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Development of Augmented Reality-Based Android Aplications on Chimical Bonding Material

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***Abstract*:** *Android devices are widely used by students and have great potential to be developed as interactive learning media. However, abstract concepts such as chemical bonding are often difficult for students to understand through conventional methods. Therefore, learning media that can visualize concepts in a concrete and interactive way are needed. Augmented Reality (AR) technology offers an innovative solution to address this issue.*

This study aims to develop and assess the feasibility of an AR-based Android application for learning chemical bonding. The research employed the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, focusing on the feasibility testing stage. The feasibility instrument was adapted from the BSNP standard and validated by three experts in Chemistry Education.

The results showed that the application achieved an average score of 90%, categorized as very feasible. The content aspect obtained the highest score (93%), followed by presentation (91%), software engineering (90%), linguistic (89%), and graphic aspects (87%). Overall, the application is considered very feasible and can be used as an effective learning medium to help students understand abstract concepts in chemical bonding.

***Keywords*:** *augmented reality; android application; chemical bonding; learning media; feasibility test.*

INTRODUCTION

At the era of globalization characterized by rapid technological advancement, education is required to adapt dynamically in facing complex changes (Rahman et al., 2021). The development of information technology has driven a transformation in the learning process to become more interactive, flexible, and student-centered. However, in the context of chemistry learning, students still face difficulties in understanding abstract concepts such as atomic structure and chemical bonding (Yudha et al., 2022). The characteristics of these concepts, which cannot be directly observed, often lead to misconceptions, thereby hindering knowledge construction and resulting in low student interest and learning outcomes (Fahreza & Suyanti, Retno Dwi, 2022); (Alkan, 2016).

Furthermore, according to (Vonari et al., 2024), chemistry is characterized by interrelated subject matters, such as chemical bonding, where mastery of preceding chapters is crucial for understanding subsequent ones. This cumulative nature of the subject is compounded by curricular constraints; as highlighted by (Priliyanti et al., 2021), a significant factor contributing to student difficulties is the vast amount of material that must be mastered within a limited timeframe. Consequently, without a solid foundation in early concepts, students struggle to grasp more complex chemical bonding topics.

To address these problems, various technology-based learning media innovations have been developed, including interactive multimedia, animation, video, virtual laboratories, and Augmented Reality (AR) (Syarifuddin & Utari, 2022). Among these technologies, AR has advantages because it can integrate virtual objects into the real world in real time, thus providing an immersive and contextual learning experience (Gomes, J.D.C & Gomes C.M, 2017) In addition, the characteristics of ubiquitous computing allow students to access learning materials flexibly through mobile devices, making AR a potential approach to facilitate the understanding of abstract concepts in a more concrete way.

Empirically, various studies have shown that AR contributes positively to improving the quality of learning. (Radianti et al., 2020) emphasized that AR significantly enhances students' conceptual understanding and engagement, while Wu et al. (2013) demonstrated that the integration of the real and virtual worlds through AR is effective in visualizing abstract concepts. In chemistry learning, (Hikmah et al., 2022) reported an improvement in students' abstract thinking skills, while (Tahir et al., 2025) found that AR-based media has high feasibility and is suitable for use. These findings are reinforced by recent studies showing that AR not only improves understanding but also supports exploratory learning, strengthens memory retention, and increases student engagement through dynamic visualization (Kim & Choi, 2025); (Alibraheim et al., 2023).

Nevertheless, the effectiveness of AR is not universal. (Tsai, 2020) showed that the use of AR does not always lead to significant improvements in learning outcomes compared to conventional learning. This inconsistency indicates that the success of AR implementation is not solely determined by the presence of technology, but highly depends on the quality of instructional design and the integration of learning components. In other words, AR that functions only as a visualization tool without being supported by a systematic learning structure tends to have limited impact.

A critical analysis of previous studies reveals fragmentation in the development of AR-based learning media (Utami et al., 2022) developed AR media focusing on 3D visualization but without interactive evaluation, thus failing to comprehensively measure student understanding. In contrast, (Yudha et al., 2023) developed Android-based multimedia with evaluation features, but without AR integration, resulting in a less immersive learning experience. Donasari and (Rahman et al., 2021) showed improved learning outcomes through interactive media, but without integrating learning components into a unified system. Meanwhile, (Nurfajriani & Farhansyah, 2023) emphasized independent learning materials but did not utilize AR technology, and (Rahman et al., 2021) focused more on media quality without developing an integrated mobile-based platform. This comparison indicates that previous studies tend to develop learning media in a fragmented manner, whether in terms of technology, learning features, or content integration.

Based on this synthesis, the research gap can be clearly formulated, namely the absence of AR-based learning media that simultaneously and comprehensively integrates 3D molecular visualization, instructional videos, student worksheets (LKPD), curriculum-aligned structured materials, and interactive evaluation within a single Android-based platform. This lack of integration causes the potential of AR to improve learning quality not to be fully optimized. Therefore, it is necessary to develop learning media that is not only technologically innovative but also pedagogically integrated.

On the other hand, the high penetration of mobile device usage among students provides a strategic opportunity for the development of Android-based learning media. (Yamtinah et al., 2023) showed that smartphone usage among adolescents continues to increase, supported by field findings indicating that students already utilize these devices in learning activities. This condition suggests that the integration of AR into mobile platforms has great potential to enhance accessibility, flexibility, and learning effectiveness.

Along with these developments, research on AR has also experienced significant growth globally, both in terms of publication volume and thematic diversity (Aksnes & Sivertsen, 2023) Studies are not only focused on technological development but also cover pedagogical aspects, learning models, and classroom implementation. However, the integration of these findings into the development of comprehensive and structured learning media remains limited, thus opening a relevant and significant research opportunity.

Based on the description above, this study aims to develop an Android-based Augmented Reality application on chemical bonding material that integrates 3D visualization, instructional videos, student worksheets (LKPD), and interactive evaluation in a single integrated platform. Unlike previous studies that were still fragmented, this research simultaneously combines all learning components aligned with core competencies. This approach emphasizes the novelty of the study in positioning AR not only as a visualization tool but as a comprehensive learning medium to improve conceptual understanding and students' independent learning skills. In addition, this study also aims to determine the feasibility level of the media based on expert validation in terms of content, presentation, language, and technical aspects.

LITERATURE REVIEW

A. ADDIE Development Model

This study is a Research and Development (R&D) project that employs the ADDIE model as the framework for developing an Android-based Augmented Reality learning media on chemical bonding material. The ADDIE model consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation (Setiawan & Ilahi, 2022) This model is used to ensure that the development process is carried out in a structured manner, starting from identifying learning needs to evaluating the final product. ADDIE also emphasizes the alignment between user needs and instructional design at each stage of development (Donasari & Silaban, 2021).

B. Android-Based Application

Android is an open-source operating system widely used as a platform for mobile application development, including educational applications (Sari et al., 2025). In this study, Android serves as the primary distribution platform that enables the Augmented Reality learning application to be accessed flexibly through devices commonly owned by students. However, Android-based applications also have technical limitations such as screen size, memory capacity, and battery consumption that need to be considered in the system design (Silaban et al., 2024).

C. Augmented Reality (AR) in Learning

Augmented Reality (AR) is a technology that integrates virtual objects into the real environment in real-time, creating an interactive visual experience. In education, AR is used to support the understanding of abstract concepts through dynamic visualization. In this study, AR is applied as a visual approach to represent chemical bonding concepts that are difficult to observe directly, thereby helping students construct conceptual understanding through concrete representations (Akçayır & Akçayır, 2017).

D. Chemical Bonding Material

Chemical bonding material includes fundamental concepts such as ionic bonds, covalent bonds, electron configuration, valence electrons, Lewis structures, atomic stability, and the properties of compounds. These concepts are abstract in nature, making visual media necessary to support student comprehension. In this study, chemical bonding concepts are represented using 3D models based on Augmented Reality to help students understand the relationships between particles in a more structured and concrete way.

E. Assembler Edu

This study utilizes the Assembler Edu platform as a tool for developing interactive three-dimensional objects based on Augmented Reality. The platform allows 3D model integration without complex installation processes, making it accessible via both mobile and web-based devices. Previous studies have shown that Assembler Edu can enhance student engagement by enabling interactive visual exploration in learning activities (Monikasari et al., 2026); Sabila,dkk 2015). In this research, Assemblr Edu is used to visualize chemical bonding structures to support conceptual understanding in a more interactive and accessible form.

F. Media Feasibility

Media feasibility in this study refers to the evaluation of the developed product based on the standards of the National Education Standards Agency (BSNP) (Krismanja, H, 2021) which include content, language, presentation, graphics, and software engineering aspects. This evaluation is conducted to determine whether the Augmented Reality-based learning media meets the required standards and is suitable for use in the learning process.

METHODS

A. Research Method

This study employed a *Research and Development* (R&D) approach using the ADDIE model (*Analysis, Design, Development, Implementation, and Evaluation*) as a conceptual framework for developing learning media. However, this study was operationally limited to the *development* stage, focusing on the production of an Augmented Reality (AR)-based Android application on chemical bonding and its feasibility through expert validation. Therefore, this study provides evidence primarily at the level feasibility, without assessing effectiveness in real classroom implementation.

The development of AR-based learning media using the ADDIE model has been shown to produce valid and feasible instructional tools through expert validation of both content and media aspects (Syarif & Astuti, 2023). This process includes an expert review stage, particularly involving subject-matter experts, to ensure the qualitative validity of the content before proceeding to further product testing (Marisa et al., 2024).

B. Research Subjects

The subjects of this study consisted of six validators selected purposively, including three Chemistry Education lecturers as subject matter experts and three Chemistry Education lecturers as media experts. The selection criteria included: (1) holding at least a master's degree, (2) having experience teaching chemistry at the university level, and (3) having experience in developing or evaluating learning media.

The subject matter experts of content suitability, linguistics, and presentation, while media experts evaluated graphical design and software engineering aspects.

C. Research Instrument

The research instrument used was a feasibility assessment questionnaire for the AR-based Android application. The instrument was developed based on the standards of the National Education Standards Board (BSNP, Ministry of National Education, 2008) with several modifications. The modification process was carried out through expert judgment, bensuring that all indicators were relevant, clear, and appropriate for evaluating digital learning media.

The instrument employed a 5-point Likert scale adapted to represent feasibility levels rather than agreement levels, as the evaluation focused on expert judgment of product quality. The scale is presented in Table 1.

Table 1. Likert Scale Used for Feasibility Assessment

Score	Criteria
1	Not Feasible
2	Less Feasible
3	Moderately Feasible
4	Feasible
5	Very Feasible

D. Instrument Blueprint

Table 2 presents the instrument blueprint used for subject matter expert validation.

Table 2. Instrument Blueprint for Subject Matter Expert Validation

No.	Aspect	Assessment Indicators
1.	Content suitability	Compliance of material with Standard Competencies and Basic Competencies
		Accuracy of material
		Updates
		Encouraging curiosity
2.	Linguistics	Straightforward
		Communicative
		Dialogic and interactive
		Suitability to student development level
		Use of terms, symbols, and representations
3.	Presentation	Presentation techniques
		Presentation support
		Presentation of learning
4.	Graphics	Use of fonts (type and size)
		Layout

(Source: BSNP, 2008)

Table 3 presents the instrument blueprint used for media expert validation.

Table 3. Instrument Blueprint for Media Expert Validation

No.	Aspect	Assessment Indicators
1.	Display Design	Visual and Audio
2.	Media Operation	Media Use

(Source: BSNP, 2008)

E. Data Analysis

The application feasibility assessment was conducted by six validators, consisting of three subject matter experts and three media experts. Each validator rated relevant indicators using a 1–5 Likert scale. Subject matter experts evaluated content, language, and presentation, while media experts assessed graphical and software engineering aspects.

The scores from each validator were summed to obtain a total score per item, with a maximum score of 15. Calculations were performed separately for each expert group to ensure clarity and consistency. The total scores were then converted into percentages using the following formula:

$$P = (\sum q / \sum r) x\ 100\%$$

Where:
P = Percentage score
$\sum q$ = Total score obtained from validators
$\sum r$ = Maximum possible score

The percentage results were categorized based on the criteria presented in Table 4.

Table 4. Feasibility Criteria Based on Percentage Scores

Percentage Range (%)	Criteria
81–100	Very Feasible
61–80	Feasible
41–60	Moderately Feasible
21–40	Less Feasible
0–20	Not Feasible

The same terminology (e.g., “Very Feasible”) is used both in the Likert scale and in the percentage-based interpretation. However, the Likert scale represents individual validator ratings, while the percentage categories represent aggregated evaluation results.

RESULT AND DISCUSSION

The feasibility test was conducted to assess the extent to which the developed augmented reality-based Android application meets learning quality standards. The assessment process covers both material and media aspects, referring to the BSNP (National Education Standards Board) feasibility criteria. The results of this test provide information on the application's level of compliance with established standards. The feasibility test covers content, language, presentation, graphics, and software engineering. The results of the material feasibility test analysis, validated by material experts, can be seen in Table 5 and Figure 1.

Table 5. Feasibility Assessment Results by Subject Matter Experts

Aspect	Percentage Score	Average Percentage Score	Eligibility Criteria
Content suitability	93%	90%	Very Feasible
Linguistics	89%		
Presentation	91%		
Graphics	87%		
Software engineering	90%		

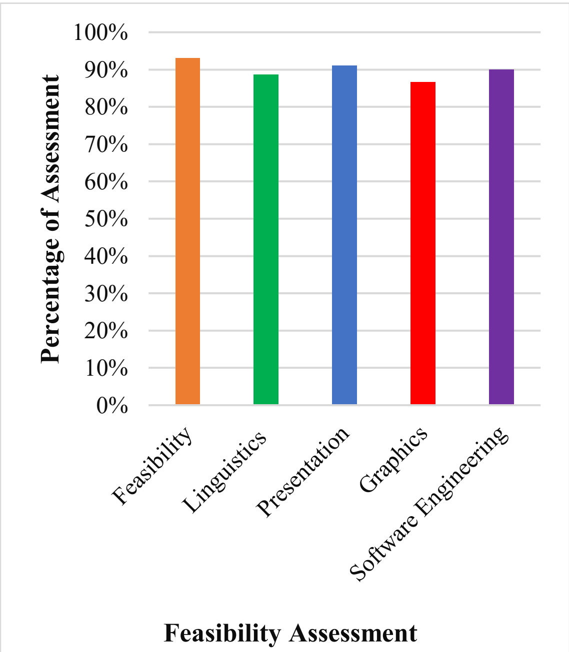

Figure 1. Feasibility Assessment Results by Subject Matter Experts

The results of material expert validation show that the Android-based augmented reality application obtained an average score of 90%, indicating a very feasible category. In detail, the content feasibility aspect achieved the highest score of 93%, followed by the presentation aspect at 91%. Based on BSNP standards, the high score in content feasibility indicates that the chemical bonding material presented is not only scientifically accurate but also aligned with curriculum competencies and basic competencies.

This high score reflects the developer’s success in translating abstract chemistry concepts, such as molecular geometry and types of chemical bonds, into concrete 3D representations. This is consistent with cognitive theory, which states that appropriate visual representations aligned with students’ mental models can reduce cognitive load and enhance conceptual understanding. Meanwhile, the presentation aspect score of 91% confirms that the application structure delivers the material in a systematic and logical sequence, supporting scaffolding so that students can build knowledge progressively without confusion.

In addition to pedagogical aspects, the technical and communicative quality of the application was also rated highly. Software engineering (90%) and language aspects (89%) indicate strong performance in terms of application stability, usability, and clarity of communication. In mobile-based learning contexts, application stability is essential to maintain students’ learning flow, as technical disruptions may hinder the internalization of concepts. The language aspect also ensures that information is delivered in a clear, concise, and grammatically appropriate manner, minimizing ambiguity.

Although the application is overall categorized as very feasible, the graphic aspect obtained the lowest score (87%). This difference suggests that evaluators prioritized pedagogical substance over visual aesthetics. It also reflects potential subjectivity in visual assessment, where different validators may have different design preferences. Qualitative feedback indicated that there is a distinction between visual attractiveness and instructional effectiveness; visually appealing elements may be considered less effective if they do not follow instructional design principles, such as inconsistent color usage that can distract students from learning content.

This finding aligns with Mayer's Multimedia Learning Theory, particularly the Coherence Principle, which emphasizes that removing irrelevant visual elements (including excessive decoration) can improve learning outcomes (Ucia et al., 2024). Therefore, the 87% score in the graphic aspect does not indicate poor design, but rather constructive feedback that visual elements should be more functional to support learning rather than distract attention. In addition, technical limitations of AR implementation also contribute to this result. Visual quality in AR applications is influenced by device variations, such as screen brightness and camera quality, which may affect validators' perception of visual performance.

The use of augmented reality can increase students' cognitive load, especially when the visual design is not optimally structured (Peeters et al., 2023). Instructional design based on cognitive load principles in AR environments can reduce unnecessary cognitive processing and improve learning outcomes (Kenneally & Bentley, 2024).

The score profile (Content 93% > Graphics 87%) indicates a content-first development approach. The primary strength of the application lies in its robust pedagogical content and systematic organization, while the graphical component functions as a supporting element that requires further refinement (Zulfadhilah & Hidayah, 2019). These findings suggest that effective learning media do not rely solely on complex visual design but prioritize content integrity and intuitive interfaces. Future revisions should focus on improving color consistency and optimizing visual elements to enhance clarity and visual comfort across different devices.

The results of the media feasibility test analysis, validated by media experts, can be seen in Table 6 and Figure 2 below.

Table 6. Feasibility Assessment Results by Media Experts

Aspect	Average Score	Percentage Score	Average Percentage Score	Eligibility Criteria
Design and Appearance	4,5	91%	91%	Very Feasible
Media Operations	4,7	92%		

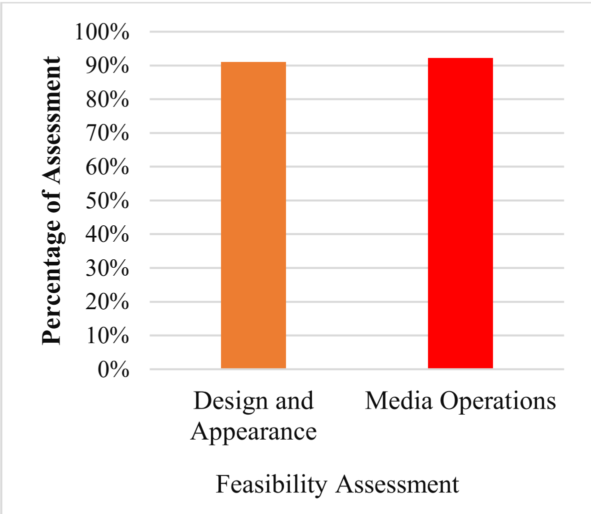

Figure 2. Feasibility Assessment Results by Media Experts

Based on the results of media expert validation, the Android-based augmented reality application obtained an average score of 91%, indicating a very feasible category. This evaluation covers two main dimensions, namely the operational aspect of the media and the design (display) aspect.

The operational aspect of the media achieved the highest score, at 92%. This score indicates that, in general, the application is considered highly user-friendly, equipped with clear instructions, and its features can be operated without significant obstacles. However, it should be noted that the stability of Augmented Reality (AR) applications is not solely determined by internal system design, but is also strongly influenced by external factors, particularly internet network quality. As stated by

(Ghozali et al., 2024), the operation of AR-based applications requires high-quality internet connectivity with low latency and stable bandwidth to maintain an optimal user experience.

In several testing conditions, the scanning and loading processes of AR objects showed performance degradation when the internet connection was unstable, which may disrupt user interaction. This finding indicates that the operational aspect of the application still has a level of dependency on network infrastructure. Therefore, further optimization is required to ensure that most AR features can run more stably, even under limited or suboptimal network conditions, in order to guarantee continuous accessibility for students across different environments.

The design aspect obtained a score of 91%. Although the difference compared to the operational aspect is relatively small, this finding suggests that evaluators placed slightly greater emphasis on functional performance rather than visual presentation. Despite being categorized as highly feasible, the relatively lower score indicates the presence of minor limitations, particularly related to color consistency and the appropriateness of color selection in molecular representations.

Inappropriate use of color can reduce information clarity, increase cognitive load, and potentially lead to misconceptions in understanding abstract chemical concepts. This finding is consistent with previous research indicating that ineffective color usage in augmented reality environments can hinder user comprehension (Bautista et al., 2025).

In this context, AR plays a strategic role by replacing physical teaching aids (such as molymod kits) with more dynamic digital visualizations (Handoyo et al., 2024). Furthermore, in chemistry learning, graphical aspects require a stronger emphasis on accurate visual representation. The AR visualization in this application does not merely function as an aesthetic element or decoration, but rather as a scientific representation of abstract concepts. Therefore, parameters such as molecular shape, relative atomic size, bond distance, and color representation must be strictly aligned with established scientific standards. Inaccurate visual representation carries a high risk of generating misconceptions among students. Thus, AR graphic development should prioritize scientific accuracy and its integration with chemistry concepts, where visual aesthetics serve as a secondary support after model accuracy.

Media expert validation results confirm the technical readiness of the application and identify specific directions for improvement. The synthesis of feasibility assessments from both material and media experts is presented in Figure 3.

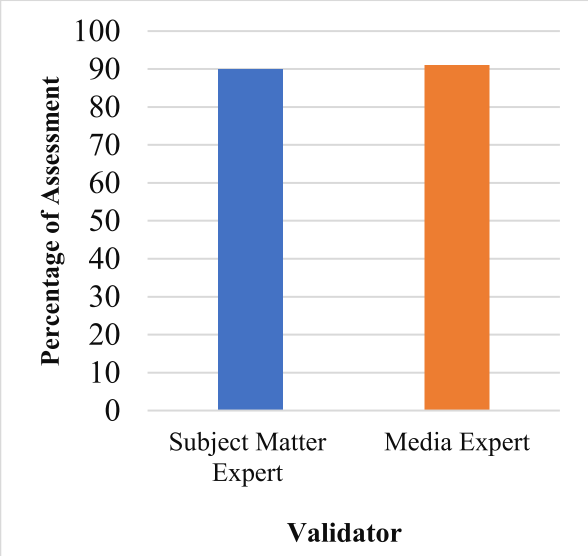

Figure 3. Feasibility Assessment Results by Subject Matter and Media Experts

The validation process in this study distinguishes between technical evaluation by media experts and content evaluation by subject-matter experts to ensure objectivity. This approach is consistent with (Pribowo, Setyo, 2018), who separated technical validation by media experts and content validation by subject-matter experts to obtain more objective assessment results.

As illustrated in Figure 3, the combined average feasibility scores from material experts (90%) and media experts (91%) indicate that the developed AR application in .apk format meets the criteria for use as a chemical bonding learning medium.

These findings are consistent with previous research demonstrating the high viability of AR in education. For instance, (Chairunnisa dkk., 2023) reported that basic science AR applications achieved an expert validation of 94.67%, while (Fakhrudin & Kuswidyanarko, 2020). found high feasibility (Aiken's V = 0.9528) for AR media. Furthermore, (Yudha et al., 2022) showed strong expert validation across media, material, and design aspects, leading to improved student learning outcomes compared to conventional methods. The consistency of these high feasibility scores across different scientific domains highlights that AR technology is not merely a supplementary tool, but a reliable and highly adaptable medium for delivering interactive learning experiences. As emphasized by (Damanik et al., 2024), the high baseline feasibility of AR applications like the one developed in this study provides a strong foundation for future integration with additional features such as interactive e-modules or quantitative assessments to further optimize student learning outcomes in chemistry.

CONCLUSION

This study developed an Augmented Reality (AR)-based Android application for chemical bonding instruction and established its feasibility through expert validation, with scores of 90% from material experts and 91% from media experts. These findings indicate that the application meets established standards for instructional content and media design. Theoretically, this study contributes to the advancement of chemistry learning media by introducing a technology-integrated, content-driven approach that facilitates the visualization of abstract concepts, particularly chemical bonding, through interactive 3D molecular representations.

From a practical perspective, the application provides an accessible instructional medium that supports the implementation of interactive and student-centered learning. The integration of multiple learning components 3D visualization, instructional videos, student worksheets (LKPD), and interactive assessment positions the application as a comprehensive tool to support conceptual understanding by linking abstract and visual representations.

This study is limited to the expert validation stage and does not include empirical testing with students. Consequently, the findings are preliminary and do not constitute evidence of instructional effectiveness or generalizability across learning contexts. Future research should extend this work through experimental or quasi-experimental designs to examine the application's impact on students' conceptual understanding, learning outcomes, and engagement in authentic classroom settings.

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