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Investigating the Effectiveness of Online Interactive Modules on Enhancing Mathematical Proficiency in Grade VI Students of Phuentsholing Primary School

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Abstract

This study examined the effectiveness of online interactive modules in improving mathematical proficiency among Grade VI students in Phuentsholing Primary School, focusing on the concepts of ordering fractions and rotation. The mixed-methods approach was used where 27 students participated in three-week intervention involving online learning tools. Data were collected through pre-tests and post-tests, surveys, and observations. The results were analyzed using Statistical Package for Social Sciences (SPSS version 22) and it demonstrated significant improvement in students' understanding, with mean test scores increasing from 2.00 to 4.96 for ordering fractions, and from 0.63 to 4.63 for rotation. Surveys indicated a positive shift in students' perceptions towards using digital tools for learning, with increased engagement and enjoyment. Qualitative analysis was derived through thematic coding and it revealed that dynamic simulations and instant feedback were key elements in facilitating understanding. Despite overall gains, some students continued to find the rotation concept challenging, as reflected in the higher post-test score variability. The study highlighted the potential of online interactive modules to enhance mathematical learning, suggesting further exploration into differentiated support for complex topics. These findings have implications for integrating technology in educational practices in Bhutan.

Keywords*— *Mathematical Proficiency, Ordering Fractions, Online Interactive Modules, Rotation, Technology Integration

I. INTRODUCTION

Mathematics has always been a part of the lives of human-beings. It is concerned with not only the everyday problems but also with using imagination, intuition, and reasoning to find new ideas to solve puzzling problems (Khan, 2015). These mathematical proficiency are a crucial component of primary education which forms the foundation for future academic success and practical life skills in students. The mathematical skills range from every little thing in their lives, from counting the number of potatoes to make fries to equating the number of words and numbers in their schools, exams, and daily lives.

With the change of the educational landscape and the needs of the time, the way students and teachers engage in the teaching and learning process has also drastically transformed. The long-lasting traditional method has long been encouraged to be discarded, especially in Bhutan, and more engaging methods are being recommended. In this light, the online interactive modules come alive. With the rise of technology in education, online interactive modules present an eminent strategy to enhance mathematical learning. It also leverages technology to provide a more personalized learning and allows a targeted intervention (NCTM, 2023).

While many researches show promising findings, there is a need to investigate how this method will unfold in the Bhutanese context. Hence, this research has investigated the effectiveness of the online interactive modules in improving the mathematical proficiency of grade VI students in Phuentsholing Primary School by intervening through the subject topics on ordering fractions and rotation.

II. BACKGROUND / PROBLEM STATEMENT

In addition to the importance of mathematics in an individual life, mathematics is a significant subject in Bhutanese education system. It is treated as a main subject, where not acquiring the required score in this subject fails

the students despite excellent score in other subjects. The Bhutanese mathematics curriculum has undergone numerous transformation due to the changing needs of the Bhutanese students and the global standards (Dorji & Tshering, 2020). It derives its significance from its innate quality of unlocking opportunities in Science, Technology, Engineering and ensuring competitiveness in the fast-changing world by instilling the mathematical skills. Mathematics skills comprise computation, reasoning, problem-solving, and clear communication of mathematical concepts (Ministry of Education and Skills Development, 2023). While it is important to master the skills of mathematics, it is equally difficult to comprehend these skills by the students in primary education.

Grade VI Students in Phuentsholing Primary School frequently encounter problem with the procedural knowledge of the mathematics. While they comprehend the conceptual knowledge during the teacher-led learning, however when the time comes to do it independently, they struggle to apply the learned concept, leading to a loss of confidence and an inability to connect and solve problems efficiently. Especially in the mathematical concepts like ordering fractions and rotation of shapes. These concepts require students to visualize the abstract concepts and then apply it in their solution. The fraction concepts require a strong grasp of the numerical value and is size-relationship, and the process of converting the fractions to a common denominator from the mixed and improper fractions can be challenging. Moreover, the concept of rotation poses a cognitive load on the students to remember and visualize the original position and then its shape when rotated.

