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Characterizing the Effectiveness of Video Recordings in Mathematics Instruction within Higher Education: Minimizing Direct Teacher-Student Interaction through Technological Modalities

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study was conducted to characterize the effectiveness of employing video recordings as a teaching tool in mathematics in higher education, with a bid to minimize direct teacher-student interactions. The research employed an experimental design, utilizing pre-tests and post-tests with a sample of 45 randomly selected first- and second-year mathematics students at Mountains of the Moon University. Video recordings were compared with alternative approaches, including online (Zoom) classes and self-study materials/handouts, to gauge their effectiveness in the absence of physical teacher-student interactions. Three experimental units were established, each undergoing

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learning of sequences via video recordings, online (Zoom) classes, or self-study printable materials/handouts. Statistical analysis was done using SPSS including percentages, descriptive statistics, Pearson correlation, and independent sample t-tests. Results revealed the relevance of both tools in mathematics learning, with video recordings proving to be more effective and superior in enhancing understanding of the learned concepts compared to the alternative tools. The study recommends the incorporation of video recordings in mathematics teaching, particularly in situations where physical meetings between teachers and students are impractical.

Keywords: Video recordings; online classes; handouts; student-teacher interactions; teaching mathematics.

1. INTRODUCTION

The shift in the landscape of mathematics education, catalyzed by the COVID-19 pandemic, has prompted a reevaluation of traditional teaching methods. Historically, mathematics education heavily relied on face-to-face interactions between teachers and students, given the intricate nature of the subject requiring a step-by-step approach and tangible engagement. However, the pandemic necessitated a drastic transformation, pushing educational institutions to explore and adopt alternative methods.

The emergence of online distance learning became a crucial avenue for ensuring educational continuity. In this context, various technological tools, including video recordings, online classes via platforms like Zoom, and self-study materials, have taken center stage. Notably, video recordings have reaped attention for their potential to provide students with both auditory and visual experiences of mathematical concepts, enhancing the overall learning process.

Research studies conducted by Rauf and Fauziah [1] Moliner et al. [2], and Ghilay [3] support the notion that video recordings play a significant role in maintaining effective mathematics instruction, especially in the context of remote learning. The flexibility offered by video recordings allows students to revisit lessons, grasp complex concepts at their own pace, and bridge the gap created by the absence of direct teacher-student interactions.

The exploration of digital learning as a response to the challenges posed by COVID-19 is evident in studies such as [4]. The study by Toquero [5] on higher education during the pandemic underscores the need for educational institutions to adapt their curriculum and teaching practices to cater to students' learning needs beyond traditional classrooms. The integration of technology, particularly video recordings, becomes a vital component in meeting these evolving educational demands.

Technological advancements, such as computers with handwriting features, have opened up new possibilities for representing mathematical learning materials in video formats [6]. This aligns with the evolving landscape of mathematics education, where traditional teaching methods are being redefined by innovative technological tools. Moreover, [7] states that students are highly motivated to watch strategic video games, which can be translated into educational videos.

The effectiveness of video recordings in mathematics education is not only acknowledged as a supplement to traditional classroom teaching but also as a standalone tool. The study by Ahillon [8] emphasizes the value of exposing students to diverse video presentations, suggesting that this enhances the learning experience. The process of creating learning videos involves preparation, production, and post-production, as highlighted by Rauf and Fauziah [1]. The study at hand aims to contribute to this body of knowledge by specifically examining the effectiveness of video recordings as a standalone tool, with a focus on reducing physical interactions between students and teachers.

Video recordings have been studied in various educational contexts, for example; the perception of teachers on the effectiveness of video presentation as an alternative to the traditional method of teaching was studied by Parvian et al. [9], who found that the method was effective in terms of usefulness, motivation, performance, and assessment. The study by Naidoo [10] indicates the perception of learners about the use of technology-based tools, specifically video and PowerPoint presentations when learning fractions and found that participants valued the method as it inspired an appealing and fun way of learning fractions. Similarly, [11] explored the students' roles when watching videos.

