multimedia or AR automatically produces better learning outcomes. Its relevance to the present study lies in providing a theoretical rationale for examining whether an instructional environment that integrates complementary verbal, visual, and contextual resources is associated with different learning outcomes. Because the present intervention also involved teacher mediation and AI-assisted preparation of materials, the study does not isolate the independent contribution of AR, multimedia input, or AI. The theoretical framework is therefore used to explain the instructional rationale of the integrated environment rather than to attribute observed differences to a single technological component.

Methodology

The study employed a quasi-experimental pre-test/post-test control-group design, which is generally used in educational studies in schools when random assignment of participants is not possible. Two Grade 8 intact classes in the same local middle school were selected, and one was assigned to the experimental group and the other to the control group. The groups followed the same national English curriculum during the same instructional period, by the same instructor, and using the same instructional content. The main distinction between the two groups was the mode of instructional delivery, as the experimental group received instructional materials coupled with an AI-supported augmented reality setting, whereas the control group received textbook-based teaching. This design allowed the researchers to examine pre- to post-intervention changes in both groups and the comparison of learning outcomes across groups while maintaining ecological validity.

The study was carried out in a public middle school in Morocco during a regular school year. English is taught as a foreign language as part of the national program, with the Grade 8 curriculum addressing vocabulary, reading comprehension, and guided writing. The sample consisted of 60 Grade 8 learners aged between 12 and 16 years, divided into two intact classes of 30 learners each. The sample was gender-balanced, with 30 male learners (50%) and 30 female learners (50%) across the two classes. The available demographic records identify the overall age range but do not provide sufficiently documented age frequencies to justify reporting separate counts for each age. Similarly, standardized proficiency levels, prior exposure to educational technology, and socioeconomic background were not systematically collected as separate demographic variables. These variables are therefore not reported as if they had been measured. Pre-test comparisons did not identify statistically significant differences between the groups in the measured domains ($p > .05$); however, the absence of statistically significant baseline differences was not treated as evidence of complete baseline equivalence because the study used intact classes rather than individual random assignment.

The intervention was implemented over four weeks of English instruction in regular classrooms. The teaching unit was aligned with the Grade 8 curriculum and included real-life topics, vocabulary activities, reading-comprehension tasks, and guided writing exercises. In the experimental condition, augmented reality was integrated as an additional pedagogical layer rather than as a substitute for teacher-led instruction.

Printed classroom resources, including textbook-related images, worksheets, and other visual materials, were augmented using Artivive triggers and QRfy codes. When learners scanned the relevant materials with mobile devices, the AR elements provided access to digital instructional resources, including short video-based explanations, contextual vocabulary support, reading prompts linked to visual elements, and guided writing activities. Visual

animations and video-based explanations created with HeyGen were used to illustrate pronunciation, intonation, and contextual use of selected vocabulary and to provide learners with repeated access to the instructional input.

The AI tools were used during the preparation of instructional materials rather than as autonomous instructional agents during classroom teaching. AI-assisted content was used to prepare instructional explanations, scripts, and prompts, after which the teacher reviewed and modified the materials before classroom use. The teacher remained responsible for presenting the materials, guiding classroom activities, and responding to learners. No automated AI feedback, grading, or AI-generated instructional decisions were used during classroom teaching.

The control group completed the same curriculum unit during the same instructional period through the official textbook and regular teacher-led classroom activities.

Treatment fidelity was not assessed through a formal observation checklist or implementation-rating instrument. Consequently, the study cannot establish the consistency with which the planned AR activities were implemented across all instructional sessions.

A structured comparison of the instructional activities implemented in both groups during the four-week intervention is presented in Table 1.

Table 1
Summary of Instructional Procedures during the Four-Week Intervention

Experimental Group: AI-Supported AR Instruction	Control Group: Textbook-Based Instruction
Printed materials augmented with AR triggers activating digital overlays (videos, vocabulary support, reading prompts).	Printed textbook materials used without digital augmentation.
Multimodal input (visual, audio, textual) delivered through AR-enhanced resources.	Teacher-led explanations and textbook-based input.
AI-assisted instructional scripting used to design contextualized explanations and guided prompts (teacher-reviewed).	Teacher-prepared explanations and textbook prompts.
Contextual vocabulary and reading scaffolding embedded within AR materials.	Vocabulary and reading exercises completed from the official textbook.
Guided writing tasks supported by AR-based visual and thematic cues.	Guided writing tasks completed using textbook instructions.
Teacher-facilitated discussion and practice following AR engagement.	Teacher-facilitated discussion and practice following textbook activities.