To address these challenges, the mathematics teachers employ hands-on activities and intensive problem-solving exercises. However, given the large class size and time constraints, this strategy appears inadequate and ineffective. Consequently, leveraging technology in our digitalized world seems like a more promising approach to helping students develop their mathematical skills. The dynamic visual, auditory, and instant feedback features of online interactive modules can provide assistance in cementing the conceptual knowledge in their procedural knowledge. Moreover, it can help provide an opportunity and experience to students to try out the concepts in ways that would be impossible in the classroom setting. Thus, this research investigated the effectiveness of the online interactive modules in addressing these issues of mathematical proficiency by incorporating a mixed-method approach of the research.

Research Questions

The key questions this study will try to investigate are as follows:

1. How do the online interactive modules impact students' proficiency in specific mathematical topics like ordering fractions and rotation?

2. Which features of the modules, such as dynamic simulations, instant feedback, or interactive games, most enhance students' understanding of ordering fractions and rotation?

Research Objectives

The specific objectives of this study are as follows:

1. To assess the effectiveness of online interactive modules in enhancing the mathematical proficiency of Grade VI students by comparing pre-test and post-test results on the topics of ordering fractions and rotation.

2. To identify and analyze, through observations open-ended survey questionnaires, the specific elements of the online interactive modules (e.g., simulations, quizzes, games, feedback mechanisms) that significantly contribute to the improvement of mathematical proficiency among Grade VI students.

3. To analyze the perceptions of Grade VI students towards the use of online interactive modules, using survey responses and thematic analysis of observations and open-ended survey questionnaires, to understand their engagement, motivation, and perceived learning benefits.

III. SIGNIFICANCE OF THE STUDY

The aim of this study is to investigate the effectiveness of online interactive tools in enhancing mathematical proficiency in grade VI students. Through this study, the researchers built and provided a concrete analysis and an action of the ways technology can be used in teaching and learning process of mathematics. Through this, it provided an opportunity to students to explore and reach their potential by experimenting and constructing mathematical concepts. Moreover, on a minor note, it also helped students learn the right and productive use of technological tools for learning. It provided an insight to teachers to explore online interactive modules to teach mathematical concepts efficiently and effectively. On the broader part, this study also served as a useful document to the stakeholders in their decision-making process in terms of integrating technologies in the education system. Addressing issues related to the mathematical concepts is an important component in the academic growth and quality of education and would go a long way in proving the standards of the Mathematics in Bhutan and hence, a quality education.

IV. LITERATURE REVIEW

Technology in Mathematics Education

Mathematics is the backbone of many disciplines such as engineering, science, business, and computer science (Yong & Gates, 2016), and the use of technology is important in making sense of mathematical concepts (Akkaya, 2016). Technologies have been available in the western school's mathematics classroom since the introduction of simple four-function calculators in the 1970s (Goos, 2010). Teachers are often expected to use digital technology to improve teaching and learning (Loong & Herbert, 2018). Technology is a partner when it provides access to new kinds of tasks or new ways of approaching existing tasks to develop understanding, explore different perspective, or mediate mathematical discussions (Goos, 2010). Introducing technology into the mathematical education transforms the learning ecology so that the new mathematical knowledge and practices may emerge (Steinbring, 2015). However, it can be seen that although technologies have significant potential in teaching and learning process of mathematics, the uptake of technologies is deemed disappointing and the grand visions are not realized (Joubert, 2012). Even in the Bhutanese context, the only form of technologies used in education is for Information and Communication Technology (ICT) classes, where students get to explore twice a week. Some factors such as the lack of access to digital devices, parent's socio-economic background, and teachers' inadequate knowledge that hinders the uptake of technologies in teaching and learning process in Bhutan (Dhendup & Sherab, 2023).

The use of technology in teaching and learning is widely accepted to have gathered sufficient quality data in education (Hegedus et al., 2017; Kerres, 2020). It has the potential to improve the teaching and learning of mathematics, leading to gains in higher order thinking skills as well as student achievement and self-efficacy (Cullen, Hertel, & Nickels, 2020). The National Curriculum of Teachers of Mathematics (2023) asserts technology as essential in teaching and learning mathematics and it enhances students' learning.