As noted, none of these studies focuses on the effectiveness of video recordings as measured by students' scores and understanding of mathematical concepts, the current study has attempted to explore this aspect. In particular, the effectiveness of the use of video recording in teaching mathematics relative to other tools employed has been investigated. This includes a comparative analysis with online classes (Zoom) and printable handouts, offering a strong understanding of the role video recordings play in optimizing the learning experience in the absence of traditional face-to-face engagements.

1.1 Theoretical Framework

The study was guided by the Multimedia learning theory that was developed by Richard Mayer in 1997. This is demonstrated in Fig. 1.

The theoretical framework underlying the study aligns with the cognitive perspective, specifically rooted in cognitivism. This theoretical paradigm asserts three fundamental aspects crucial for facilitating effective learning. Firstly, it posits that optimal learning occurs through the integration of images and words, encompassing both auditory and visual elements. This dual modality aims to cater to diverse learning preferences and enhance the overall comprehension of educational content. This aligns with the works of Kanellopoulou and Kermanidis [12] and Ibrahim [13] who emphasize the importance of combining visual and auditory stimuli in the learning process.

The second key aspect of the theory posits that human beings, or learners, have inherent limitations in processing information. This restriction implies that there exists an optimal threshold for the amount of information individuals can effectively absorb and retain. This aspect acknowledges the cognitive load theory, suggesting that learners can only handle a certain level of complexity in instructional materials before their cognitive resources become overwhelmed.

The third aspect of the theory characterizes learning as an active cognitive process involving the intricate tasks of filtering, selecting, organizing, and integrating information. This dynamic engagement with information is influenced by the learner's existing knowledge base. The theory recognizes that learners do not passively absorb information but rather actively participate in the construction of knowledge by connecting new information to their pre-existing understanding of the subject matter.

It is noteworthy that the multimedia learning theory, as described, is a general framework that transcends specific multimedia tools or subject matter. While not tied to particular media or concepts, it acknowledges that different media may yield varied outcomes when applied to diverse subjects. This theoretical flexibility suggests that the effectiveness of multimedia tools may be contingent on the context in which they are employed.

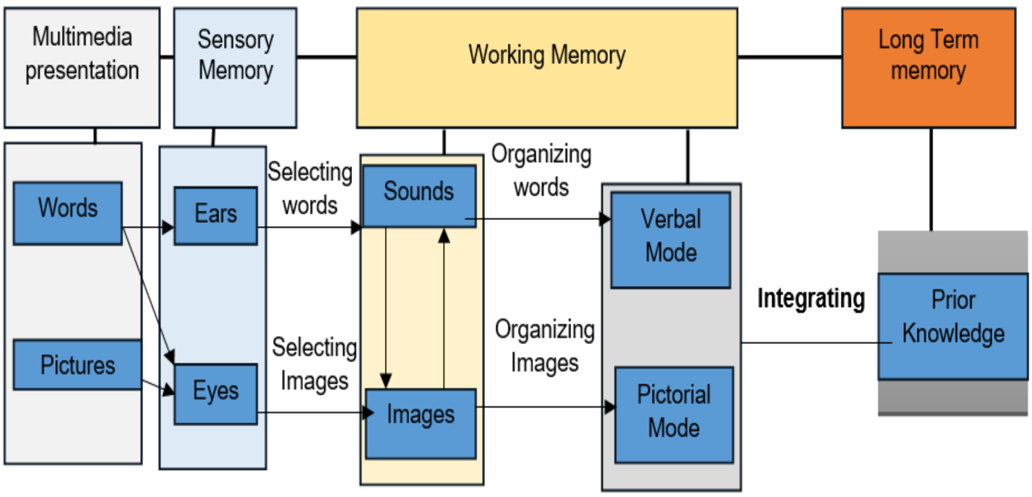

Fig. 1. Multimedia learning theory, (adopted from Mayer, 1997 in [12]

The present study aims to experimentally validate the multimedia learning theory by focusing on the utilization of video recordings as a specific form of multimedia tool in the context of learning mathematics. This approach allows for a targeted exploration of the theory's applicability to the intricacies of mathematical instruction. By examining how video recordings influence learning outcomes in mathematics, the study seeks to contribute empirical evidence to the broader theoretical framework.