Curriculum-based achievement tests were used as pre-tests and post-tests to assess learning outcomes in the two groups. The tests targeted three areas: vocabulary, reading comprehension, and writing, with each domain scored out of 20 points in accordance with the local classroom

assessment practices. The instruments were teacher-developed and aligned with the Grade 8 curriculum and the learning objectives addressed during the intervention. A preliminary pilot test was conducted with 10 students who were not part of the main study. Seven students (70%) reported that the test items were clear and that they experienced no particular difficulty in completing the tests. This pilot was used to check the clarity and comprehensibility of the assessment materials rather than to establish psychometric validity or reliability.

The instruments were not standardized or externally validated, and no internal-consistency coefficient or item-level psychometric analysis was calculated. These limitations are therefore acknowledged when interpreting the findings. The writing component consisted of short guided tasks based on the instructional themes and was evaluated using a common scoring rubric addressing content relevance, lexical and grammatical accuracy, and coherence. The same scoring criteria were applied to the pre-test and post-test writing tasks in both groups.

Because the writing responses were scored by the course instructor using the common scoring rubric, independent inter-rater reliability could not be established. This potential source of measurement bias is therefore acknowledged as a limitation of the study. The use of the same scoring criteria across the two testing occasions and instructional conditions was intended to maintain consistency in the assessment process.

Data were collected in three phases. First, vocabulary, reading, and writing pre-tests were administered to all participants before the intervention. This was followed by the instructional phase, where the experimental group, in the normal lessons, worked with the AI-supported augmented reality materials, and the control group was instructed in the traditional way. Finally, the same assessment instruments were administered as post-tests to both groups at the end of the instructional period under similar conditions. The course instructor administered all tests using standardized classroom practices.

The quantitative data were analyzed using descriptive and inferential statistics appropriate to the pre-test/post-test design. Pre-test and post-test means and standard deviations were calculated for each language domain. Within-group changes from pre-test to post-test were examined using paired-samples *t*-tests. Between-group differences in improvement were examined using gain scores, calculated by subtracting each participant's pre-test score from the corresponding post-test score. Because the gain-score distributions showed non-normality and unequal variances between the two groups, Welch's independent-samples *t*-test was used for the between-group comparisons. Mean differences and 95% confidence intervals were reported together with Hedges' *g* as a standardized effect-size estimate. Because three related between-group comparisons were conducted, Holm's adjustment was applied to the corresponding *p* values.

As a sensitivity analysis, analysis of covariance (ANCOVA) was also examined, with post-test scores as the dependent variable, instructional condition as the between-group factor, and pre-test scores as the covariate. Robust standard errors were used because the variance assumptions for conventional ANCOVA were not fully satisfied. The ANCOVA results were treated as supplementary rather than as a replacement for the primary gain-score analysis. The homogeneity-of-regression-slopes assumption was examined before interpreting the adjusted group comparisons. After adjustment for pre-test performance, the experimental group showed higher post-test scores than the control group for vocabulary, adjusted mean difference = 1.45, 95% CI [1.05, 1.86], $p < .001$; reading comprehension, adjusted mean difference = 1.61, 95% CI [1.19, 2.02], $p < .001$; and writing, adjusted mean difference = 0.99, 95% CI [0.58, 1.40], $p < .001$. The pre-test-by-condition interaction was not statistically significant for vocabulary ($p = .075$), reading comprehension ($p = .825$), or writing ($p = .764$), supporting the use of a common covariate slope in the adjusted comparisons. Statistical tests were evaluated at the .05

significance level. These supplementary analyses were consistent with the primary gain-score results.

Ethical considerations were addressed throughout the study. Authorization to conduct the activity was obtained from the school administration, and participation was organized as a voluntary parascholastic activity without academic penalty for non-participation. Learner identities were anonymized in the research data, and the instructional activity did not result in the withholding of regular classroom instruction from either group. Because the participants were minors, particular attention was given to the ethical requirements associated with their participation. The study did not involve the collection of identifying information in the reported dataset, and the research data were used for the purposes of the study and reported in aggregate form.

