THE INFLUENCE OF INTERACTIVE MULTIMEDIA TOOLS ON MATHEMATICAL ACHIEVEMENTS AND CONCEPTUAL UNDERSTANDING IN PRIMARY EDUCATION

Sher Alam Khan[1], Giorgio Poletti[2], Mazhar Alam[3], Farooq Nawaz Khan[4], Iram Naeem[5]

[1]University of Ferrara and University of Modena Reggio Emilia, Italy. [0009-0002-7184-1635]
[2]University of Ferrara, Italy. [0000-0002-7270-6083]
[3]University of Swat, Pakistan. [0009-0006-7478-1358]
[4]University of Swat, Pakistan. [0009-0006-7738-7225].
[5]Punjab School Education Department.

Sher.khan@unimore.it[1]
giorgio.poletti@unife.it[2]
mazharalam1374@gmail.com[3]
farooq@uswat.edu.pk[4]
irumnaeem44@gmail.com[5]

Corresponding author (sher.khan@unimore.it)

Abstract: In the context of rapid technological advancements and their influence on education, this study investigated the effects of digital technologies on the development of mathematical knowledge in primary education within Pakistani context. To compare the effects of traditional versus digital-based instruction on mathematical achievement, 76 fourth-grade students from a primary school in Khyber Pakhtunkhwa, Pakistan, were divided into two groups: control and experimental. The study employed a quasi-experimental research design. The experimental group was taught using digital-based instruction, while the control group received traditional teaching methods. The Mathematics Achievement Test (MAT) was administered to assess students' academic performance, and the results were analysed using independent samples *t*-tests, ANOVA and MANOVA. The findings indicates that digitized instruction enhances problem-solving skills, engagement, and conceptual understanding, while accommodating diverse learning styles. Furthermore, it promotes critical thinking, and prepares students for future technological advancements, making learning both applicable and meaningful.

KEYWORDS. Traditional instruction; Digital-Based Instruction; Mathematics Achievements; Primary school.

Introduction

Mathematics is mostly considered one of the core subjects in school curriculum. In the present quantitatively complex society, an individual needs a functional knowledge of mathematical content to make informed decisions as a citizen and as a worker [1]. However, researchers and theorist have argued that mathematics in schools is often taught in a motorized manner emphasizing on rote memorization rather than conceptual understanding [2]. As a result, many high school students face challenges comprehending mathematical concepts [3]. Resultantly, enhancing students' mathematical abilities remains one of the major challenges faced by the mathematics teachers [4]. Since educational technology is developing rapidly, numerous studies have proposed that incorporating technology into the mathematics curriculum has a positive impact on students learning conceptual understanding [5; 6]. Practitioners and researchers have researched and identified alternative teaching methodologies and strategies in order to motivate and engage students in the learning process. These developments have transformed the ways in which students acquire knowledge, access to information, collaborate with peers and teachers, and remained motivated in their studies. As reported by [7] digital technologies can be used to enhance student engagement and motivation, personalize learning, and make teaching more effective. Educational uses of digital technologies include the use of devices such as computers and tablets, as well as smartphones, for learning purposes. The integration of these tools enhances students' learning outcomes by providing access to diverse learning materials and fostering teacher-student collaborations, and personalizing the learning experience [8]. Researchers found that digitized instructions can create impactful learning experiences by providing learners with access to diverse digital resources, including text, videos, interactive activities, and virtual environments. It enables learners to engage through experimentation, exploration, and collaboration. Additionally, digital technologies can enhance assessment practices by offering learners more meaningful and personalized feedback [9]. Research indicates that digital technologies can enhance student engagement and improve educational outcomes. For instance, [10] found that integrating digital tools into classrooms instruction increased student engagement, heightened motivation, and improved academic achievement. Furthermore, digital technologies facilitate personalized learning opportunities. Moreover, [11] found that students who engaged in customized digital learning demonstrated improved learning outcomes. Overall, digital technology is assuming an increasing significance in education, as it can enhance students' engagement, and motivation, personalize learning experiences, and improve teaching effectiveness. According to [12] using digital tools in education expands learning beyond the classroom, offering students more opportunities for engagement and assistance. Further the study highlights that technology enables educators to utilize adaptive learning tools to customize teaching for individual student needs, offering instant feedback and support. Furthermore, she underscores technology's role in fostering inclusivity by enabling differentiated instruction and providing access to resources not typically available in traditional classrooms. Additionally, [13] defines digital technology in education as the application of digital tools to enrich and extend teaching, learning, and assessment. Similarly, digital based interventions can change education by making learning more interesting and interactive. It also gives access to a wide range of resources and materials [14]. Mathematics teachers throughout the world employed a range of instructional tactics to make mathematics more productive and enjoyable in basic education. As a result, digitized instructional interventions have been found to boost student learning in mathematics by increasing access to educational resources, improving cooperation, and permitting tailored instruction. Digital-Based Interventions and tools are becoming more vital in education, especially in teaching mathematics. These tools and technologies provide students with new and improved learning chances and enable them to interact with mathematics in a more dynamic and captivating manner. Studies have shown that digital based interventions can enhance students' grasp of mathematics, especially in primary education [15; 16; 17]. Furthermore, digital-Based instructions can give students with visual representations of mathematical concepts, allowing them to explore and experiment with new concepts in such a way that traditional teaching techniques cannot offer. Furthermore, digital technology can provide students with more individualized educational adventures and enable teachers to tailor their instruction to each student's unique needs and priority [18]. According to the study conducted by the Organization for Economic Cooperation and Development (OECD), "students who regularly use digital tools and technologies for schoolwork score higher in mathematics than those who do not" [19]. Additionally, research by the National Education Association (NEA) found that "students who engage in mathematics activities on computers score higher on standardized tests than those who do not" [20]. Digital-based Instruction also assist bridge the mathematical achievement gap between kids from various backgrounds. For example, the National Center for Education Statistics discovered that "students who used computers for mathematics scored significantly higher than those who did not" [21]. Additionally, the American Educational Research Association (AERA) found that digital tools can assist children learn mathematics more successfully by delivering visual, interactive, and individualized training [22]. Several researchers have studied the impact of digital technology on primary mathematics education. For instance, [23] found that using digital tools and interventions can boost student engagement and enhance performance in mathematics classes, improving the logical thinking and cognitive abilities of young learners. Likewise, research by [24] revealed that utilizing digital-base instructions enhanced student engagement, motivation, and fun for learning mathematics. Furthermore, research by [25] indicated that employing digital technology enhanced student learning in mathematics, proving especially advantageous for students with learning disabilities. These findings highlight the potential of digital technology in advancing mathematics education at the primary level.