In essence, the research endeavors to bridge the theoretical underpinnings of the multimedia learning theory with practical insights derived from the application of video recordings as a multimedia tool in the domain of mathematics education. This empirical investigation not only tests the validity of the theory but also provides important insights into the potential of specific multimedia tools, such as video recordings, in enhancing the learning experience, particularly in a discipline as complex and abstract as mathematics.

1.2 Hypotheses

In the current study, the following hypotheses were tested:

1. There is no significant difference between the mean scores of the V-group and the H-group in the post-test.
2. There is no significant difference between the mean scores of the V-group and the Z-group in the post-test.

2. MATERIALS AND METHODS

The research employed an experimental design, incorporating both pre-test and post-test assessments, to investigate the impact of different instructional tools on students' understanding of the topic of "sequences" in mathematics.

Forty-five pre-service students studying mathematics as a teaching subject at Mountains of the Moon University in Uganda were selected randomly from first and second-year classes. They were equally distributed among three groups: Video recordings (V-group), online (Zoom) mode (Z-group), and self-study materials/handouts (H-group). This random assignment seeks to minimize potential biases, ensuring that any disparities observed in the post-test are linked to the interventions rather than existing group differences [14].

Three experimental units were established, each undergoing teaching via video recordings, online (Zoom) classes, or self-study printable materials/handouts experimental groups (V-group, Z-group, and H-group respectively) by the same instructor respectively. The use of the same instructor for all groups was to ensure consistency in teaching quality and style across the experimental conditions, minimizing potential confounding variables related to instructional delivery.

The study included a control group (H-group) that engaged in self-study using handouts. This allowed for a comparison between the experimental groups (V-group and Z-group) and the control group, helping to assess the relative effectiveness of video recordings and online classes. All participants took lessons from their homes, contributing to ecological validity by reflecting real-world learning conditions during the COVID-19 pandemic. This also aligns with the experimental setup that aims to minimize physical interactions between learners [14].

The topic taught during the experiment is "sequences," and this consistency ensures that the assessment is specific to the content covered. This is essential for drawing meaningful conclusions about the impact of the instructional methods on the targeted subject matter. The choice of sequences in the experimental lessons was motivated by their relevance in higher education mathematics, addressing core principles, and enhancing understanding. This aligns with the Multimedia Learning Theory by Richard Mayer, which emphasizes varied instructional tools, including video recordings, online lessons, and printed handouts, to assess their impact on student comprehension and engagement in a structured framework [12].

The explanation of experiment rules to participants, ensuring that they do not physically interact during the lessons, adds rigor to the experimental design by minimizing potential contamination of results through unintended interactions or collaborations.

The duration of teaching was one week for each learning group, allowing for a focused investigation within a reasonable time frame. This ensures that the study is manageable and practical while still providing meaningful insights into the short-term effects of the interventions.

Both pre-test and post-test assessments were administered as a fundamental aspect of experimental research. The pre-test serves to establish baseline performance, while the post-test allows for the assessment of changes resulting from the interventions. This design helps measure the effectiveness of each instructional method in a controlled manner [15].

Both descriptive and inferential statistics, including group means, standard deviations, correlations, percentage scores, and independent-sample t-tests, were used to demonstrate a comprehensive and rigorous approach to data analysis. This allowed for an understanding of the results and facilitated comparisons between groups.

3. RESULTS AND DISCUSSION

The study aimed to evaluate the effectiveness of using video recordings in the teaching of mathematics in a university in Uganda as an approach that reduces physical student-teacher interactions. The use of video recordings was compared using an experimental design with the other two commonly used approaches; online (Zoom) classes and self-study printable materials/handouts. The pre-test and post-test consisted of 10 questions each from the topic of sequences based on the content and learning outcomes set. The pre-test was administered to 45 mathematics students before they were subjected to learning in three different groups using the three tools. The minimum and maximum scores expected for each learner were 0 and 10 respectively. In this study two main hypotheses; were tested; that is, “There is no significant difference between the mean scores of the V-group and the Z-group in the posttest”, and “There is no significant difference between the mean scores of the V-group and the H-group in the post-test”. With in group analysis was also conducted. The results from both tests are presented and discussed in the subsequent sections.

3.1 Correctly Answered Questions before and After the Intervention

The percentage number of questions answered before and after the intervention is illustrated in Fig. 2.

From Fig. 2, for all three groups of learners, most answered 3-4 questions correctly, and none answered the above 4 questions correctly before the intervention; while after the intervention at least 3 questions were answered correctly for all the students in each group. Most (87%) of the students in the V-group answered 7 questions and above correctly compared to 14% and 27% in the Z-group and H-group respectively. Generally, there was an improvement in the overall number of questions answered correctly after the intervention in all three groups.

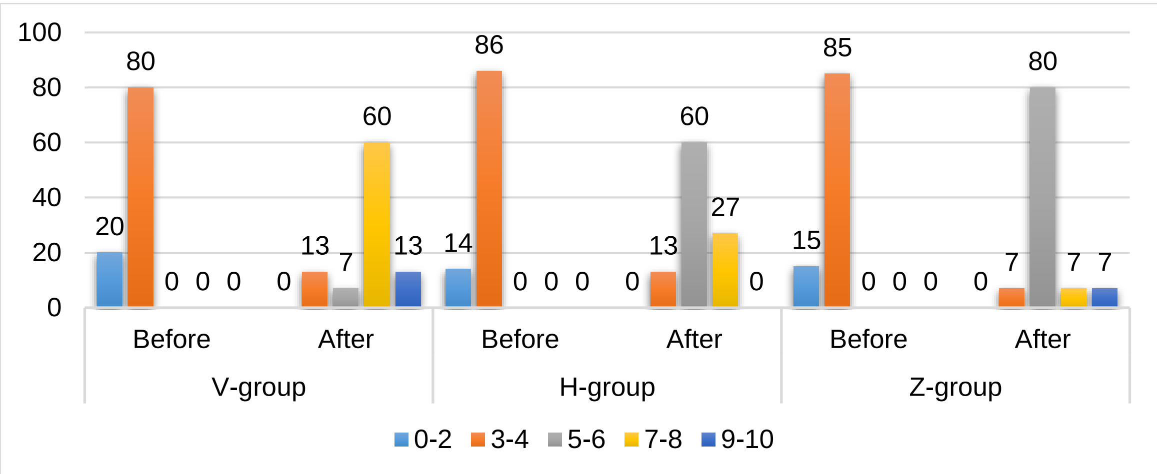

Fig. 2. Percentage of the correctly answered questions

3.2 Students' Scores in the V-Group

Most of the students under the V-group had scores of 3 (46.7%) and 4 (46.7%) while only 6.7% had a score of 2 in the pre-test. While the post-test indicated an improvement with 25.7% scoring 7, 40% scoring 8, 26.7% scoring 9, and 6.7% scoring 10.

The student's scores from the post-test $[N = 15, M = 8.13,\ Sd = 0.92]$ showed a significant improvement as compared to the pre-test scores $[N = 15, M = 3.4, Sd = 0.63]$ within the V-group. This result means that students who learned through video recording showed improved scores after learning. They obtained higher scores in the post-test than the pre-test and this is attributed to the learning that was conducted by the students using video recordings. The results further indicate that the use of video recording can contribute significantly to students' test scores. These results support what was reported by Rauf and Fauziah [1] that video lessons are effective and motivate students to learn.

The post-test scores had a weak relationship with the pre-test scores; $r = 0.395$ and r^2 =0.156. This reveals that the contribution to students' level of knowledge resulting from learning through video recordings has less dependence on the background knowledge of the learners. Learners can use the tool and understand the concepts with little or no prior knowledge. This result further reveals that video recordings are suitable for both introductory and main content lessons.

The mean scores of the pre-test $[M = 3.4, Sd = 0.63]$ and post-test $[M = 8.13, Sd\ 0.92;\ t(28) = -16.475\,, P = 0.001]$ of the V-group indicated a significant difference between the two tests. This implies that the students gained knowledge from the use of the video recording for learning mathematics. Thus, the use of video recording is suitable for learning mathematics. The results are in agreement with what was revealed in the study by Ahillon [8].

3.3 Students' Scores in the H-Group

Similarly, 46.7% of the students under the H-group had a score of 3, 33.3 % had a score of 4, and 20% had a score of 2 in the pre-test. While 33.3%, 26.7%, 33.3%, and 6.7% had scores of 7, 5, 4, and 3 respectively.

The results indicate that students under the H-group (learning using the printable handouts) all scored less than 5 in the pre-test while slight improvement was noted in the post-test with a considerable number of students scoring up to a score of 7. However, no student achieved a score of 8 and above. This means that printable handouts can contribute to students' knowledge when used; however, the contribution to the knowledge is small.

The Pearson correlation between the post-test and pre-test scores of the H-group indicated a moderate relationship with $r = 0.705$ and r^2 =0.459. This relationship means that the post-test results from the H-group can moderately be predicted by the pre-test results; an indication that the knowledge gained through learning using printable handouts depends on learners' previous knowledge. This is partially because the learners under this mode of learning only interact with the handout for all the learning stages; so, their background knowledge is key for effective learning. Also, this result reveals that the tool cannot be used effectively when delivering/learning a new concept, especially at introductory levels of topics where learners need the teacher's input that cannot be conceptualized by the learners on their own.

The post-test scores $[M = 4.8, Sd = 0.99]$ were seemingly better than the pre-test scores $[M = 3.1, Sd = 0.74]$. However, the mean of the post-test was below average; indicating that the tool may require supplements for its betterment. While the independent $t - test$ for comparing the mean scores of the post-test $[M = 4.8, Sd = 0.99]$ and the pre-tests $[M = 3.1, Sd = 0.74]$ revealed a significant difference between the two mean scores of the H-group $[t(28) = 5.42\,, P = 0.001\,]$. This means that the tool employed contributes to learning to some extent, this result is in agreement with the results of Iannone and Miller [16].

3.4 Students' Scores in the Z-Group

The student's scores in the pre-test showed that 20% had a score of 2, 40% had a score of 3, and 40% had a score of 4. While in the post-test, 6.7% had a score of 4, 20% had a score of 5, 46.7% had a score of 6, and 26.7% had a score of 7. All students scored less than a score of 5 on the pre-test. While students' scores improved slightly during the post-test with the majority scoring 6 and 7. This indicates that online (Zoom) classes conducted contributed to the student's scores. This is further supported by the mean scores from the pre-test $[N = 15, M = 3.2, Sd = 0.77]$ and the post-test $[N = 15, M = 5.9, Sd = 0.88]$.

The post-test scores had a moderate relationship with the pre-test scores in the Z-group with $r = 0.647$ and $r^2 = 0.419$. This shows the student's understanding of the concepts using online (Zoom) classes depends on their background knowledge. This is partially because the effectiveness of online (Zoom) classes entirely depends on the existence of stable and faster internet which is still a problem in Ugandan universities. Thus, learning online (Zoom) requires students to have a basic level of knowledge of the concepts taught since online (Zoom) classes turn up being too summarized for learners to get the details of the lesson.

The t-test between the pre-test and post-test of the z-group indicated a significant difference between the mean scores of the pre-test $[M = 3.2, Sd = 0.77]$ and post-test $[M = 5.9, Sd = 0.88]$ $[t(28) = -9.008, P = 0.001]$. This shows that the scores of the pre-test and post-test were not the same. So, online (Zoom) classes contributed to a change in the knowledge accumulation of learners under this kind of learning.

3.5 Comparing Scores of the V-Group & H-Group, and the V-Group & Z-Group

The purpose of the pre-test was to measure the baseline scores of students in all three groups to show the starting point for measuring the effect of the different learning tools on students' scores and knowledge acquisition. The scores of the pre-test in all three groups were found to be in the same range. There was no significant difference in the mean scores of the pre-test between V-group $[N = 15, M = 3.4, Sd = 0.63]$ and H-group $[M = 3.1, Sd = 0.74; t(28) = 1.058, P = 0.299]$ and V-group $[N = 15, M = 3.4, Sd = 0.63]$ and Z-group $[N = 15, M = 3.2, Sd = 0.77; t(28) = 0.775, P = 0.445]$.

This result indicates that the pre-test results meet the principles for baseline as base values of the experiment to measure the relative contribution of the three different approaches of learning in the three learning groups. This is not the main result of the study but a point of interest and assurance for the validity of the main results.

To answer the aim of the current study, two hypotheses were set and tested; there is no significant difference between the mean scores of the V-group and the H-group in the post-test, and there is no significant difference between the mean scores of the V-group and Z-group in the post-test. These are tested in the subsequent sections.

3.6 Significance Test for the Difference in the Mean Scores of the V-Group and H-Group in the Post-Test

To test the first hypothesis "there is no significant difference between the mean scores of the V-group and the H-group in the post-test", a t-test was conducted and the results are illustrated in Table 1.

An independent sample t-test was conducted to compare the mean scores of the post-test in the V-group and H-group. The results indicate that there is considerable evidence for rejecting the null hypothesis, with this, therefore, a significant difference exists in the mean scores of the post-test between the V-group $[M = 8.13, Sd = 092]$ and the H-group $[M = 4.9, Sd = 0.99; t(28) = 9.38, P = 0.001]$.

These results indicate that the scores of the students who were subject to learning through the V-groups are different from the mean scores of their classmates in the H-group who learned through the printable handouts. There is a positive mean difference of 3.267 which indicates that the scores of the learners in the V-group were better than the scores of the learners in the H-group by an average of the mean difference. In this regard, the study points out that the students in the V-groups were exposed to an effective tool of learning relative to those in the H-group.

3.7 Significance Test for the Difference between the V-Group's and Z-Group's Mean Scores in the Post-Test

Similarly, to test the second hypothesis "there is no significant difference between the mean scores of the V-group and the Z-group in the post-test", a t-test was conducted and the results are illustrated in Table 2.

The study conducted a two-sample t-test to compare the mean scores of the pre-test between the V-group and Z-group. The analysis yielded compelling evidence to reject the null hypothesis, indicating a significant difference in the mean scores of the post-test between the

Table 1. Showing the independent sample t-test results for V-group and H-group in the post-test

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Comparing means of V_H-group	Equal variances assumed	0.367	0.55	9.38	28	0	3.2667	0.3482	2.5533	3.98
	Equal variances not assumed			9.38	27.83	0	3.2667	0.3482	2.5531	3.98

Table 2 .Showing the independent sample t-test results for the V-group and Z-group in the post-test

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Comparing means of V_Z-groups	Equal variances assumed	0.148	0.7	6.7	28	0.00	2.2	0.32854	1.52702	2.873
	Equal variances not assumed			6.7	27.97	0.00	2.2	0.32854	1.52698	2.873

V-group $(M = 8.13, SD = 0.92)$ and the Z-group $(M = 5.9, SD = 0.88;\ t(28) = 6.7, P = 0.001$. These results suggest a noteworthy distinction in the post-test outcomes between the two groups, highlighting the impact of the instructional interventions on the participants' performance.

The analysis indicates a notable difference in scores between the students in the V-groups and the mean scores of those in the H-group. The positive mean difference of 2.2 suggests that learners in the V-group outperformed those in the Z-group. This implies that the learning tool employed by the V-group students is superior to the one utilized by the Z-group, providing insight into the effectiveness of the instructional methods and highlighting the potential advantages of the approach used in the V-group for learning mathematics. As highlighted by Parvian et al. [9], the use of video recording in teaching was found effective in terms of motivation, performance, and assessment.

In summary, the findings align with and find support in the research of other scholars, including [7,9, 11,17–22]. This consistency across various studies enhances credibility and underscores the reliability of the observed outcomes within the wider scholarly discussion. Also, in line with this finding, Khanal et al. [23] noted that the online mode of teaching mathematics is characterized by numerous challenges that affect its effectiveness such as internet accessibility and affordability by learners and instructors.

4. CONCLUSION

This study set out to assess the effectiveness of video recordings as a teaching tool in university-level mathematics education, specifically aiming to reduce student-teacher interaction, a need accentuated by the challenges posed by the COVID-19 pandemic. The findings of the study have yielded valuable insights into the effectiveness of various instructional tools.

The study acknowledges that all three tools play a role in supporting mathematics knowledge acquisition, albeit to varying degrees. Online (Zoom) classes and printable handouts are deemed relevant, but their contribution is described as mild in comparison to the substantial impact attributed to video recordings. This suggests that while online classes and handouts have their place in the educational landscape, the use of video recordings emerges as a more potent and impactful method.

The substantial contribution of video recordings to learner scores and knowledge acquisition signifies their effectiveness in delivering mathematical content. Importantly, the study underscores the versatility of video recordings, asserting their suitability for use across all stages of learning, including introductory sessions. This stands in contrast to the limitations identified for printable handouts at the introductory level, where direct teacher input is deemed crucial.

The study draws attention to the practical challenges associated with online (Zoom) classes, specifically highlighting the impact of internet accessibility on student interactions with both instructors and content. This observation points to a potential limitation of online platforms in certain educational contexts, raising concerns about equitable access to education when relying solely on such tools.

In summary, the research findings suggest that, while all three instructional tools contribute to mathematics education, video recordings emerge as the most effective means for facilitating learning in a university setting, particularly during a period marked by the demands of the COVID-19 pandemic. The study's insights provide valuable considerations for educators, institutions, and policymakers seeking to optimize distance learning strategies in the field of mathematics, emphasizing the pivotal role that video recordings can play in enhancing both accessibility and effectiveness across various learning levels.

5. RECOMMENDATIONS

The study recommends that mathematics instructors at the university prioritize the use of video recording in teaching and learning mathematics where it is not possible for the teachers to physically interact with learners. Further research should be conducted to seek learners' opinions on the use of these tools in learning to generate qualitative insights into the tools. The university's readiness in terms of infrastructure to use the suggested tool is another area of research.

6. STRENGTH AND LIMITATIONS OF THE STUDY

The strength of this study is in its rigorous methodology, clear objective, and conclusive findings. Using an experimental design with a substantial student sample, it compares video recordings with online classes and self-study materials. The statistical analysis, including SPSS and various tests, adds credibility. Conclusively, the study recommends incorporating video recordings in mathematics teaching, emphasizing their superiority in enhancing understanding. The combination of a well-defined purpose, methodological robustness, and practical recommendations enhances the overall strength of the research.

The study's limitations include the necessity to thoroughly examine drawbacks associated with video recordings, address generalizability by considering diverse institutions, and incorporate qualitative insights alongside the heavy reliance on quantitative data.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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