Results

This section presents the pre-test and post-test results of the control group, which received conventional instruction, and of the experimental group, which was taught in the AI-supported augmented reality environment. The design is quasi-experimental, which means that the findings are viewed as associative tendencies but not as demonstrations of causal effects. Table 2 presents the mean scores and mean gains for vocabulary, reading comprehension, and writing for both groups on a 20-point scale.

Table 2
Descriptive Statistics for Pre-Test and Post-Test Scores (20-Point Scale)

Measure	Group	Pre-test *M*	Pre-test *SD*	Post-test *M*	Post-test *SD*	Mean Gain
Vocabulary	Control (*n* = 30)	12.70	2.42	13.46	2.23	+0.76
Vocabulary	Experimental (*n* = 30)	12.67	2.31	14.88	2.01	+2.22
Reading	Control (*n* = 30)	13.59	1.98	14.18	1.82	+0.59
Reading	Experimental (*n* = 30)	13.70	1.91	15.89	2.09	+2.19
Writing	Control (*n* = 30)	12.53	1.93	13.18	1.97	+0.64
Writing	Experimental (*n* = 30)	12.51	1.94	14.14	2.20	+1.63

Note. *M* = mean; *SD* = standard deviation. Scores were calculated on a 20-point scale. Mean gain was calculated as post-test score minus pre-test score.

In the pre-test phase, both groups showed similar pre-test performance in all three language areas. After the instructional period, both groups showed improvement. Nevertheless, mean gains in vocabulary, reading comprehension, and writing were higher in the experimental group than in the control group.

To examine changes over time within each instructional condition, paired-samples *t*-tests were conducted separately for the control and experimental groups. The results are summarized in Table 3.

Table 3
Paired-Samples *t*-Test Results for Pre-Test to Post-Test Changes

Measure	Group	*t*(29)	*p*
Vocabulary	Control	9.82	< .001
Vocabulary	Experimental	10.65	< .001
Reading	Control	11.18	< .001
Reading	Experimental	10.95	< .001
Writing	Control	17.20	< .001
Writing	Experimental	8.27	< .001

Note. All tests were two-tailed. *p* values are reported as < .001 where applicable.

The findings show statistically significant pre- to post-test differences in both groups across all three measures. These within-group changes indicate observable improvement over the four-week study period but do not, by themselves, establish that either instructional condition was responsible for the observed gains. The paired-samples *t* statistics should therefore not be interpreted as indicators of the relative magnitude of improvement between the two groups because they are also influenced by the variability of individual changes. Direct comparisons between instructional conditions are therefore based on the between-group analysis of gain scores reported below.

To determine whether the magnitude of improvement differed between instructional conditions, gain scores were calculated for each participant by subtracting the pre-test score from the corresponding post-test score. Because the gain-score variances differed between the two groups, Welch's independent-samples *t*-test was used to compare the mean gains. The analyses indicated statistically significant between-group differences across vocabulary, reading comprehension, and writing. Mean differences, 95% confidence intervals, and Hedges' *g* estimates are reported in Table 4.

Table 4
Independent-Samples *t*-Test Results for Gain Score Comparisons

Measure	Mean Gain Control	Mean Gain Experimental	Mean Difference	Welch *t*	df	*p*	Hedges' *g*	95% CI for Mean Difference
Vocabulary	0.76	2.22	1.46	6.57	36.83	< .001	1.67	[1.01, 1.91]
Reading	0.59	2.19	1.60	7.73	33.04	< .001	1.97	[1.18, 2.02]
Writing	0.64	1.63	0.99	4.93	31.06	< .001	1.26	[0.58, 1.40]

Note. Mean difference = experimental-group mean gain minus control-group mean gain. Welch's independent-samples *t*-test was used because the gain-score variances differed between groups. Hedges' *g* is a standardized effect-size estimate based on the gain scores. *CI* = confidence interval.

Despite the higher gains in the experimental group, there are various considerations that limit the interpretation of these results. First, the evaluation tools were curriculum-related and teacher-made, which could make them sensitive to the teaching material and restrict their applicability to other settings than the classroom setting. Second, the use of intact classes limits the degree to which the observed differences can be described as purely related to the instructional condition. Although statistically significant, the effect sizes should be interpreted cautiously and do not represent the overall instructional effects given the exploratory nature of the study and the lack of standardized measures.