Based on this context, our research focused on how technology influences primary school students' mathematical achievement and conceptual understanding. This study will explore the following research questions: 1) What is the effect of digital-base instruction on the mathematical achievement of primary school students. 2) How digital-base instruction can enhance students' mathematical conceptual understanding. Prior to outline the methodology, the authors reviewed the literature on conceptual mathematics comprehension and the cognitive theory of multimedia learning (CTML) as a learning framework.

Theoretical Background

In mathematics, the development of conceptual understanding is essential because it helps foster critical thinking, problem-solving skills, and other mathematical competencies required in the workforce. To enhance the quality of mathematics education, researchers and practitioners worldwide have increasingly focused on strengthening students' conceptual understanding. Some of these studies examine the use of technology in mathematics education [26, 27, 28, 29, 30], while others explore alternative instructional approaches [31]. For example, a study conducted by [32] found that developing students' conceptual understanding technology play a vital role. Similarly, [27] suggest mathematics teachers should integrate technology into mathematics instruction to engage students in more interactive meaningful learning and to provide a technology-based learning environment.

According to [33] describe multimedia as computer-based software that combines text, color, graphical visuals, animation, auditory sound, and full-motion video in a single package. [34a, 34b]. [35] defines CTML as learning process that includes both visual and auditory messages. In the same line, [36] "identified three principles of Cognitive Theory of Multimedia Learning (CMTL) that impact learning outcome. First, the limited capacity learning state that the that learners' working memory can process only a limited amount of information at a time. Second, the dual-channel principle suggests that learners process information through separate verbal and visual channels. Third, the active processing principle asserts that meaningful learning occurs when learners engage in cognitive processes such as attention, organization, and integration with prior knowledge. Multimedia learning environments present information in either static formats (e.g., text and images) or dynamic formats (e.g., animations), which must be designed to support these cognitive processes effectively". According to [37] CTML is appears to be an effective ICT-based learning theory that can support students in learning through instructional multimedia [35b]. In classroom settings, CTML is learner-centered approach that encourages meaningful and active learning experiences, which can be measured through student performance on assignments or assessments.

2. Research Methodology

The study aimed to explore how digital-base instruction enhance mathematics learning among primary school students. The duration of the study was nine (6) weeks (May & June-2025). A total of 76 grade 4th students (57 male and 19 female) participated in this study. All students were of different ages, ranging from 9 to 10 years old, and belongs to various family backgrounds.