Online Interactive Modules

The online interactive modules are the interactive educational tools that enables learners to actively engage with the learning content. It is creative, innovative, and adaptive teaching and learning method that helps students feel comfortable and learn effectively and efficiently (Wijaya & Vidianti, 2019). The online interactive modules are the educational online games, quizzes, and puzzles which provides an engaging experience through its aspects of multi-medias, simulations, and feedbacks. These are easily accessible to students where ever they dwell. For instance, dynamic geometry software has provided opportunities, especially in teaching geometry, in visualization, dynamic drawing of geometry shapes and exploring various geometric relationships (Akkaya, 2016).

Students' Perceptions and Engagement

Students' perception, belief and feelings towards mathematics and use of technology are important determinants in reinforcing or weakening their mathematics learning. Research has indicated that students' attitude towards mathematics learning with technology is greatly influenced by their attitude towards the subject itself and technology in general (Yong & Gates, 2016). Students' motivation to learn mathematics is built based on their interest, self-efficacy, and attributions (Ifinedo et al., 2020). To motivate students in mathematics learning, many efforts and innovations have been put forward in recent years by integrating digital technology such as video or computer games into mathematics education (Chang, 2019). Similarly, in Bhutan, the National Education Curriculum has integrated incorporated every aspect and features of technology in the lesson plans. Moreover, technology can change the nature of school mathematics by engaging students in more active mathematical practices such as experimenting, investigating, and problem-solving that bring depth to their learning and encourage them to ask questions rather than only looking for answers (Goos, 2010).

The literature reviews of various research papers and books depicts tremendous recommendation for the use of technological tools in teaching and learning mathematical concepts. It has also provided insights on the cautions to be taken while integrating technological tools in teaching and learning process.

V. METHODOLOGY

For this action research study, the mixed-method research approach was employed to investigate the effectiveness of online interactive tools in enhancing mathematical proficiency in grade VI students. The detailed methodology plan for the use of qualitative and quantitative data collection tools are presented below.

Study Sample and Participants

The sampling method for this research is the purposive sampling. The students who could not achieve their pass mark in the mid-term written exam was selected for this research. As per the mid-term result, the student participant totals up to 27 grade VI students from sections A to G. The student participants will be referred to as pseudonym R1, R2, R3, and so on till R27.

Data Collection Tools

The research method and framework adopted for this study was the mixed-method under which tests, survey and questionnaires, and observations were being used.

Baseline Data Collection Tools

The baseline data collection tools that were used in this study are as reflected below.

Pre-Test

The aim of this study was to investigate the effectiveness and bring out improvement in the students, therefore as a yardstick to measure and analyze the present and the latter level of performance of the students through the intervention, the pre-test was used.

A written test was done on the mathematics topics of ordering fractions and rotation. The test papers were developed as per the standard of the grade and in consultation and validated with their mathematics teachers.

Survey

The student participants were asked to fill an online survey questionnaire. They were asked on their perception, familiarity, and opinion with the mathematical concept of ordering fraction and rotation and the online interactive modules.

Observation

Observation was mainly used during the intervention period. The researchers maintained an observational sheet to note the process, engagement, and interaction of the students while they learned about ordering fractions and rotation concepts through the online interactive modules.

Intervention

The intervention process used in this study involved students engaging in online interactive modules to explore on the mathematical concept on ordering fractions and rotation for the period of three weeks with four sessions of 40 minutes each week. The Information and Communication Technology(ICT) lab of the school were used during the conduct of the interventions.

The process involved first a brief initial lesson on the mathematical topic on ordering fractions and rotation delivered by the mathematics teacher (the researcher) which covered the fundamental concepts which set the foundation for further exploration by the students. This was then followed by a short instruction on which online interactive modules to use and how to use it by the researchers.

The online interactive modules comprised of the online manipulative, simulations, videos, games, and quizzes found online on the given topic. Some of the names of the sources of these online interactive modules and the mathematics topic associated are;

1. Toytheater.com, Mathgames.com, Mathlearningcenter.org, Khanacademy.com, teacher.desmos.com, mathsbot.com and abcya.com for the lessons on ordering fractions

2. Geo-Gebra, Math Playground, and IXL for the lessons on rotation.

Post-Intervention Data Collection Tools

Post-test

Similar to the pre-test, to see the impact of the intervention and for a comparative analysis, the post-test was conducted on the same topic with the same questions of the grade's standard. This helped the researchers comprehend and analyze the effectiveness more efficiently.

Survey Questionnaires

Students were asked to fill the survey questionnaires after the intervention to know their perception on the use of the online interactive modules and the impact it had on their learning process of the mathematical concept.

Data Analysis Method

The research approach being mixed-method, the qualitative part of this study was analyzed using thematic coding and the quantitative part was analyzed using SPSS22 (Statistical Package for the Social Sciences). The themes derived from the questionnaires provided along with the survey and the observation were further interpreted through validation of the information. The data from the surveys and tests were entered in the SPSS and then analyzed thereafter.

Ethical Consideration

To conduct this study, prior permission and consent from the school, teachers, and parents of the participants were requested and the identity of the participants and their results during this study were kept confidential.

VI. FINDINGS

The data collected through-out the course of this study was analyzed according to the guiding questions:1. How do the online interactive modules impact students' proficiency in specific mathematical topics like ordering fractions and rotation? 2. Which features of the modules, such as dynamic simulations, instant feedback, or interactive games, most enhance students' understanding of ordering fractions and rotation? The online interactive modules used focused on the mathematical concept on ordering fractions and rotation of shapes. The data were collected from 27 students through pre-tests, post-tests, observation and survey questionnaires to capture both quantitative and qualitative improvements.

Test Results

The test was a necessary tool and a yardstick to measure the efficacy of the intervention. Table 1 displays the mean mark of the pre-test and post intervention test on ordering fractions and rotation respectively.

Table 1: Mean mark of Pre-test and Post intervention test (n=27)

	N	Mean	Std. Deviation
Pre-test on Ordering Fractions	27	2.00	.877
Pre-test on Rotation	27	.63	1.275
Post intervention test on Fraction	27	4.96	.854
Post intervention test on Rotation	27	4.63	1.115
Valid N (listwise)	27		

In the pre-test on Ordering Fractions, the low mean mean = 2.00 and moderate variability in the standard deviation = 0.87 indicate that, prior to the intervention, students struggled with the concept of ordering fractions. Many students performed below the expected proficiency level. However, the post-test on ordering fraction's scores with the mean = 4.96, standard deviation = 0.854 shows a substantial increase in performance, with the mean near the maximum possible score (5.00). This indicates that students developed a much stronger understanding of the concept after the intervention. The relatively low standard deviation also suggests that most students performed consistently well.

For the pre-test on rotation, the extremely low mean, mean = 0.63,combined with a high standard deviation, standard deviation = 1.275, suggests that students initially struggled with this concept even more than with ordering fractions. Nevertheless, there was also significant variation in student performance, meaning some students understood the concept slightly, while others found it very difficult. In the post-test on rotation, after the intervention, the mean score improved drastically, mean = 4.63, and the standard deviation = 1.115 remained higher compared to the fraction's post-test, indicating that some students still faced challenges with this concept, the overall improvement reflects the effectiveness of the intervention in teaching and learning through online interactive modules.

The substantial improvement in both areas of mathematical concept demonstrates that the online interactive tools were highly effective in enhancing students' understanding of both fractions and rotation. However, the slightly higher standard deviation in post-intervention test in rotation suggests that the concept of rotation is more challenging for students to grasp, even after intervention.

For further understanding on the results derived from the tests, one-sample t-test on each of the concept on ordering fractions and rotation were analyzed and are presented in the following tables respectively.

Table 2: One-Sample Test on Pre-test and Post intervention test on Ordering Fraction

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Pre-test on Ordering Fractions	11.84	26	.00	2.00	1.65	2.35
Post intervention test on Ordering Fraction	30.19	26	.00	4.93	4.63	5.30

The results from the one-sample t-test strongly suggest that the online interactive modules had a significant positive impact on the students' ability to order fractions. The large increase in both the t-value (from 11.84 to 30.19) and the mean difference (from 2.00 to 4.93) between the pre-test and post-test demonstrates a substantial improvement in students' performance after the intervention. The statistical significance ($p < .05$) in both tests indicates that these improvements are unlikely to be due to chance. Furthermore, the relatively narrow confidence intervals, particularly in the post-test, suggest consistency and reliability in the results. Overall, the data provide strong

evidence that the interactive modules effectively enhanced students' mathematical proficiency, with the substantial rise in test scores reflecting a meaningful improvement in their understanding of ordering fractions.