The between-group comparisons showed statistically significant differences in mean gain scores across all three language domains. Compared with the control group, the experimental group showed a greater mean gain in vocabulary (1.46 points), reading comprehension (1.60 points), and writing (0.99 points). The corresponding standardized effect-size estimates were Hedges' $g = 1.67$ for vocabulary, 1.97 for reading comprehension, and 1.26 for writing. These results indicate that the experimental group showed larger observed improvements during the four-week study period. However, because learners were assigned to two intact classes rather than randomly allocated to conditions, the results should be interpreted as between-group differences associated with the instructional conditions rather than as definitive evidence of a causal effect. The findings therefore provide evidence of an association between participation in the experimental instructional condition and greater observed gains in the three measured language domains within this particular school context. After Holm adjustment for the three between-group outcome comparisons, all three adjusted *p* values remained below .001.

Discussion

The aim of the present study was to investigate whether involvement in a pedagogically organized, AI-supported augmented reality (AR) learning setting was linked to differences in the vocabulary, reading comprehension, and writing outcomes of Grade 8 EFL students compared with traditional teaching. The results show that, although both instructional groups showed statistically significant improvement with time, learners who interacted within the AI-supported AR instructional environment experienced significantly greater improvements in all the three language areas. The results are discussed in relation to the existing literature and to pedagogical and methodological limitations.

The gains attained by both the experimental and control groups between pre-test and post-test are in line with what is expected from formal instruction. Planned exposure to curriculum-based instruction has been shown to produce measurable gains in EFL proficiency within a comparatively brief time of instruction (Miller et al. 220). This finding indicates that learning gains cannot be attributed solely to the technological treatment and emphasizes the significance of looking at relative gains as opposed to absolute performance outcomes.

Reading comprehension showed the largest between-group difference in gains, which is consistent with the research findings indicating that AR-based instruction can stimulate comprehension through the connection of textual information and visual and situational prompts. Contextual anchoring of this nature has been found to ease cognitive load and facilitate construction of meaning when tasks involved reading (Huang et al.). The patterns of improvement observed in the present study are consistent with prior research.

The experimental group also performed better in vocabulary development. This observation is in line with studies that have shown that vocabulary acquisition is facilitated when learners are exposed to lexical items in contextualized and multimodal input. Repeated exposure to target vocabulary in meaningful contexts has been associated with deeper processing and retention among EFL learners. Such contextual reinforcement occurred in the present study via visual and situational cues of the AR-supported environment.

Despite the fact that writing gains were not as large as reading and vocabulary gains, the experimental group still improved more than the control group. Writing development is gradual and cognitively demanding, and a short instructional intervention usually results in gradual but not radical changes in the quality of writing. Learning environments that are supported by technology have been demonstrated to operate more as scaffolding tools that aid the production of ideas and access to vocabulary rather than as a means of increasing grammatical accuracy (Khan et al.).

It is necessary to underline that the AI aspect of the instructional setting was not used as an independent instructional agent. Rather, AI-based applications were incorporated throughout the instructional design process to facilitate linguistic clarity and task alignment, whereas all the classroom interaction was mediated by the teacher. This difference is consistent with the existing literature that warns against attributing learning outcomes directly to AI systems without considering pedagogical design and teacher involvement (Kundu and Bej 2294).

This research nevertheless contributes to the literature because it offers empirical data from a middle school EFL setting, a context underrepresented in research on AI- and AR-mediated language learning. Most existing studies have been conducted in higher education or laboratory-based contexts where learners may have greater technological independence (Yan et al.). In comparison, the current research shows that pedagogically focused, AI-supported AR content can be incorporated into regular middle school lessons without disrupting the curriculum.

Pedagogically, the results indicate that the potential value of an AI-supported AR instructional environment lies not in technological novelty but in its ability to support contextualization, multimodal input, and learner engagement, provided that it serves specific instructional objectives. Teachers still play the key role in this process, and the technological tools seem to work best when they are presented as pedagogical aids rather than substitutes for instruction. Several methodological limitations should be considered when interpreting these findings.

First, the study used intact classes, a characteristic of the quasi-experimental design, which constrained the ability to isolate differences associated with the instructional condition from pre-existing class-level characteristics. Although the pre-test results did not show statistically significant differences between the groups, such findings do not establish complete baseline equivalence. Unmeasured differences between the classes may therefore have contributed to

the observed patterns. In addition, because each instructional condition corresponded to a single intact class, classroom-level effects could not be separated from the instructional condition. The use of the same instructor and curriculum reduced some sources of variation but did not eliminate this limitation. The four-week duration also prevents conclusions about long-term retention or persistence of learning gains. Finally, no formal classroom-observation checklist or implementation-rating instrument was used to quantify treatment fidelity across sessions. The findings are therefore interpreted as associative rather than causal.

Second, the sample was relatively small and drawn from one public middle school. No a priori power analysis was conducted before data collection. The sample consisted of the two available intact Grade 8 classes included in the study, and the resulting sample size therefore reflects the classroom-based setting rather than a sample-size calculation designed to achieve a predetermined statistical power. Although the observed between-group differences were statistically significant, the limited sample size reduces the precision and generalizability of the findings. The results should therefore be interpreted as context-specific evidence rather than as estimates that can be readily generalized to larger populations of EFL learners.

Third, the research was based on curriculum-based, teacher-made assessment tools as opposed to standardized tests. This approach ensured strong alignment with the instructional content and activities used during the intervention, yet it also creates the possibility of measurement bias. Local instruments can also be more responsive to local instructional practices and less generalizable across contexts. Despite the similarity in the scoring processes across groups and test administrations, because the instruments lacked external validation, the results can only be interpreted within these limits.

Fourth, the intervention was short (four weeks of instruction). The process of language development, especially writing, is often experienced over a long period of time and short-term gains may not indicate long-term change. The research lacks evidence of long-term retention, learning transfer, and delayed effects, which are important outcomes that should be examined in future research.

Fifth, the instructional environment was not analytically separated into its elements, such as teacher mediation, augmented reality resources, and AI-assisted content development. Consequently, the research does not permit making statements about the independent role of AI or AR. Rather, the intervention should be understood as an integrated pedagogical setup. This limitation resulted from the study design, which prioritized classroom validity over experimental control (Egunjobi and Adeyeye 1167).

Lastly, the involvement of minors and the integration of the intervention into regular teaching created both ethical and procedural constraints on the collection of data. Although these limitations helped ensure instructional equity and learner protection, they also restricted the possibility of experimental manipulation and prolonged data collection.

These restrictions accentuate the exploratory approach of the research. They do not invalidate the findings, but they clearly limit the claims that can be made. Subsequent studies would be appropriate with larger samples, longer intervention periods, standardized assessment measures, and designs that enable analysis of individual technological elements.

Conclusion

This study examined the association between participation in a teacher-mediated AR-supported EFL instructional environment and changes in vocabulary, reading comprehension, and writing performance among Grade 8 learners in a Moroccan middle school. Using a quasi-experimental pre-test/post-test design with two intact classes, the study found statistically significant pre- to

post-test improvements in all three language domains in both the control and experimental groups. The experimental group showed larger mean gains than the control group across vocabulary, reading comprehension, and writing, and the between-group differences in gain scores were statistically significant.

These findings should be interpreted cautiously. The study does not establish causality, and it does not permit the independent contribution of AI, AR, teacher mediation, or other features of the instructional environment to be isolated. AI was used primarily during the preparation of instructional materials, while AR provided the digital layer experienced by learners during teacher-mediated classroom activities. Moreover, the use of one intact class per condition means that instructional condition and classroom membership were confounded, and the four-week intervention provides no evidence concerning long-term retention.

The study nevertheless contributes context-specific evidence from a Moroccan lower secondary EFL setting, an area that remains comparatively underrepresented in the literature on technology-supported language learning. Its findings emphasize the importance of pedagogical integration, teacher mediation, curricular alignment, and cautious interpretation when emerging technologies are incorporated into classroom instruction. Future research should involve larger samples and multiple classes per condition, stronger treatment-fidelity procedures, validated or externally reviewed assessment instruments, and follow-up measurements to examine whether observed learning gains are sustained over time.

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