The study employed an experimental research design to investigate the influence of digital technology on mathematics learning. Two groups were established: a control group and experimental group. The research was conducted by the principal author in a collaboration with two volunteer mathematics teachers from the selected sample school. Permission to conduct the study was obtained from the District Education Officer of District Shangla and from the students' parents.

Mathematics Achievement Test (MAT) was developed to assess students' understanding of selected topics and was aligned with Grade 4 Mathematics textbook prescribed by the Khyber Pakhtunkhwa curriculum. The test consisted of 35 questions: 13 multiple-choice questions (MCQs) on Least Common Multiple (LCM), 12 on Highest Common Factor (HCF), and 10 from Fractions. The MAT was validated by mathematics expert and teachers from two other schools.

The researcher explained the study's objectives and course content to both students and teachers in detail. Before the intervention, a pre-test was administered to assess students' achievements level. Based on the pre-test results, the students were equally divided into two groups. Both the control and experimental groups received separate instructions. The experimental group was taught by a mathematics teacher using digital-base instruction, while the control group was taught using traditional teaching methods. Although, a total of 76 students initially enrolled in this study, only 70 students participated in this intervention. Of these, 35 were in the experimental group and 35 was in the control group. The remaining 6 students did not participate in this experiment due to various reason.

3. Results and Analysis

Table 1 presents the results of independent sample t-test that was applied on students Mathematical Achievements Test (MAT). The aim of this test was to compare the score of both groups control and experimental on pre-test. The results indicates that there is no significant difference in score between control (M = 8.46, SD = 3.35) and the experimental group (M = 8.40, SD = 3.33); t (68) = 0.07, p = .943. Levene's test indicated that the assumption of equal variances was satisfied, as the result was not significant (F = 0.00, p = .997). The 95% confidence interval for the difference [-1.54, 1.65] included zero, and the mean difference between groups was minimal (0.06), suggesting that both groups were similar and equally distributed before the intervention.

Table 1. *Results of independent samples t-test of participants for different achievements level*

Groups	N	MS	SD	df	t	Sig
Control Group	35	8.4571	3.354	68	0.72	.943
Experimental Group	35	8.4000	3.327	67.99	0.72	.943

Before applying ANCOVA, Levene's test of homogeneity of variance was conducted. Since $p = .986 > .05$, the assumption of homogeneity of variances was satisfied, indicating that the group variances were equal enough to proceed with ANCOVA. Table 2 presents the results of the analysis of covariance (ANCOVA) for students' MAT test scores between the control and experimental groups. The results indicate a statistically significant difference between the two groups, $F(1, 67) = 22.13$, $p < .001$, partial $\eta^2 = .25$, which represents a large effect size [26]. Furthermore, as shown in Table 2, the experimental group ($M = 12.31$, $SE = 0.29$) outperformed the control group ($M = 10.41$, $SE = 0.29$), indicating that the treatment enhanced performance. This suggests that students in the experimental group performed better than those in the control group.

Table 2. Analysis of co-variance for MAT scores

Source	SS	df	MS	F	Sig.	Partial Eta Squared	Observed Power^b
Pretest	531.437	1	531.437	185.182	.000	.734	1.000
Group	63.500	1	63.500	22.127	.000	.248	.997
Error	192.277	67	2.870				

R Squared = .755 (Adjusted R Squared = .747)

Table 3 shows the results of independent sample t-test of pre-test between two groups based on achievements level, the mean score of 8.4571 with a standard deviation of 3.35492 on the pre-test and 8.4000 with a standard deviation of 3.32705 on the post-test indicates that the mean score of both groups was very close to each other, so before the intervention there was no statistically significant difference between the two groups.

Table 3. Independent sample t-test of pre-test between two groups based on achievements

Test	Group	Mean	SD	MD	Df	t	Sig
Pre-Test	Control	8.4571	3.35492	.05714	68	0.72	.000
Pre-Test	Experimental	8.4000	3.32725				

Table 4 presents the results of independent sample t-test of post-test between two groups based on achievements level.The results clearly indicates that in the control group the (*M*=10.4286, *SD*=3.59154) and in the experimenal group (*M*=12.2857, *SD*=2.89595), there is statistically significant differnece between the mean score of both groups, as evident in a means difference -1.85714. The results indicate that the students in the experminal group performed better as compare to the tradatioanl method. This statistically significant difference suggest that digital-base instruction or multimedia teaching enhance students mathematical performance.

