How to Cite (APA Style):
Lolyta, BA., Wiyaka, W., & Silitonga, LM (2026). Integrating AR/VR into 21st-century flipped classrooms: Enhancing engagement, HOTS, and English vocabulary mastery in young learners. *EduLite: Journal of English Education, Literature, and Culture*, *11* (1), 186-201. http://dx.doi.org/10.30659/e.11.1.186-201

Integrating AR/VR into 21st-century flipped classrooms: Enhancing engagement, HOTS, and English vocabulary mastery in young learners

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Received:	Revised:	Accepted:	Published:
04 November 2025	15 February 2026	18 February 2026	21 February 2026

Abstract

The growing demand for 21st-century learning highlights the need for instructional approaches that actively engage young learners while supporting higher-order thinking and language development. Although flipped classrooms and AR/VR technologies have independently demonstrated educational benefits, limited research has examined their combined effects in early English learning contexts. This study investigated the impact of integrating AR/VR tools into a flipped classroom on young learners' engagement, higher-order thinking skills (HOTS), and vocabulary mastery. A mixed-methods quasi-experimental design was employed involving 60 elementary school students assigned to an experimental group and a control group. Quantitative data were collected through pre- and post-tests and analyzed using ANCOVA and regression analyses. Qualitative data were gathered through semi-structured interviews and analyzed thematically using MAXQDA 2024 to explore learners' experiences and perceptions. The quantitative findings indicated that students in the experimental group achieved significantly higher outcomes than those in the control group in HOTS ($F(1,57) = 15.401$, $p < .001$, $\eta^2 = .270$), English vocabulary mastery ($F(1,57) = 22.865$, $p < .001$, $\eta^2 = .290$), and learner engagement ($F(1,57) = 32.085$, $p < .001$, $\eta^2 = .334$). The qualitative results supported these findings by revealing strong learning interest, active participation, and increased speaking comfort among learners. Students also demonstrated engagement in sentence construction and self-correction processes, reflecting emerging higher-order thinking skills. Furthermore, the visual and interactive features of AR/VR flashcards were perceived as helpful for vocabulary learning, although some learners reported occasional difficulties requiring assistance. Overall, the integration of AR/VR tools in a flipped classroom created an engaging and supportive learning environment that enhanced young learners' engagement, thinking skills, and English vocabulary mastery. These findings highlight the pedagogical potential of AR/VR-supported instruction for elementary-level EFL learning.

Keywords: *augmented reality/virtual reality; English vocabulary mastery; flipped classroom; higher-order thinking skills; young learners.*

INTRODUCTION

In recent years, the integration of immersive technologies such as Augmented Reality (AR) and Virtual Reality (VR) into innovative pedagogical models has

EduLite *Journal of English Education, Literature, and Culture*
Vol. 11, No. 1, February 2026, pp.186-201

E-ISSN: 2528-4479, P-ISSN: 2477-5304
http://jurnal.unissula.ac.id/index.php/edulite
DOI: http://dx.doi.org/10.30659/e.11.1.186-201

gained increasing attention in language education. Particularly in English as a Foreign Language (EFL) context, educators are challenged to design learning environments that not only improve English vocabulary mastery but also nurture higher-order thinking skills (HOTS) and student engagement among young learners. Despite the growing interest in technology-enhanced instruction, limited research has examined how AR/VR can be systematically integrated within a flipped classroom model to support deeper vocabulary learning and cognitive development. Furthermore, the rapid development of digital technology has changed the way that education is taught in school, making it more engaging and dynamic (Suciati et al., 2024). Our lives have changed as a result of the quick development of information technology, and in the modern era, students are raised in a world of media, including video games and consoles (Angelelli et al., 2023; Huang et al., 2022). Nonetheless, conventional learning still frequently focuses on the teacher, which restricts students' participation and critical thinking opportunities (Alsowat, 2016; Angelelli et al., 2023; Huang et al., 2022; Roiha & Sommier, 2021; Wu et al., 2024; Zebua, 2024).