Table 3: One-Sample Test on Pre-test and Post intervention test on Rotation

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Pre-test on Ordering Fractions	2.56	26	.016	.63	.13	1.13
Post intervention test on Fraction	21.54	26	.000	4.63	4.19	5.07

The results from the one-sample t-test on table 3 offer strong evidence that the online interactive modules significantly improved students' understanding of rotation. Initially, the pre-test t-value of 2.56 and a modest mean difference of 0.63 suggest that students had a limited grasp of the concept, demonstrating only a basic level of proficiency. However, the substantial increase in the post-test t-value to 21.54, alongside a mean difference of 4.63, indicates a meaningful and significant enhancement in their knowledge following the intervention. Both tests show statistically significant results, reinforcing that the observed improvements are not random. Additionally, the narrow confidence intervals, particularly in the post-test, reflect the consistency and reliability of the results, providing further validation of the intervention's effectiveness.

In summary, the data with the substantial rise in test scores reflected a meaningful improvement in their understanding of ordering fractions and rotation. It clearly demonstrate that the interactive modules successfully addressed the initial gaps in students' understanding of rotation, resulting in a marked improvement in their overall proficiency. The robust statistical outcomes, combined with the tight confidence intervals, underscore the effectiveness of the modules in boosting students' comprehension of rotational concepts.

Survey Data

The survey questionnaire was conducted twice, one before the intervention and one after the intervention. In the survey questionnaire before the intervention, the open-ended questions were included to capture the detailed perception on their mathematical learning and their prior idea, use, and perception of online interactive modules.

The open-ended questions asks the students on their perception on the challenging aspect of mathematical concepts and using online interactive modules, the teaching module and the online interactive module they preferred. On these questions, most students listed fraction as the difficult concept and one students, R1 stated that the most challenging part while learning mathematics in class is the concepts of geometry. Not only this, while R1 stated that the online interactive modules makes it visually easy to learn the concept, R1 would prefer teaching and learning in the class with the teacher so as to be able to clear the doubts. Moreover, when asked about their knowledge and use of online interactive module for education, it can be seen that the students had very little idea on the various online interactive modules and has only used the facility of YouTube videos as a mean to learn mathematics concepts. Nevertheless, all students stated their willingness and enthusiasm in using various online interactive modules for learning.

The table below, Table 4, statistically displays the quantitative description of the survey questions which used the likert scale; 1- Strongly Disagree, 2- Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree. After the analysis of the survey response data in the SPSS, it was found that most students when asked if the online interactive modules made their learning mathematics more enjoyable, the mean score on this response was 4 meaning that most students responded as to Agreeing with the statement.

Table 4: Comparative Descriptive Statistics on Survey Questions

	N	Minimum	Maximum	Mean	Std. Deviation
Perception on Interactive Module before intervention	27	17.00	40.00	29.22	5.14
Perception on Interactive Module after intervention	27	26.00	45.00	35.92	4.50
Valid N (listwise)					

This data from table 4, suggests that the intervention—using online interactive modules—had a positive impact on student perceptions. The increase in the mean score(difference of 6.7) and the narrower spread of the standard deviation(difference of 0.64) in the responses in the post-intervention indicate that students generally felt more favorably toward the modules after they had used them. The improvement in both the minimum and maximum scores post-intervention indicates that students who were previously less positive about the module became more favorable after using it, and those who already had positive views either maintained or slightly increased their positivity. Overall, the intervention seems to have contributed to a significant enhancement in student perception, suggesting that the interactive modules were well-received and potentially effective in improving mathematical proficiency through increased engagement.

Key Interactive Features of Online Interactive Modules that Enhanced the Conceptual Understanding

In analyzing the specific features within the online interactive modules that helped enhance the student' learning and understanding, data from open-ended survey questionnaire and observations provide valuable insights. The prominent themes derived through coding the data from these two sources were mostly, improvement, engagement, peer collaboration, individualized learning, and attitude towards learning mathematics. Through observation, it was also revealed that during the use of interactive games on ordering fractions, students were more engaged, often discussing strategies with peers and showing increased enthusiasm. The frequency of students asking doubts to the teacher freely were higher than in the normal class setting. Not only this, while using the online manipulatives, students were seen becoming more enthusiastic and goes on to explore more fraction and rotation problems on their own.

Through the open-ended question, one student commented:

"I like the online interactive modules that we used so far as it helps us understand properly through the simple ways on solving the problem through the blocks that we can carry and shuffle around. "

This clearly depicts the level of engagement and the attitude toward learning mathematics that the online interactive modules provided. Moreover, the students were seen comparing and validating their understanding through the visual representation on the screen and learning on their own pace but with a progressive speed through the games. Some students were even observed exploring and using other features of the online interactive modules that were not mentioned by the researchers.

VII. DISCUSSION

The findings of this study indicate a significant enhancement in students' understanding and performance on the concept of ordering fractions and rotation following the intervention of online interactive modules, evidenced by both quantitative test scores and qualitative observation and survey responses.

The pre-test results highlighted a concerning lack of proficiency in both mathematical concepts, with means of 2.00 for ordering fractions and 0.63 for rotation. However, post-intervention data showed a remarkable increase in mean scores, reaching 4.96 for fractions and 4.63 for rotation. These results not only reflect the efficacy of the online interactive modules but also underscore the potential of technology to transform mathematical learning experiences. The statistical analyses, including one-sample t-tests, further validate these improvements, revealing significant gains that are unlikely to be attributed to chance.

Students engagement and perceptions of learning through the salient features of the online interactive modules emerged as critical factors in this study. The qualitative data from open-ended survey questions and classroom observations indicated that the online modules fostered an environment of active learning. Students reported feeling more comfortable with the content, as the interactive features, such as dynamic simulations, allowed for individualized pacing and collaborative exploration. The enthusiasm observed during peer discussions and interactions with the modules suggested that online interactive modules not only enhances comprehension but also promotes a more engaging and collaborative learning

atmosphere. This findings is in accordance with the existing literature, which showed that students' attitude towards mathematics learning with technology is greatly influenced by their attitude towards the subject itself and technology in general (Yong & Gates, 2016).

Interestingly, while the overall results indicate strong improvements, the higher standard deviation in post-test scores for rotation suggests that this concept remains more challenging for some students. This variance highlights the necessity for further study, ongoing support and differentiated instruction, even in technology-enhanced learning environments. Some students still struggled with rotation despite significant overall gains, pointing to the complexity of spatial reasoning tasks and the need for varied teaching strategies to address diverse learning needs.

The data also reflected that although students seemed skeptical and lacking in using online interactive modules to learn mathematics concept, there was a shift in students' attitudes toward mathematics. The increase in mean scores from the pre-test to post-intervention survey indicates a positive change in perceptions regarding the use of online interactive modules, with students expressing greater enjoyment and engagement in their mathematical learning. This shift is crucial, as student attitudes and self-efficacy are strongly linked to their overall academic success in mathematics.

VIII. IMPLICATION

This study has implications for policymakers, curriculum developers, education and school administrators, teachers, and students. These findings encourage and provides opportunity to think and act in the global standards and use technology to its full potential for the learning process of our students. It provides as a support to curriculum developers, administrators and teachers to provide time and opportunity for students to explore technology within the concept learning.

IX. LIMITATION AND FURTHER RESEARCH

There were several limitation to this study. First the small sample size may limit the generalizability of the study's findings. Second, the open-ended question data collected were self reported through the form by the participants which may have limited their expression. Third, our study only focused on two concept of mathematics, which limits validating its effectiveness in other areas. Hence, further studies could use a larger sample, conduct in-depth interviews, and study on other areas of mathematical concepts.

X. CONCLUSION

In conclusion, this study underscored the transformative potential of integrating online interactive modules into mathematics education. By enhancing student engagement, improving proficiency, and positively influencing attitudes towards learning, technology serves as a vital ally in the quest to develop deeper mathematical understanding. Future research could explore long-term impacts on mathematical proficiency and strategies for addressing remaining challenges, particularly in complex topics like rotation. This study provides valuable insights for educators seeking to implement technology effectively in their teaching practices, emphasizing the need for a thoughtful approach that considers both the strengths and limitations of technological tools in the classroom.

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