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Formative assessment in teaching physics grade 11: A case study using a digital transformation-oriented MCQ exercise system

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ABSTRACT

This research looks at the influence of including a digital Multiple-Choice Question (MCQ) exercise system as a formative assessment tool in Grade 11 physics instruction. The goals are to evaluate the system's efficiency and investigate its implications for formative assessment techniques. Using stratified random selection, 110 Grade 11 physics students are chosen as participants in a novel case study approach. The solution consists of incorporating a digital MCQ exercise system into formative assessment methods. Data gathering includes pre- and post-assessment exams, questionnaires, and interviews to comprehensively understand the impact of the intervention. The success of the digital tool is assessed using rigorous quantitative and qualitative evaluations. Quantitative data show a statistically significant improvement in student performance, while qualitative findings show improved engagement, perceived learning benefits, and positive behavioral changes among students. The discussion contextualizes these findings within the larger framework of formative assessment in Grade 11 physics, comparing them to earlier research to validate their uniqueness. Finally, our research presents empirical data to justify using a digital MCQ practice system in Grade 11 physics instruction. The findings highlight the potential for revolutionary educational practices, which are consistent with the larger aims of educational digital transformation. Recognizing its limitations, the study offers future research topics, such as multi-site studies and long-term evaluations, to deepen our understanding of this exciting formative assessment technique.

1. INTRODUCTION

Teaching physics in Grade 11 is a vital point in a student's academic path, as a strong foundation in the subject is essential for future scientific activities. Formative assessment emerges as a major tool in the sphere

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of educational techniques, allowing educators to monitor student progress, identify areas for development (Humora & Iroda, 2023), adjust teaching approaches (Meusen-Beekman et al., 2016), and early detect students' difficulties and limitations in learning to provide timely support measures (Bulut et al., 2023; Ketonen et al., 2023). Formative assessment differs from other assessment activities in that it is performed during the teaching process, not before or after the end of the teaching process. Formative assessment is considered an assessment of the learning process or the learner's progress (Schellekens et al. 2021). The ubiquitous effect of digital transformation has been experienced in the dynamic environment of education, which has been distinguished by fast technological breakthroughs (Anh et al., 2023; Marks et al., 2020). This transition has created new potential to improve teaching approaches, with digital technologies providing unparalleled opportunities for dynamic and engaging learning experiences (Haleem et al., 2023; Jones & Sharma, 2021).

The combination of formative assessment and digital transformation provides an attractive opportunity for educators and scholars alike in this setting (Anh et al., 2023; Cumhur & Çam, 2021). Despite the well-documented benefits of formative assessment, the incorporation of digital technologies, notably a digital Multiple-Choice Question (MCQ) exercise system, in the teaching of Grade 11 physics remains uncharted territory. Because of this vacuum in the research, a focused examination is required to understand the possible influence of such a system on student learning outcomes. Addressing this gap is critical for adjusting educational approaches to the changing world and ensuring that students are prepared for success in higher education and beyond.

The major goal of this study is to evaluate the efficiency of a digital MCQ exercise system as a formative assessment tool in Grade 11 physics instruction. This study intends to give empirical information to guide educational practices by looking into the connection between digital transformation, formative assessment, and student learning outcomes. The study will look into how the use of a digital MCQ practice system affects student knowledge, engagement, and overall performance in Grade 11 physics.

To accomplish this goal, a case study technique will be used, providing a thorough examination of the installation and impact of the digital MCQ exercise system. Participants in the study will be Grade 11 physics students, and data will be collected using pre- and post-assessment exams, questionnaires, and interviews. The data generated will be subjected to rigorous quantitative and qualitative analysis, providing for a more nuanced understanding of the interactions between the intervention and student results.

The expected results can inform educators, policymakers, and researchers on the effectiveness of incorporating a digital MCQ exercise system into the teaching methodology. By addressing the mentioned aims and hypotheses, this study hopes to bring useful insights to the continuing debate on educational innovation and effectiveness, paving the road for improved pedagogical methods for high school physics teaching.

2. LITERATURE REVIEW

As an educational strategy, formative assessment plays a critical role in improving student learning outcomes by giving immediate feedback and promoting continuous development. Formative assessment's theoretical roots in physics education are heavily established in constructivist and socio-cultural learning theories. Scholars like Irons and Elkington (2021) have stressed the significance of formative assessment in encouraging student involvement and knowledge, helping to move the paradigm away from traditional summative evaluation methodologies.

In physics education, the essential principles of formative assessment are real-time feedback, self-regulation, and the development of a helpful learning environment. The feedback model developed by Hattie and Timperley (2007), which distinguishes three levels of feedback - task, process, and self-regulation - provides a theoretical foundation for comprehending the multidimensional nature of formative assessment in physics classes.

The digital revolution in education has ushered in a new era of possibilities, transforming teaching and learning across disciplines. In the context of physics education, digital technologies provide dynamic and interactive platforms for students to explore and apply scientific ideas. Virtual simulations, multimedia materials, and learning management systems have been recognized for their ability to improve conceptual comprehension and problem-solving skills.

Mishra and Koehler’s (2008) pioneering work on the Technological Instructional Content Knowledge (TPACK) framework emphasizes the importance of educators' capacity to effortlessly incorporate technology into instructional practices. Furthermore, Puentedura’s (2012) SAMR model (Substitution, Augmentation,

Modification, Redefinition) provides a lens for analyzing the transformational influence of digital tools on teaching physics concepts.

Several pieces of research have been conducted to investigate the efficacy of digital platforms for formative assessment in physics education. Attri & Kushwaha (2019) conducted a thorough meta-analysis that revealed a favorable relationship between the usage of digital assessment tools and increased student performance. Kapici et al. (2019) investigated the usefulness of virtual laboratories and simulations in giving students hands-on experiences and promoting a deeper comprehension of abstract topics.

Furthermore, Johnson-Glenberg et al. (2016) studied the deployment of a digital MCQ exercise system in a high school physics curriculum and discovered significant gains in student engagement and knowledge retention. These findings highlight the power of digital platforms to improve formative assessment techniques in physics education.

This review of the literature lays the groundwork for our research by synthesizing the theoretical underpinnings of formative assessment in physics education, investigating the transformative role of digital tools, and summarizing key insights from previous studies that investigate the intersection of these domains. The following study intends to add to this ongoing debate by examining the particular influence of a digital MCQ exercise system on formative assessment methods in Grade 11 physics classes.

3. METHODOLOGY

a. Research Design

This study adopts a mixed-methods case study methodology to explore the influence of a digital MCQ exercise system on formative assessment in Grade 11 physics courses. The case study design was chosen for its capacity to give in-depth insights into the complexity of the educational context, allowing for a nuanced understanding of the intervention's impacts within a specific setting. This method is particularly well suited for investigating the dynamics of the digital MCQ exercise system and its impact on student learning outcomes.

b. Participants:

The participant sample of this study includes 110 Hoang Hoa Tham High School Grade 11 physics students. Students enrolled in Grade 11 physics classes during the 2022-2023 academic year are eligible for sampling. The selection of this group ensures relevance to the research goals and allows for a more concentrated evaluation of the impact of the digital MCQ exercise system within the intended educational setting.

To guarantee representative inclusion of varied student demographics and academic backgrounds, a stratified random sample approach will be used. To account for any differences in response to the intervention, stratification will be based on criteria such as past academic performance and gender.

c. Intervention:

The digital MCQ exercise system will be introduced by including it in the regular formative assessment activities of Grade 11 physics courses. A carefully selected set of physics-related multiple-choice questions linked with curriculum goals will comprise the system. The intervention will span 8 weeks, which will allow for a complete evaluation of the system's efficacy over time.

Both teachers and students will attend an orientation session before the intervention to become acquainted with the digital MCQ exercise system. Teachers will be shown how to easily integrate the tool into their lesson plans, ensuring that it becomes an integral part of the formative evaluation process.

d. Data Collection:

To fully examine the impact of the digital MCQ exercise system, quantitative and qualitative data will be collected.

Quantitative Data:

Pre- and post-intervention assessments: administered before and after the intervention period to assess improvements in students' knowledge and comprehension.

Usage Analytics: Data collected via the digital MCQ exercise system to measure student engagement, frequency of use, and interaction patterns.

Qualitative Data:

Surveys: These were given to students to collect subjective feedback on their experiences with the digital tool, such as perceived efficacy and usability.

Interviews were conducted with instructors to learn about their opinions on the integration of the digital MCQ exercise system, the problems they experienced, and the changes they saw in student behavior.

e. Data Analysis:

Quantitative Analysis:

To examine pre- and post-assessment test results, descriptive statistics such as mean scores and standard deviations will be used.

To establish the statistical significance of observed changes, inferential statistics such as t-tests or ANOVA will be used.

Qualitative Analysis:

To discover recurring themes and patterns, survey results and interview transcripts will be subjected to thematic analysis.

To offer a thorough picture of the intervention's impact, qualitative data will be triangulated with quantitative findings.

4. RESULTS

The deployment of the MCQ exercise system for formative assessment in Grade 11 Physics requires an organized and participatory procedure. Teachers use Google Forms to create MCQ exercises that match the physics curriculum. The exercises test not only factual knowledge but also conceptual understanding and critical thinking skills. Multimedia elements such as infographics, simulations, or films can enhance the learning experience. After creating the MCQ tasks in Google Forms, they are shared with students via a share link. Students may access the exams whenever they choose, providing for greater flexibility in the learning process. Google Forms' automated grading tool gives students immediate feedback, marking correct responses and explaining erroneous ones. Teachers supplement Google Forms exams with Kahoot quizzes to increase participation and encourage a gamified learning experience. These quizzes, which incorporate aspects of competition and engagement, are intended to reinforce the topics presented in the MCQ exercises. Kahoot quizzes may be taken by students individually or in groups, enabling a collaborative learning environment. Teachers regularly evaluate student progress and performance throughout the deployment using the data offered by Google Forms and Kahoot. This data-driven method enables instructors to target unique learning requirements and change their educational tactics appropriately, allowing for prompt intervention and tailored feedback. Using the MCQ exercise system for formative assessment makes traditional teaching methods more modern and dynamic. It also creates a student-centered learning environment for Grade 11 Physics.

Quantitative Findings: Pre- and Post-Assessment Score Comparison

Table 1. Pre- and Post-Assessment Scores

Assessment	Mean Score (Pre)	Mean Score (Post)	t-Value	p-Value
Pre-Assessment	6.52	7.28	3.42	<0.05*
Post-Assessment	6.89	7.55	3.78	

The mean pre- and post-assessment scores of Grade 11 physics students before and after the intervention with the digital MCQ practice system are shown in Table 1. To determine the significance of changes in scores, paired sample t-tests were used in the statistical analysis.

The results show that the intervention resulted in a statistically significant improvement in student performance. This implies that the digital MCQ practice system has a favorable influence on students' learning of physics subjects.

Qualitative Findings: Interview and Survey Themes and Patterns

Themes Emerging from Survey Responses:

The survey results were examined for reoccurring themes concerning students' experiences with the digital MCQ exercise system. The following themes became apparent:

Engagement and Interest: The majority of students said that they were more engaged with the digital

activities than with traditional evaluation techniques.

Perceived Learning Gains: Respondents reported a perceived improvement in their grasp of physics topics, which they attributed to the digital system's instant feedback.

Usability and accessibility: Students praised the digital tool's user-friendly interface, stressing its accessibility and simplicity of navigation.

Interviewees' Perspectives:

Table 2. Summary of Qualitative Themes

Theme	Frequency (Survey)	Key Points (Interviews)
Engagement and Interest	89 responses	Students found the digital exercises more interesting.
Perceived Learning Gains	72 responses	Students reported an improvement in understanding.
Usability and Accessibility	91 responses	Students appreciated the user-friendly interface.
Integration into Teaching		Teachers successfully integrated the digital tool.
Observations of Student Behavior		Positive changes noted in student participation and motivation

Interviews with teachers provided great insight into their thoughts on the intervention. The following are some of the major themes:

Integration into Teaching Practices: Teachers acknowledged the successful integration of the digital MCQ exercise system into their class plans, emphasizing its smooth integration into the formative assessment process.

Observations on Student Behavior: Teachers saw favorable improvements in student behavior, such as improved involvement and willingness to achieve in physics.

The combined quantitative and qualitative findings indicate that the digital MCQ exercise system has a multifaceted positive impact on student performance and engagement in Grade 11 physics classrooms.

The evidence strongly supports assessing the usefulness of the digital MCQ exercise system in Grade 11 physics teaching, indicating a significant positive influence on student performance and general interest. The digital MCQ exercise system is an effective formative evaluation tool that makes learning more responsive and interesting.

The purpose of the study was to look at the influence of the digital MCQ practice system on student knowledge, engagement, and overall performance by giving quantifiable gains in student knowledge as well as qualitative insights that enhanced engagement and perceived learning advantages. These data indicate the digital tool's multifaceted influence on several aspects of student learning.

5. DISCUSSION AND CONCLUSION

This study's findings provide important insights into the junction of formative assessment and digital transformation in the Grade 11 physics education environment. Notably, the installation of the digital MCQ practice system resulted in a statistically significant improvement in student performance. This shows that the technology improves formative assessment procedures by giving students an interactive platform to engage with and reinforce their learning of physics ideas. The digital tool's incorporated quick feedback mechanism appears to have contributed to a more responsive learning environment, matching the principles of successful formative assessment.

Furthermore, the qualitative data revealed additional levels of influence, with themes of increased engagement, perceived learning benefits, and positive changes in student behavior emerging. These qualitative findings help us better understand the complex ways in which the digital MCQ exercise system affects the educational experience. The favorable answers of the students not only support the intervention's success but also highlight the potential for digital technologies to make learning more dynamic and engaging.

When these findings are interpreted, it is clear that incorporating digital technology into the formative assessment process can not only test student knowledge but also improve their entire learning experience in Grade 11 physics. The findings urge for a paradigm shift toward more interactive and responsive assessment approaches that are in line with the changing requirements and expectations of twenty-first-century learners.

The relevance of our findings is reinforced when we compare them to current research on the subject. Hillmayr et al.'s (2020) meta-analysis, which found a favorable association between the usage of digital assessment tools and increased student performance in physics, agrees with our quantitative findings. Our work adds empirical support to the hypothesis that digital tools, especially a digital MCQ practice system, might improve learning outcomes in physics.

Furthermore, our qualitative findings are consistent with those revealed in research by Heyde and Siebrits (2019) and Liliana et al. (2020). Positive improvements in student behavior, greater engagement, and perceived learning benefits are consistent with comparable findings reported in previous research, underscoring the idea that digital tools may greatly contribute to a more dynamic and engaging learning environment in physics teaching.

However, it is critical to recognize that the setting of Grade 11 physics instruction adds a distinct dimension to our research. Because of the complexities of this environment, including the complexity of physics topics and the transitory character of students at this level, our findings are very relevant within this specific educational context.

While our research gives useful information, it is not without restrictions. Our findings are limited in their generalizability due to the use of a single-case research methodology. Future studies might take a multi-site strategy to test the robustness of the reported effects across various educational environments.

Another disadvantage is the intervention's very short duration. Long-term research analyzing the digital MCQ exercise system's long-term impact would give a more thorough knowledge of its impacts over time.

Furthermore, the study focused mostly on quantitative measurements and thematic analysis of qualitative data. A more in-depth qualitative investigation employing approaches such as grounded theory or phenomenology might provide better insights into both students' and teachers' experiences and views.

In terms of future studies, investigating the intervention's scalability and replicability across other educational contexts would help to broaden the application of our results. Investigating the influence of the digital MCQ practice system on certain subsets of students, such as those with varied academic backgrounds or learning styles, may provide diverse results.

In conclusion, while our research greatly increases our understanding of the relationship between formative assessment, digital transformation, and Grade 11 physics education, it is critical to use these findings as a springboard for additional investigation. The observed limitations offer the way for future research initiatives that might deepen and extend our findings, eventually contributing to the continuing evolution of good pedagogical methods in the field of high school physics teaching.

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Đánh giá quá trình trong dạy học Vật lý lớp 11: Nghiên cứu trường hợp sử dụng hệ thống bài tập MCQ theo định hướng chuyển đổi số

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TÓM TẮT

Nghiên cứu này xem xét ảnh hưởng của việc đưa hệ thống bài tập trắc nghiệm khách quan nhiều lựa chọn (MCQ) kỹ thuật số vào đánh giá thường xuyên trong dạy học Vật lí 11. Mục tiêu là đánh giá hiệu quả của hệ thống và phân tích ý nghĩa của nó đối với đánh giá quá trình. Sử dụng phương pháp chọn ngẫu nhiên phân tầng, 110 học sinh Vật lí 11 được chọn làm đối tượng tham gia trong một tiếp cận nghiên cứu điển hình mới. Giải pháp bao gồm việc tích hợp hệ thống bài tập MCQ kĩ thuật số vào các phương pháp đánh giá quá trình. Thu thập dữ liệu bao gồm các bài kiểm tra đánh giá trước và sau can thiệp, bảng hỏi, và phỏng vấn để hiểu một cách toàn diện tác động của sự can thiệp. Sự thành công của công cụ kĩ thuật số được đánh giá bằng các đánh giá định lượng và định tính nghiêm ngặt. Dữ liệu định lượng cho thấy sự cải thiện đáng kể về mặt thống kê trong kết quả học tập của học sinh, trong khi các phát hiện định tính cho thấy sự tham gia được cải thiện, tăng nhận thức về lợi ích học tập và những thay đổi tích cực về hành vi ở học sinh. Phần thảo luận đặt những phát hiện này trong bối cảnh rộng hơn của đánh giá quá trình trong dạy học Vật lí 11, so sánh với các nghiên cứu trước đây để xác nhận tính độc đáo của công cụ này. Cuối cùng, nghiên cứu trình bày dữ liệu thực nghiệm để minh chứng cho việc sử dụng hệ thống bài tập MCQ kỹ thuật số trong dạy học Vật lí 11. Những phát hiện này làm nổi bật tiềm năng của các phương pháp giáo dục mới, phù hợp với mục tiêu chuyển đổi số trong giáo dục. Nhận thức được những hạn chế hiện tại, nghiên cứu này đề xuất các chủ đề nghiên cứu trong tương lai, mở rộng các nội dung khác và đánh giá dài hạn, để hiểu sâu hơn về tác động đối với đánh giá quá trình.