Based on the efficacy of knowledge transmission, educators cannot argue against the positive consequences of this mode. However, students using this way are learning passively, and as a result, the innovative approach to education is the flipped classroom, where students learn independently at home and use class time to engage in more in-depth interactions (Qu & Miao, 2021). This learning method aims to address the traditional teaching methods that are constantly passive and teacher-centered (Alsowat, 2016; Huang et al., 2022; Kadel, 2020). The flipped classroom approach differs from typical education in that students finish their coursework at home while classmates or teachers interact, communicate, collaborate, and offer help in the classroom (Del Arco Bravo et al., 2019; Flores-Alarcia et al., 2022; Ma, 2023; van Alten et al., 2019).

The rise of digital technology has spurred growing interest in technology-assisted vocabulary learning tools. Flashcard-based activities, whether in digital, augmented, or traditional paper formats, support vocabulary acquisition by strengthening form-meaning connections through repetition, visual association, and retrieval practice. These processes promote semantic encoding and facilitate long-term memory retention. Building on this foundation, immersive augmented and virtual reality environments extend vocabulary learning beyond recognition tasks by situating lexical items within interactive and context-rich experiences. By engaging multiple sensory modalities and encouraging learners to manipulate, interpret, and apply vocabulary in meaningful contexts, AR/VR environments enhance semantic engagement and deepen lexical retention (Contrino et al., 2024; Jalaluddin et al., 2024; Weerasinghe et al., 2022; Zhang et al., 2025).

Learning a language is a challenging process that requires dedication, perseverance, and hard work, as it involves comprehending input, such as speaking or writing, and receiving feedback, including recognizing mistakes and making corrections, all of which contribute to vocabulary growth (Haoming & Wei, 2024; Jalaluddin et al., 2024; Weerasinghe et al., 2022; Wulandari & Pratama, 2026). Effective communication relies on a strong vocabulary, an

essential part of language learning that connects the four core language skills, and flashcards remain a widely used and effective method for building it .

Despite the demonstrated potential of AR/VR to enhance motivation, self-efficacy, and provide context-rich learning experiences, there is a lack of comprehensive research examining the extent to which AR/VR technologies support vocabulary mastery through enhanced learner engagement and the cultivation of higher-order thinking skills (Huang et al., 2023; Huang et al., 2022; Kwong & Churchill, 2023; Parsazadeh et al., 2021; Pusparini & Silitonga, 2025; Silitonga et al., 2023; Suciati et al., 2024; Wang et al., 2024; Wiyaka et al., 2024; Wu et al., 2024). Contemporary research often emphasizes memory-based tasks and superficial vocabulary recall, with limited attention given to how learners critically assess, interpret, and apply newly acquired vocabulary within meaningful contexts (Belda-Medina & Marrahi-Gomez, 2023; Linda & Shah, 2020; Theodorou et al., 2023).

For instance, several previous studies have relied on multiple-choice assessments or basic recognition tasks to evaluate vocabulary acquisition, which may not adequately capture the depth of learners' vocabulary mastery (Haoming & Wei, 2024; Tampubolon et al., 2022). These approaches often overlook learners' ability to use vocabulary creatively, interpret meanings critically, and apply lexical items appropriately across diverse communicative contexts, thereby underscoring the potential of immersive technologies to support both vocabulary retention and the development of higher-order cognitive processes in language use.

Higher-order thinking skills, such as analyzing, evaluating, and creating, help learners move beyond memorizing words to using vocabulary meaningfully (Albus et al., 2021; Chowdhury et al., 2024; Linda & Shah, 2020; Weerasinghe et al., 2022). Research indicates that activities like digital games and student-made videos improve vocabulary retention and increase engagement (Al-Ansi et al., 2023; Cents-boonstra et al., 2021; Figueroa & Jung, 2025; Huang et al., 2022; Ollerhead & Pennington, 2024; Palumbo, 2021; Songsiengchai et al., 2023; Vretos et al., 2019; Wiyaka et al., 2024). To support lasting vocabulary mastery, instruction should actively promote both engagement and higher-order thinking skills (Caetano et al., 2023; Huang et al., 2022; Theodorou et al., 2023; Weerasinghe et al., 2022).