Table 4. Independent sample t-test of post-test between two groups based on achievements

Test	Group	Mean	SD	MD	df	t	Sig
Post-Test	Control	10.4286	3.59154	-1.85714	67	-2.381	.341
Post-Test	Experimental	12.2857	2.89595				

Table 5 demonstrates descriptive statistics and univariate ANOVA results for test scores by group. The analysis indicates, that prior intervention, there was no statistically significant difference between the control groups (*M*= 8.45, *SD* =3.35) and the experimental group (*M*=8.40, *SD*= 3.32) on the pre-test scores, F (1,68) = 0.02, p = .90, η^2 = .001.
In contrast, post-test results revealed statisticaly significant difference between the groups $F(1,68) = 20.52$, $p < .001$, $\eta^2 = .232$, indicating that the expermintal group performed better as shown in thier (M = 12.29, SD = 2.90) as compared to the control group (M = 10.43, SD = 3.59).
These findings suggest that students in the experimental group demonstrated significantly greater improvement than those in the control group, who were taught using traditional methods.

Table 5. Descriptive Statistics and Univariate ANOVA Results for Test Scores by Groups

Variable	Group	N	M	SD	F	P	Partial η^2
	Control		8.45	3.35			
Pre-Test		35			≈ 0.02	.900	.001

	Experimental		8.40	3.32			
Post-Test	Control	35	10.42	3.59	20.52	.000	.232
	Experimental		12.28	2.89			
MANOVA (effect of time)	Wilks' Λ= .261	F (1, 68) =192.10	p.900	Partial η^2= .739			
MANOVA (time and group effect)	Wilks' Λ = .768	F(1, 68) = 20.52,	$p < .001$	η^2 = .232			

4. Discussion

The aim of the study was to compare the effects of traditional and digital-based instruction on the mathematical achievements of Grade 4 students. The main findings revealed that students who received mathematics lessons through digital-based instruction showed significantly greater improvement in mathematical achievements and enhanced their capacity in STEM related learning compared to those taught in the traditional method. Furthermore, students who learned mathematics using digitally base instruction demonstrated notable gains in knowledge and comprehension skills relative to those instructed through conventional teaching methods. The results also indicated a statistically significant difference between the control and experimental groups. These findings suggest that incorporating digital tools into mathematics instruction can provide a more effective and engaging learning experience for students. Previous studies [9; 10; 11] have also provided the same findings.

The analysis indicated that employing digitally based instruction to teach mathematics to young learners is highly effective strategy. Moreover, the use of digital-based instruction in education is rapidly expanding, particularly in the teaching of mathematics, making learning environments more interactive and engaging, while offering students enriched and meaningful learning experiences. The findings of this study are consistent with those reported by [3].

The findings also revealed that advanced digital tools and interactive platforms provide a dynamic and stimulating environment that captures students' interest and promotes active engagement. By incorporating multimedia resources, adaptive learning technologies, and collaborative online activities, digital-base instruction helps students' to developed deeper understanding of mathematical concepts, and enhance long -term retention. Similar findings were reported in the study of [6]. The results indicate that integration of digital tools and technology in education is invaluable. It provides students with numerous opportunities for engagement and support, extending learning far beyond what is taught in the classroom. Digitally-base instructions also give teachers the ability to design inclusive learning environment and deliver resources and instruction tailored to each student's needs. Thus, digital technology has the potential to transform education by enabling interactive learning and facilitating easy access to a wealth of resources and materials. These findings are consistent with those reported by [8].

The statistical analysis indicates that digitally-base instruction provides students with visual representations of mathematical ideas, enabling them to learn in diverse ways. These visual

representations motivate students to explore and comprehend mathematical concepts in ways that traditional teaching tactics could not achieve. Furthermore, digitally-based instructions empower teachers to customize their teaching to meet the specific needs of individual students, offering a more personalized learning experience. These findings are aligned with [12].
The study also found that students who used digital technology in mathematics sessions were more engaged and performed better, which improved their analytical and cognitive skills. Digital technology improved student engagement, motivation, and learning in mathematics. Similar findings were reported in the studies of [7,18,19,].

5. Conclusion

The study findings indicate that the impact of emerging digital technology and digital base instruction on mathematical achievements surpasses that of traditional teaching methods. The results suggests that digital technology serves as a powerful tool for improving mathematical performance among primary school students. However, it's crucial to integrate this technology into comprehensive teaching approaches to ensure students receive relevant and effective educational experiences. Further research is necessary to evaluate the effectiveness of specific digital technologies and to determine optimal strategies for leveraging them to enhance learning outcomes. Moreover, digital base instruction facilitates interactive learning experiences that engage students and promote active participation in mathematical concepts. By providing access to diverse educational resources and fostering collaboration among peers, digital tools enrich the learning environment and accommodate to individual learning styles. It is essential for educators to continually adapt their teaching methods to incorporate innovative digital technologies that align with educational goals and enhance overall student learning outcomes.

Author contributions

For this research article, the authors contributed in the following ways: the conceptualization was carried out by Giorgio Poletti and Sher Alam Khan, while the methodology was developed by Sher Alam Khan, Mazhar Alam, and Farooq Nawaz Khan. The analysis was conducted by Sher Alam Khan and Mazhar Alam, and the validation was performed by Farooq Nawaz Khan together with Giorgio Poletti. The investigation was undertaken by Sher Alam Khan, Mazhar Alam, and Farooq Nawaz Khan. The original draft was prepared by Sher Alam Khan, and the review and editing were completed by Giorgio Poletti, and Farooq Nawaz Khan, the overall supervision was provided by Giorgio Poletti.

References

[1] Wilkins, J. L. M., & Ma, X. (2003). Modeling change in student attitude toward and beliefs about mathematics. The Journal of Educational Research, 97(1), 52-63. doi:10.1080/00220670309596628
[2] Rajghatta, C. (2014). Math teaching in India is robotic, make it creative: Manjul Bhargava. The Times of India, 26(1), 5-17.
[3] Offer, J., & Bos, B. (2009). The Design and application of technology-based courses in the mathematics classroom. Computers & Education, 53(4), 1133-1137. doi:10.1016/j.compedu.2009.05.020

[4] Tan, C.-K., & Tan, C.-P. (2015). Effects of the handheld technology instructional approach on performances of students of different achievement levels. Computers & Education, 82, 306-314. doi:10.1016/j.compedu.2014.11.011
[5] Lazakidou, G., & Retalis, S. (2010). Using computer supported collaborative learning strategies for helping students acquire self-regulated problem-solving skills in mathematics. Computers & Education, 54(1), 3-13.
[6] Grouws, D. (Ed.). (2006). Handbook of research on mathematics teaching and learning:(A project of the national council of teachers of mathematics). IAP.
[7] OECD. (2020). Harnessing digital technology to enhance learning. Retrieved from https://www.oecd.org/education/Harnessing -Digital-Technology-to-Enhance- Learning.pdf
[8] Fischer, F., & Loveless, A. (2016). Digital tools for learning: What works and why? Educational Leadership, 73(5), 12-17.
[9] Khan, S. A., Poletti, G., Alam, M., Khan, F. N., & Hussain, S. (2025). The Effect of Flipped Classroom Instruction on Primary Students' Science Achievement: An Experimental Study. Contemporary Journal of Social Science Review, 3(3), 189-197. DOI: https://doi.org/10.63878/cjssr.v3i3.943
[10] Schmidt, J. R., Stein, A., Dale, B., & Georghiou, L. (2020). Digital technologies in the classroom: Student engagement and motivation. Digital Education Review, 34, 1- 15
[11] Zollman, A. & Miller, J. (2016). The impact of personalized digital learning on student outcomes: A meta-analysis. Journal of Educational Computing Research, 54(3), 349-367.
[12] Dickson-Deane, C. (2021). Moving practical learning online. Educational Technology Research and Development, 69, 235-237.
[13] Khan, S. A., Poletti, G., & Khan, F. N. (2025). From Chalkboards to Digital Screens: How Classroom Technology Influences Student Academic Behavior, Engagement and Motivation. Formazione & insegnamento, 23(2), 1-xx. DOI: https://doi.org/10.7346/-fei-XXIII-02-25_12
[14] Kumar, A., Sood, S., & Sood, S. (2016). Digital technology in education: A review. International Journal of Educational Research, 75, 91-98.
[15] Kafai, Y.B. (2009) 'Learning mathematics through design-based learning: exploring the notion of mathematical knowledge for design', International Journal of Computers for Mathematical Learning, 14(2), pp. 109-128.
[16] Kalyuga, S. (2011) 'Expertise reversal effect', Educational Psychology Review, 23(1), pp. 507–5
[17] Shanahan, T. (2016) 'Mathematics and technology: understanding the impact of the digital age', Mathematics Teaching in the Middle School, 21(8), pp. 462-468.
[18] Korat, O. and Tatar, O. (2018) 'Learning mathematics with digital technologies: effects of digital technologies on students' mathematical learning', International Journal of Technology Enhanced Learning, 10(2), pp. 181-196. 31.
[19] OECD. (2016). The Impact of Digital Technology on Student Learning. Organization for Economic Cooperation and Development. Retrieved from https://www.oecd.org/education/ceri/digital -technology-and-student-learning.pdf
[20] NEA. (2019). Using Technology to Support Mathematics Learning. National Education Association. