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Enhancing Students' Mathematical Representation Through an Interactive Quizizz-Based Learning Tool: An ADDIE Model Approach

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ABSTRACT:
Background: Mathematics is widely perceived by students as a difficult subject, often due to limited engagement and abstract content. One essential skill required in mathematical learning is the ability to represent concepts visually, symbolically, and verbally. However, students' mathematical representation skills remain low, particularly on topics like relations and functions. This highlights the need for interactive and technology-integrated learning tools that can enhance motivation and cognitive abilities.
Aims: This study aims to design, develop, and evaluate the effectiveness of an interactive quiz-based learning tool using the Quizizz platform to improve students' mathematical representation skills, focusing on the topic of relations and functions.
Methods: The study employed the ADDIE development model, which includes Analysis, Design, Development, Implementation, and Evaluation phases. The product was validated by experts in both content and media, then tested in small and larger classroom settings involving 43 students in total. Instruments included expert validation rubrics, student interest questionnaires, and pretest-posttest evaluations based on N-Gain analysis.
Result: The developed Quizizz-based quiz achieved high validation scores from experts (92% for content and 84% for media), with student attractiveness ratings of 79% and 81% in small and large groups, respectively. The effectiveness test yielded an N-Gain score of 0.76, indicating a high level of improvement in students' mathematical representation ability.
Conclusion: This research confirms that integrating interactive digital quizzes into mathematics instruction significantly enhances students' engagement, motivation, and mathematical representation competencies. The product is not only feasible and attractive but also pedagogically effective. It offers a scalable solution for math educators aiming to modernize learning environments and can serve as a model for future innovations in digital mathematics education.
Keywords: ADDIE Model, Interactive Learning, Mathematical Representation, Quizizz, Relations and Functions
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INTRODUCTION

Mathematics remains one of the most challenging subjects for secondary school students, largely due to its abstract nature and lack of engaging instructional strategies. One of the essential competencies in mathematical learning is the ability to represent mathematical ideas in multiple forms—visually, symbolically, and verbally. However, many students struggle to achieve proficiency in mathematical representation, particularly when dealing with complex topics such as relations and functions. These difficulties are often exacerbated by the use of conventional teaching methods that do not encourage active learning or support cognitive visualization (Lombardi et al. 2021 and Stanciulescu et al. 2024). Consequently, there is a need for innovative pedagogical approaches that not only foster conceptual understanding but also promote learner engagement and motivation.

In recent years, the integration of digital platforms in mathematics education has received considerable attention as a means to enhance learning outcomes. Interactive tools such as Quizizz have emerged as powerful media for formative assessment and student engagement. Quizizz enables personalized, game-based learning environments that stimulate competition and reduce academic anxiety (Fatimah. 2025 and My et al. 2024). Furthermore, its immediate feedback mechanisms provide students with meaningful insight into their understanding, while allowing teachers to tailor instruction accordingly. Incorporating such platforms into instruction can be particularly beneficial in developing mathematical representation skills, which require both repetition and contextual understanding.

Given the significant role that digital interactivity plays in fostering mathematical thinking, the development of technology-based instructional tools becomes essential. Interactive quizzes can serve as cognitive scaffolds, helping students transition from informal reasoning to formal mathematical representations. Moreover, by embedding representations in various forms—such as graphs, symbols, and narratives—within digital assessments, students are provided with opportunities to internalize and re-express mathematical concepts (Team. 2025). The urgency of this study lies in bridging the gap between traditional instruction and contemporary digital pedagogy to support student representation skills effectively.

The rationale behind this study stems from the urgent need to enhance students' mathematical representation skills using digital-based interventions. While many digital learning tools exist, few are explicitly designed to target representational competencies in mathematics. The use of the ADDIE development model in this research ensures systematic instructional design, from analysis to evaluation, thus enabling a robust development and implementation of an interactive Quizizz-based learning tool. By evaluating its effectiveness through expert validation and empirical testing, this study aims to provide an evidence-based model that can be replicated across educational contexts. Furthermore, as technological literacy becomes increasingly essential in 21st-century education, integrating such tools into daily teaching practices not only enhances learning outcomes but also equips students with critical digital competencies.

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Previous research has shown the effectiveness of integrating digital tools in improving learning engagement and cognitive outcomes. For example, Das et al. (2025) successfully employed the ADDIE model to develop a childhood obesity module, highlighting its flexibility in educational media design. Similarly, Putri et al. (2025) demonstrated the impact of animated video learning tools in enhancing early mathematical skills. In the context of augmented reality, Wulandari et al. (2025) found that integrating local cultural wisdom through gamification significantly boosted learning in poetry classes. Saputri et al. (2025) also emphasized the importance of STEM-RME-based e-modules in improving high school numeracy skills. Meanwhile, Arum et al. (2025)underlined how genially-based interactive multimedia can increase student motivation in civics education. These studies provide a strong foundation for developing engaging, interactive tools in various subject areas.

Specifically within mathematics education, several works support the relevance of this study. Zainudin et al. (2025) validated a GeoGebra-based toolkit for mathematical reasoning, while Alhusna et al. (2025) advocated for inquiry-based learning to improve literacy. Anwar. (2025) utilized virtual media to support children with autism in understanding math, and Efendi et al. (2025) proposed augmented reality mobile learning as a solution to the Industry 4.0 skills gap. Lastly, Sasongko & Sari. (2025) highlighted the effectiveness of interactive videos in improving student-teacher understanding in differential equations. Despite these advancements, limited research directly addresses the improvement of mathematical representation through structured digital quizzes using platforms like Quizizz, particularly for topics such as relations and functions in secondary education.

Although numerous studies have examined the impact of digital tools on mathematics learning, most focus on broader cognitive outcomes or subject-specific skills, such as reasoning or problem-solving. Very few directly target mathematical representation, and even fewer use platforms like Quizizz in a structured development model such as ADDIE. Furthermore, existing tools often lack rigorous validation or scalability across different school settings. This study fills that gap by offering a systematically developed and validated Quizizz-based interactive quiz, aimed explicitly at enhancing representation skills in middle school students learning about relations and functions. The combination of digital interactivity, representational focus, and methodological rigor offers a novel contribution to the field of mathematics education.

The purpose of this study is to design, implement, and evaluate the effectiveness of a Quizizz-based interactive quiz in improving students' mathematical representation skills on the topic of relations and functions. Using the ADDIE model, the study seeks to create a pedagogically sound and technologically engaging learning tool, validated through expert review and tested in authentic classroom contexts. The hypotheses underlying the study suggest that such an intervention will lead to improved student engagement, higher learning motivation, and significantly increased post-test scores in mathematical representation. Additionally, the study anticipates that students will perceive the tool as both attractive and easy to use, further contributing to its practical value. Ultimately, this research aspires to offer a replicable model for educators seeking to modernize their instructional practices using digital assessments tailored to specific mathematical skills.

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METHOD

Research Design

Research Design

This study employed a Research and Development (R&D) approach using the ADDIE instructional design model, which includes five systematic phases: Analyze, Design, Develop, Implement, and Evaluate. The ADDIE model is widely recognized in educational technology research for its iterative and user-centered structure (Giacumo & Breman. 2021 and Kister. 2016). During the analysis phase, researchers examined students' needs and existing instructional gaps through teacher interviews and diagnostic tests. In the design phase, the structure of the Quizizz-based interactive quiz was mapped out, including content alignment and multimedia integration. The development phase involved the creation and expert validation of quiz content, student questionnaires, and test items. The implementation phase consisted of small-group and field trials to test feasibility, attractiveness, and effectiveness. The final evaluation stage included revisions based on feedback and quantitative effectiveness analysis. Figure 1 illustrates the ADDIE model utilized in this study.

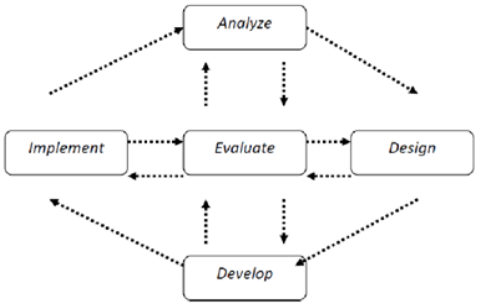

Figure 1. The ADDIE Model Used in the Development Process

Figure 1 presents the ADDIE model, which serves as the instructional framework guiding the design and development of the interactive Quizizz-based learning tool. This model consists of five phases—Analyze, Design, Develop, Implement, and Evaluate. In the Analyze phase, researchers identify learning problems and student needs. The Design phase outlines instructional strategies, learning objectives, and content flow. The Develop phase produces the learning materials and instruments, followed by Implementation, which includes trials in real classroom settings. Finally, Evaluation involves revising the product based on expert and student feedback. This model was chosen for its flexibility and systematic nature, ensuring that the product is pedagogically sound and technologically effective (Bizami et al. 2023 and Yue et al. 2022).

Participants

The participants in this study were eighth-grade students from MTs Negeri 2 Bandar Lampung, Indonesia. The research was conducted in two stages: a small-group trial involving 15 students and a larger implementation involving 28 students from a different class. Participants were selected using purposive sampling, ensuring they had not previously used the Quizizz platform in mathematics instruction. The teacher of the selected classes confirmed that traditional lecture methods were

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predominantly used prior to the study. Student demographics such as age, gender, and academic background were documented to ensure a balanced group. Before participating, all students and their guardians provided informed consent. Ethical clearance was obtained from the school administration. This participant selection strategy helped ensure the contextual validity of the study outcomes.

Instruments

Several instruments were employed to ensure comprehensive data collection and validation of the developed product. Expert validation forms were used to assess the content and media quality of the Quizizz-based tool, focusing on presentation, material accuracy, design, and usability. Students' attitudes were measured using a four-scale Likert questionnaire covering attractiveness, clarity, and ease of use. To measure learning gains, a mathematical representation test was designed based on indicators from Mudzakir's framework: visual, symbolic, and verbal representation (Rifat et al. 2024 and Salsabila et al. 2023). The instruments were first validated for content by three experts and then tested for reliability and discrimination. Table 1 presents the example of the item validation result for six questions used in the pretest and posttest.

Table 1. Sample Validity Results of Mathematical Representation Test

Item	r_{count}	r_{table}	Decision
1	0.719	0.374	Valid
2	0.600	0.374	Valid
3	0.812	0.374	Valid
4	0.765	0.374	Valid
5	0.849	0.374	Valid
6	0.894	0.374	Valid

Table 1 shows the results of item validity testing for the mathematical representation test used in the pretest and posttest. Each item's r-count was compared against the r-table value at a significance level of 0.05 with degrees of freedom (df = N−2). All six items yielded r-count values greater than the threshold of 0.374, indicating validity across all questions. This confirms that the test items measure what they are intended to measure—students' mathematical representation abilities. The validation process is critical for ensuring the reliability and credibility of the assessment instruments (Musuamba et al. 2021 and Shaheen et al. 2023).

Data Analysis Plan

The analysis of data was conducted both qualitatively and quantitatively to evaluate feasibility, attractiveness, and effectiveness. Qualitative feedback from expert validators and students was used to revise and refine the product. Quantitative analysis included descriptive statistics (mean and percentage) and inferential analysis using normalized gain (N-Gain) to measure the improvement in students' test scores. The N-Gain formula is defined as:

$$N - Gain = \frac{skor\ posttest - skor\ pretest}{skor\ ideal - skor\ pretest}$$

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Where Post is the average post-test score, Pre is the average pre-test score, and Max is the maximum score. The results were interpreted using Suryono's (2015) effectiveness criteria. Table 2 displays the interpretation scale for N-Gain values.

Table 2. N-Gain Score Classification

N-Gain Score	Category
g ≥ 0.7	High
0.3 ≤ g < 0.7	Medium
g < 0.3	Low

This study obtained an N-Gain score of 0.76, indicating a high level of effectiveness. Furthermore, Likert scale responses from students and expert validators were analyzed to determine the tool's attractiveness and appropriateness for classroom use. The use of multi-source triangulation ensured the reliability of findings.

Table 2 presents the interpretation scale for N-Gain values as proposed by Suryono (2015). It categorizes learning effectiveness into three levels: high (≥0.7), medium (0.3–0.69), and low (<0.3). The categorization helps in interpreting how much a student's learning has improved as a result of the intervention. This table provides a benchmark for educational researchers and educators to evaluate whether a learning tool is impactful. In the context of this study, the Quizizz-based interactive quiz produced an N-Gain score of 0.76, which is classified as high, indicating substantial improvement in students' mathematical representation ability.

RESULTS AND DISCUSSION

Results

The development of a Quizizz-based interactive quiz using the ADDIE model yielded highly favorable results based on expert validation, student responses, and test effectiveness. Content experts rated the material with a mean score of 92%, indicating the instructional content is highly suitable for enhancing students' mathematical representation skills. Table 1 shows detailed evaluation across four aspects: presentation, content quality, construction, and language. Each component received ratings above 90%, with the overall category marked as "Very Feasible." These results confirm that the product aligns well with pedagogical standards and is ready for classroom application.

Table 3. Expert Validation – Content (Material)

Aspect	Criteria Count	Total Score	Percentage	Category
Presentation	7	80	95%	Very Feasible
Content Quality	4	44	91%	Very Feasible
Construction	2	23	95%	Very Feasible
Language	2	22	91%	Very Feasible
Average	-	-	92%	Very Feasible

In terms of media validation, three media experts evaluated the tool on presentation, content design, and ease of use. The results, presented in Table 3, show a total mean score of 84%, categorized as "Very Feasible." Media features such as layout, navigation, and visual appeal were positively received, and recommendations were implemented in the final version of the quiz. This demonstrates that both content and interface aspects of the learning tool meet high-quality standards.

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Table 4. Expert Validation – Media

Aspect	Criteria Count	Total Score	Percentage	Category
Presentation	3	31	86%	Very Feasible
Content Design	8	75	78%	Feasible
Ease of Use	4	42	87%	Very Feasible
Average	-	-	84%	Very Feasible

Students' perceptions were gathered in both small-group and full-class trials. As shown in Table 4 and Table 5, the attractiveness of the product was consistently rated highly. In the small-group test involving 15 students, the average attractiveness score was 79%. In the full-class implementation, 28 students rated the product with an average of 81%, categorized as "Highly Attractive." These results confirm that the Quizizz-based quiz is engaging and positively received by students.

Table 5. Small Group Trial – Student Response

Aspect	Items	Total Score	Percentage	Category
Ease of Use	6	290	80%	Attractive
Engagement	9	445	82%	Attractive
Content	6	280	78%	Attractive
Language	4	186	78%	Attractive
Average	-	-	79%	Attractive

Table 5 presents the results of a small group trial with 15 students, intended to assess the appeal of the interactive quiz product using Quizizz. Four aspects were assessed: ease of use, student engagement, content quality, and language. All aspects scored above 75%, with an overall average of 79%, which falls into the "Attractive" category. This means the product was considered engaging and easy to use by students. These results indicate that on a limited scale, the developed tool can generate interest and increase student active participation in mathematics learning, particularly on the topics of relationships and functions.

Table 6. Full-Class Implementation – Student Response

Aspect	Items	Total Score	Percentage	Category
Ease of Use	6	584	82%	Highly Attractive
Engagement	9	812	81%	Highly Attractive
Content	6	545	81%	Highly Attractive
Language	4	355	79%	Attractive
Aspect	Items	Total Score	Percentage	Category
Average	-	-	81%	Highly Attractive

The effectiveness of the quiz was evaluated using pretest and posttest results analyzed through the N-Gain method. The average pretest score was 45.35, while the posttest average increased to 87.82. This yielded an N-Gain value of 0.76, which falls into the "High" effectiveness category. This result shows a significant improvement in students' mathematical representation abilities after using the Quizizz-based learning tool.

Table 7. N-Gain Calculation

Post - Pre	Max - Pre	N-Gain	Category
42.28	54.64	0.76	High

Table 7 shows the results of the learning effectiveness analysis using the N-Gain score, a method for assessing learning outcomes. The average pretest score was 45.35, and the posttest score increased to 87.82, resulting in a difference in improvement of 42.28 points. With a maximum score of 100, the N-Gain score is calculated as:

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$$g = (Post - Pre) / (Max - Pre) = 42.28 / 54.64 = 0.76,$$

which falls into the "High" category according to Suryono's (2015) classification. These results confirm that the use of Quizizz in the learning process is not only preferred by students but also has a significant impact on improving their mathematical representation skills.

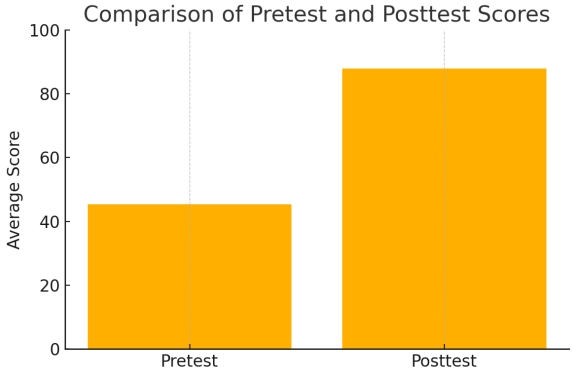

Figure 2. Comparison of Pretest and Posttest Scores

Figure 1 depicts a visual comparison between students' pretest and posttest mean scores. The high posttest bar indicates a substantial increase in scores after the implementation of the Quizizz-assisted interactive quiz. The pretest started with an average of 45.35, while the posttest reached an average of 87.82. This visualization emphasizes the improvement in students' understanding of the concepts of relations and functions after they used the learning media designed with the ADDIE model. This graph visually reinforces the quantitative findings in Table 7 and supports the claim of the effectiveness of digital learning tools in representation-based mathematics learning.

Discussion

The findings of this study affirm the significant role of students' critical thinking skills in determining their cognitive performance in physics. While the instructional method did not yield significant differences, students categorized as high critical thinkers consistently outperformed their peers. This aligns with the theoretical perspectives of Essien et al. (2024) and Ho et al. (2023), who assert that critical thinking is foundational to effective learning, particularly in science education. The insignificant impact of the instructional method may indicate that both demonstration and experimentation, when conducted under the SAVI model, provide comparable learning experiences. Prior research Wardani et al. (2024) corroborates that SAVI-based instruction enhances understanding across diverse learning styles, making both approaches viable.

The absence of a significant interaction effect further supports the universality of the SAVI model's effectiveness. As demonstrated by Alam & Mohanty (2023) and Yeganeh et al. (2025), instructional models incorporating sensory and intellectual engagement foster deep learning irrespective of delivery format. This implies that student outcomes are more likely to be optimized when internal learner traits—such as critical thinking—are supported. Bernacki et al. (2021) and Lin et al (2024) argued that personalization of instruction based on cognitive traits amplifies learning gains, particularly in STEM education. The current study validates this argument within the physics domain. Thus, instructional design should prioritize the cultivation of cognitive dispositions alongside content delivery.

Another significant implication arises from the consistent findings across both groups. The results suggest that critical thinking should be integrated not as a supplementary skill but as a core objective of physics instruction. Al-Thani & Ahmad. (2025) and Clemente-Suárez et al. (2024) emphasized that cognitive strategies are essential for navigating complex science content.

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Additionally, the findings support the inclusion of assessment tools that measure and track cognitive skill development over time. Studies by (Chang et al., 2021; Wu et al., 2024) demonstrate that when assessment aligns with higher-order thinking, both engagement and performance improve. Therefore, assessment reform must accompany pedagogical innovation to fully realize the benefits of models like SAVI.

Finally, the study offers evidence for policy recommendations in curriculum development. Given the statistically significant effect of critical thinking, teacher training programs should include modules that emphasize this skill. Okolie et al. (2022) and Yulian. (2021) found that targeted training in critical thinking pedagogy led to improvements in classroom practice and student performance. Embedding critical thinking within national curriculum frameworks would also support broader educational goals such as innovation, problem-solving, and lifelong learning. While further research is needed to explore long-term outcomes, this study provides a strong basis for integrating cognitive skill development into everyday physics teaching.

Implications

This study reinforces the importance of integrating critical thinking development into science instruction, especially in physics education. The findings suggest that instructional models like SAVI can serve as a flexible platform to support diverse teaching methods while still emphasizing core cognitive outcomes. Educational stakeholders should consider incorporating critical thinking as a core competency in both instructional design and assessment criteria. The study also highlights the need for teacher professional development that equips educators with strategies to foster higher-order thinking. Furthermore, policymakers may use these insights to reform science curricula to be more aligned with 21st-century learning standards. By doing so, equitable and effective learning environments can be fostered across varied student populations. The application of multimodal instructional frameworks may help bridge learning disparities. Finally, future initiatives should focus on contextualizing such pedagogies in local and national education systems.

Limitations

Despite its contributions, the study is subject to certain limitations. First, the sample size was relatively small and confined to a single school, limiting generalizability. The duration of intervention was also short, which might not capture long-term learning effects. Moreover, the assessment tools—while validated—may not fully encapsulate the breadth of critical thinking and cognitive processing in physics. The study also did not account for external variables such as teacher quality or classroom resources. Statistical methods used, while robust, may still be influenced by sampling error. Additionally, the categorization of critical thinking into only two levels may overlook more nuanced cognitive profiles. Further studies should consider longitudinal designs and larger samples. Finally, qualitative data could complement quantitative findings for richer interpretation.

Suggestions

Future research should involve more diverse and larger student populations to validate the generalizability of the findings. Longitudinal studies may help reveal the lasting impact of SAVI-based instruction on academic performance and critical thinking. It is also recommended to explore hybrid instructional designs that combine demonstration and experimentation for optimal learning engagement. Researchers should integrate qualitative methods such as interviews or classroom observations to enrich the understanding of student experiences. Additionally, developing dynamic and real-time assessment tools for critical thinking may enhance instructional feedback. Further investigation into how SAVI interacts with other cognitive or emotional traits would also be valuable. Finally, teacher training programs should be expanded to include practical modules on SAVI implementation. Collaborations with curriculum developers and policymakers can help scale successful models across educational systems.

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CONCLUSION

This study concludes that the development of a Quizizz-based interactive quiz using the ADDIE model is both feasible and effective in enhancing students' mathematical representation skills, particularly on the topic of relations and functions. The tool received high ratings from content and media experts, with average feasibility scores of 92% and 84%, respectively, indicating that the product met high pedagogical and technological standards. Student responses further validated the attractiveness and usability of the tool, with average ratings of 79% in small-group trials and 81% in larger implementations. These findings highlight the product's potential to increase learner engagement, motivation, and conceptual understanding.

The effectiveness of the learning tool was statistically confirmed through the N-Gain analysis, which yielded a score of 0.76, categorized as "High." This reflects a substantial improvement in students' post-test scores, suggesting that the integration of interactive digital quizzes into classroom instruction can significantly support the development of mathematical representation competencies. The use of a systematic instructional design model ensured that the product addressed learners' needs and aligned with educational objectives.

In conclusion, this research contributes to the growing body of knowledge on digital learning innovation by offering a validated and scalable solution that bridges traditional mathematics teaching with modern, interactive methods. The results encourage educators and curriculum developers to adopt structured, technology-enhanced learning tools that promote both academic performance and learner autonomy. Future implementations of similar tools across different mathematical topics and educational levels may further strengthen their role in improving students' mathematical literacy in the digital era.

AUTHOR CONTRIBUTION STATEMENT

Imanisa Auliana contributed to the conceptualization and design of the study, developed the Quizizz-based interactive learning tool, and was responsible for data collection and initial analysis.

Rizki Wahyu Yunian Putra contributed to the literature review, refinement of research instruments, and conducted expert validation sessions.

Fredi Ganda Putra led the data analysis process, including statistical evaluation and interpretation of the N-Gain results, and assisted in drafting the results and discussion sections.

Binti Khoiriyah provided academic supervision throughout the research process, contributed to the revision of the manuscript, and ensured alignment with scientific writing and publication standards.

All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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