As a result of the advancement of digital technologies in education, Augmented Reality (AR) and Virtual Reality (VR) have emerged as innovative tools with significant potential to enhance language learning (Alfadil, 2020; Alizadehsalehi et al., 2021; Haoming & Wei, 2024; Reeve & Tseng, 2011; Virgana & Lapasau, 2021). These technologies provide immersive and interactive environments that nurture deeper cognitive engagement and support the development of higher-order thinking skills. By offering meaningful and context-rich learning experiences, AR/VR enables learners to encounter and apply new vocabulary in ways that go beyond traditional instructional approaches.

However, the existing research predominantly addresses short-term vocabulary recall or general language skills, with limited focus on English vocabulary mastery among young learners (Caetano et al., 2023; Contrino et al., 2024; Figueroa & Jung, 2025; Khan et al., 2023; Maghfiroh et al., 2025;

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http://jurnal.unissula.ac.id/index.php/edulite
DOI: http://dx.doi.org/10.30659/e.11.1.186-201

Parsazadeh et al., 2021; Wahyuningsih & Afandi, 2020). Additionally, there is a scarcity of studies examining the role of AR/VR in enhancing higher-order thinking skills such as evaluation, analysis, and creation. This indicates a significant gap in understanding how these technologies can facilitate deeper and more sustained learning outcomes. Addressing this gap is particularly important in early language education, where young learners' engagement and cognitive development are essential for long-term English vocabulary acquisition and effective application in real-world contexts (Kevin et al., 2025).

In response to gaps identified in the existing literature, this study aims to address the following research questions: a. Does the integration of AR/VR in a flipped classroom enhance young learners' behavioral engagement, emotional engagement, and cognitive engagement? b. Does the integration of AR/VR in a flipped classroom improve young learners' problem-solving skills, critical-thinking skills, and creativity compared to conventional learning? c. Does the integration of AR/VR tools improve young learners' vocabulary skills compared to the use of conventional flashcards? d. What are young learners' perceptions of using AR/VR tools to enhance their English vocabulary mastery in a flipped classroom environment?

METHOD

Research Design

This study adopted a quasi-experimental mixed-method design to investigate the effects of AR/VR integration within a flipped classroom on young learners' engagement, higher-order thinking skills (HOTS), and English vocabulary mastery. The quantitative component employed a pretest-posttest non-equivalent control group design, in which intact classroom groups were assigned as the experimental and control groups without random assignment (Creswell, 2020).A quasi-experimental approach was selected because the participants were organized based on existing classroom groupings rather than being randomly assigned.

In this design, the independent variable was the type of instructional approach, consisting of two conditions: (1) a traditional flipped classroom model and (2) a flipped classroom integrated with AR/VR tools. The dependent variables included learner engagement, higher-order thinkings skills (HOTS), and English vocabulary mastery. The experimental group received AR/VR-supported flipped instruction, while the control group experienced the traditional flipped classroom model.

The qualitative component complemented the quantitative findings through semi-structured interviews with selected students from the experimental group. These interviews aimed to explore learners' perceptions and experiences when using AR/VR tools within the flipped classroom environment. The integration of quantitative and qualitative data enabled a more comprehensive understanding of the instructional impact, with qualitative insights providing explanatory support for the statistical results.

Figure 1 illustrates the conceptual framework of the research design. It shows the independent variable (instructional approach: traditional flipped

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classroom vs. flipped classroom with AR/VR) and its relationship with the three dependent variables (engagement, HOTS, and English vocabulary mastery). The arrows indicate the hypothesized influence of the instructional intervention on each outcome variable.

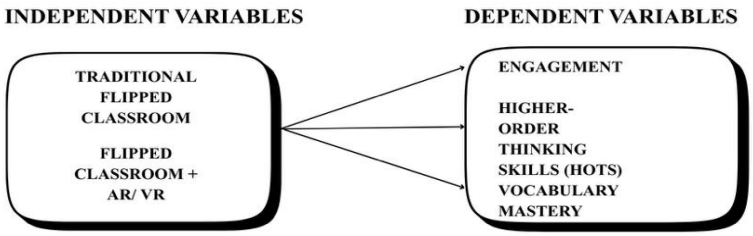

Figure 1. Research Design

Research Participants

This research was conducted in a private elementary school in Semarang, Central Java. The participants were 60 young learners from K3 and K4 classes, aged 9-10 years old. These students were divided into experimental and control groups based on their class grouping.

Instruments

The instruments used in this research included an engagement questionnaire (Reeve & Tseng, 2011), an English vocabulary mastery test based on the school standards' rubric, using a rubric scored 0-100 points (Brown, 2014a), and performance-based tasks assessed using a higher-order thinking skills (HOTS) rubric. The HOTS rubric employed a 5-point Likert scale to assess young learners' problem-solving, critical thinking, and creativity (Hwang et al., 2018). A semi-structured interview guide was used to explore students' perceptions of using AR/VR in a flipped classroom. The English vocabulary mastery can be seen in Table 1.

Table 1. English Vocabulary Assessment Rubric (Brown, 2014)

Score	Vocabulary Use	Description
0-44	Poor	Very limited vocabulary range. Word usage is often unclear or incorrect.
45-59	Fair	Limited vocabulary range. Frequent errors reduce clarity.
60-74	Satisfactory	Basic vocabulary. Some repetition or unclear word choices.
75-89	Good	Good range. Minor word choice issues.
90-100	Excellent	Wide, accurate, and effective vocabulary use.

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Experimental Procedures

A total of 60 young learners (ages 9-10, from K3 and K4) participated in the study, divided into two groups of 30 each. The control group learned vocabulary using traditional flashcards, while the experimental group used AR/VR-based flashcards in a flipped classroom setup. The topics included hobbies, school, food and drink, and animals. A pretest was administered in Week 1, followed by lessons in Week 2 (control) and Week 3 (experimental). A posttest was conducted in Week 4. The control group was taught by their regular teacher, while the experimental group was taught by the researcher (see Figure 2).

English vocabulary mastery tests were held each session and scored using a standardized school's rubric (Table 1), covering pronunciation, grammar, vocabulary, comprehension, and fluency. Students also completed engagement and HOTS questionnaires using a 5-point Likert scale (Hwang et al., 2018; Reeve & Tseng, 2011). Data were analyzed using ANCOVA, with qualitative insights from Maxqda 2024.

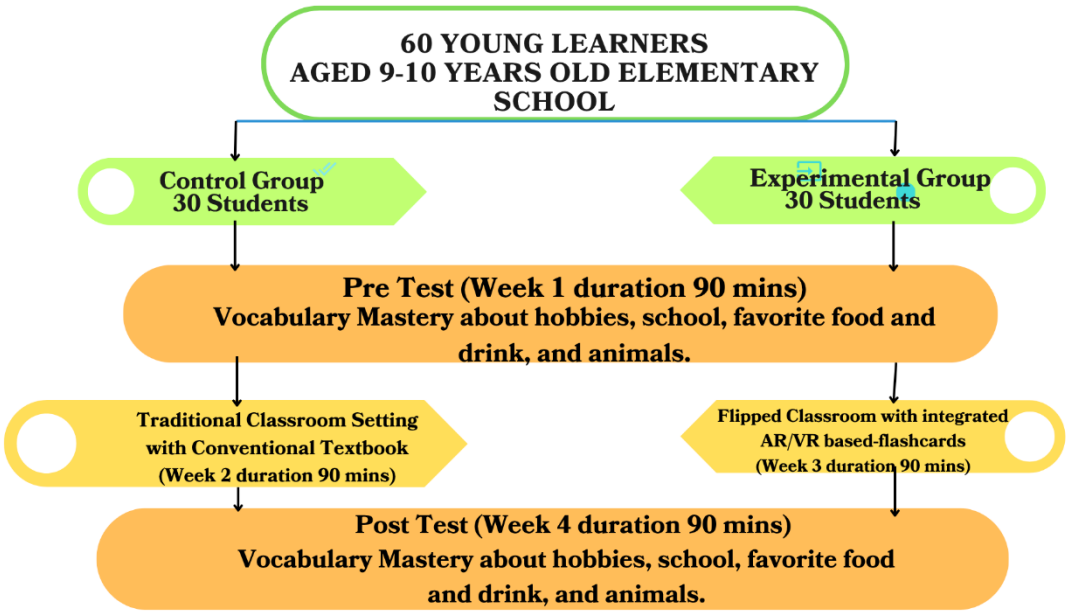

Figure 2. Experimental Procedures

RESULTS AND DISCUSSION

This section presents and discusses the findings in relation to the study's research questions. The analysis examines whether the integration of AR/VR technology in a flipped classroom influences young learners' engagement, higher-order thinking skills (HOTS), and English vocabulary mastery compared to conventional instruction. Quantitative findings are presented first, followed by qualitative findings that provide deeper insight into learners' learning experiences and perceptions.

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Quantitative Approach

Instrument Reliability Test

Prior to data analysis, the validity and reliability of the research instruments were examined. Instrument validity was assessed using item total correlation coefficients, with values exceeding 0.30 indicating acceptable validity. Reliability was measured using Cronbach's Alpha, where coefficients of 0.60 or higher indicate acceptable internal consistency. The results show that all instruments met the required validity and reliability criteria. The engagement, HOTS, and English vocabulary mastery instruments demonstrated acceptable to very high reliability, indicating that the instruments consistently measured the intended constructs and were suitable for further statistical analysis (see Table 2).

Table 2. Reliability Test Table

Variable	Validity	Cronbach's Alpha	Interpretation
Engagement	0.928	0.820	Valid and very reliable
Higher-Order Thinking Skills	0.350	0.753	Valid and very reliable
English Vocabulary Mastery	0.380	0.751	Valid and very reliable

Descriptive Data Analysis

Descriptive statistics were calculated to provide an overview of learners' performance across groups. Table 3 presents the mean scores and standard deviations for engagement, higher-order thinking skills, and vocabulary mastery in the experimental and control groups. The table is intended to describe the general distribution of scores prior to inferential analysis.

Table 3. Descriptive Data Analysis

Variable	Group	N	Mean	SD
Higher-Order Thinking Skills	Control	30	35.65	5.99
	Experimental	30	44.58	7.92
English Vocabulary Mastery	Control	30	61.20	8.30
	Experimental	30	78.50	7.10
Engagement	Control	30	80.68	12.89
	Experimental	30	86.20	13.37

Assumption Testing

Before conducting Analysis of Covariance (ANCOVA), assumption tests were performed. Normality was examined using the Shapiro-Wilk test, and homogeneity of variance was assessed using Levene's test. The results indicated that all variables were normally distributed and that variances across groups were homogeneous ($p > 0.05$). Therefore, the data met the assumptions required for ANCOVA.

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DOI: http://dx.doi.org/10.30659/e.11.1.186-201

Table 4. Assumption Test Results

Variable	Test	Statistic	df1	df2	Sig.	Decision
Engagement	Shapiro–Wilk	–	–	–	> .05	Normal
HOTS	Shapiro–Wilk	–	–	–	> .05	Normal
Vocabulary Mastery	Shapiro–Wilk	–	–	–	> .05	Normal
Engagement	Levene's Test	11.470	1	58	.274	Homogeneous
HOTS	Levene's Test	2.680	1	58	.607	Homogeneous
Vocabulary Mastery	Levene's Test	23.379	1	58	.100	Homogeneous

Effect of AR/VR Integration on Higher-Order Thinking Skills

ANCOVA results indicated a significant effect of the AR/VR-based flipped classroom on young learners' higher-order thinking skills (HOTS), $F(1,57) = 15.401$, $p < 0.001$, partial $\eta^2 = 0.270$. This reflects a huge effect size and confirms that the intervention led to a meaningful improvement in HOTS (Figueroa & Jung, 2025; Huang et al., 2023; Huang et al., 2022; Suciati et al., 2024; Wang et al., 2024). In this study, AR/VR allowed young learners to interact with learning materials in a more exploratory and engaging way, likely enhancing their ability to analyze and apply information.

Table 6. ANCOVA Results for Higher-Order Thinking Skills

Source	SS	df	MS	F	Sig.	Partial η^2
HOTS (Covariate)	1404.731	1	1404.731	54.193	.000	0.487
Group	399.315	1	399.315	**15.401**	**.000**	**.270**
Error	1477.321	57	25.909			

English Vocabulary Mastery

ANCOVA also revealed a significant difference in vocabulary mastery between the experimental and control groups, $F(1,57) = 22.865$, $p < 0.001$, partial $\eta^2 = 0.290$. The AR/VR-supported flipped classroom was effective in improving vocabulary mastery. This finding aligns with prior research, which showed that immersive tools like AR can support vocabulary mastery through multisensory learning (Belda-Medina & Marrahi-Gomez, 2023; Haoming & Wei, 2024; Jalaluddin et al., 2024; Parmaxi & Demetriou, 2020; Zhang et al., 2025).

Table 7. ANCOVA Results for English Vocabulary Mastery

Source	df	F	Sig.	Partial η^2
Vocabulary (Covariate)	1	–	.000	–
Group	1	22.865	.000	.290
Error	57			

Qualitative Approach

To address Research Question 4 regarding students' perceptions of using AR/VR in a flipped classroom, qualitative data were collected through semi-structure interviews. Six elementary school students from the experimental

groups were selected using purposive sampling, based on their participation during the learning activities. The interview data were analyzed using Maxqda 2024 following a thematic analysis approach.

The analysis process involved open coding, in which meaningful statements related to group related codes into broader themes. The resulting themes were aligned with the quantitative variables examined in this research namely young learners' engagement, higher-order thinking skills (HOTS), and English vocabulary mastery. The qualitative findings are presented to provide explanatory support for the strong and statistically significant quantitatively results.

Young Learners' Engagement

The coding results indicate that learner engagement was the most prominent theme across the interview data. A large proportion of coded segments reflected **learning interest (33%)**, suggesting that students perceived the AR/VR flashcards as enjoyable and engaging compared to regular classroom activities. Students frequently described the activities as interactive and fast-paced, which helped maintain their attention.

In addition, many coded segments were associated with **active participation (27%)**, showing that students actively interacted with the flashcards by speaking, responding to prompts, and repeating tasks. **Speaking comfort (25%)** also emerged, as students reported feeling more comfortable using English without the pressure of speaking in front of classmates. In contrast, **assistance need (15%)** appeared less frequently and was mainly related to technical issues or unclear feedback. As illustrated in Figure 3, learning interest and active participation accounted for the largest proportion of coded segments, while the need for assistance was less dominant.

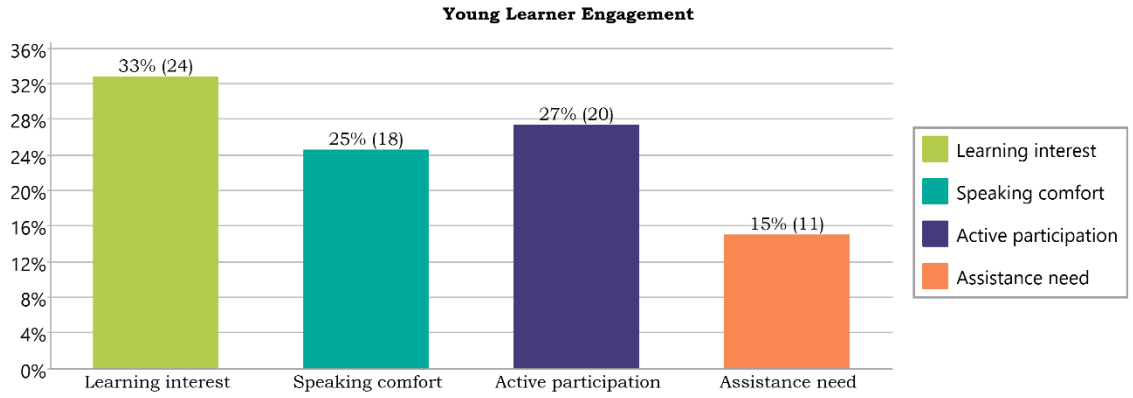

Figure 3. Young Learners' Engagement

Higher-Order Thinking Skills (HOTS)

The analysis of higher-order thinking skills revealed a more balanced distribution of coded segments. **Sentence construction (41%)** appeared frequently, indicating that students attempted to produce sentence-level responses rather than isolated words. **Self-correction (24%)** was also evident, as students described retrying tasks after receiving incorrect feedback.

EduLite *Journal of English Education, Literature, and Culture*
Vol. 11, No. 1, February 2026, pp.186-201

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Coded segments related to **difficulty awareness (17%)** showed that students were able to recognize challenges, such as starting sentences or pronouncing longer words. **Guidance need** (**17%)** was present but less prominent, suggesting that some students required support when tasks became more demanding. Overall, the findings indicate that AR/VR-supported activities encouraged higher-order thinking processes appropriate for elementary learners. As illustrated in Figure 4, sentence construction and self-correction were more prominent than guidance need (Hwang et al., 2018).

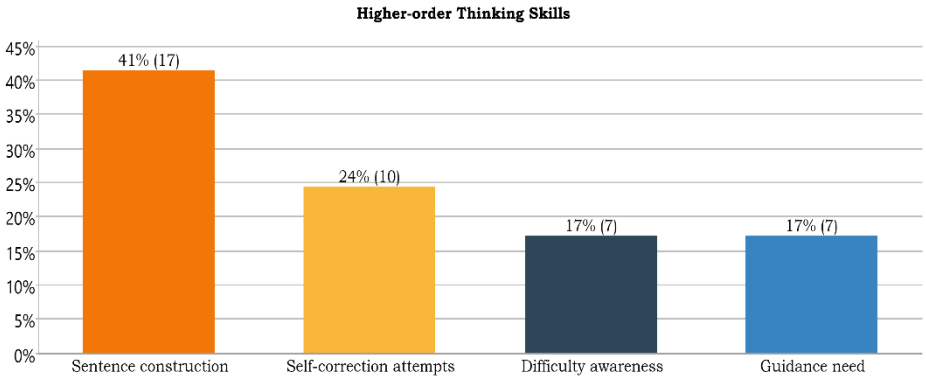

Figure 4. Higher-Order Thinking Skills

English Vocabulary Mastery

For English vocabulary mastery, **visual support (36%)** was the most frequently coded subtheme. Students often referred to images and interactive features as helpful for understanding word meanings. **Word learning (33%)** was also prominent, indicating that students perceived the flashcards as supporting vocabulary practice and recall.

Speaking confidence (31%) appeared in several coded segments, reflecting students' increased willingness to use English during the activities. As illustrated in Figure 5, visual support and word learning represented the most frequently coded segments, while partial understanding appeared less dominant.

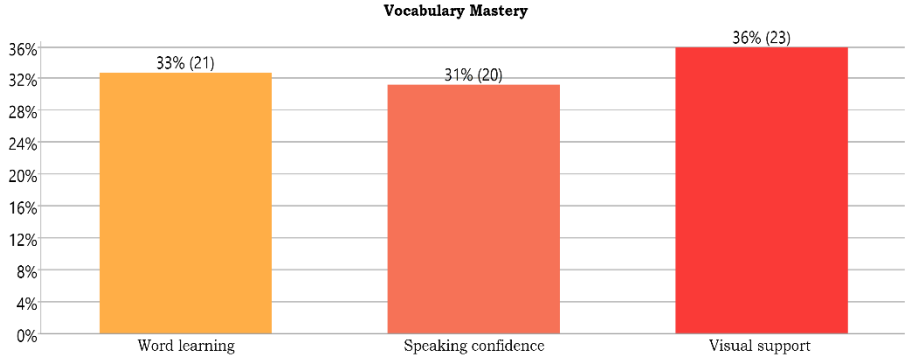

Figure 5. English Vocabulary Mastery

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CONCLUSION

This study investigated the integration of AR/VR technology in a flipped classroom to enhance young learners' engagement, higher-order thinking skills (HOTS), and English vocabulary mastery. Quantitative analyses showed that AR/VR integration had a significant effect on all three outcomes. The ANCOVA results indicated marked improvements in HOTS ($F(1,57) = 15.401$, $p < .001$, partial $\eta^2 = .270$), English vocabulary mastery ($F(1,57) = 22.865$, $p < .001$, partial $\eta^2 = .290$), and engagement ($F(1,57) = 32.085$, $p < .001$, partial $\eta^2 = .334$). Reliability tests (Cronbach's $\alpha \geq .69$) confirmed the consistency of the instruments. These findings demonstrate that AR/VR-based flipped learning effectively supports both cognitive and affective aspects of language learning.

The qualitative findings show that learner engagement was most strongly represented, followed by English vocabulary mastery and higher-order thinking skills. Positive learning experiences were dominant across themes, while challenges appeared as secondary patterns. These findings provide explanatory support for the significant quantitative results of the study.

Overall, the integration of AR/VR in the flipped classroom created a stimulating, student-centered learning environment that enhanced participation, reflection, and linguistic growth. The findings suggest that AR/VR-based instruction can serve as an effective pedagogical model for developing engagement, higher-order thinking, and English vocabulary mastery among young learners. Teachers are encouraged to strategically adopt AR/VR to combine motivation with meaningful learning, providing guidance and support to ensure its purposeful use. Future studies may examine long-term retention, collaborative learning in virtual spaces, and the transfer of AR/VR-enhanced skills to broader language contexts.

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AUTHOR STATEMENTS

Bunga Ayu Lolyta collected and analyzed the data, and wrote the findings and discussion sections. She also formatted the manuscript according to the journal's guidelines and carefully proofread all drafts. **Wiyaka** and **Lusia Maryani Silitonga** assisted in the data analysis process and provided feedback to ensure the accuracy of the data and conclusions.

ACKNOWLEDGMENTS

The authors would like to sincerely thank Universitas Perguruan Tinggi Republik Indonesia Semarang and all of the participants who helped to complete this study.

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E-ISSN: 2528-4479, P-ISSN: 2477-5304
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How to Cite (APA Style):
Lolyta, BA., Wiyaka, W., & Silitonga, LM (2026). Integrating AR/VR into 21st-century flipped classrooms: Enhancing engagement, HOTS, and English vocabulary mastery in young learners. *EduLite: Journal of English Education, Literature, and Culture*, *11* (1), 186-201. http://dx.doi.org/10.30659/e.11.1.186-201

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Conflict of Interest Statement: The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.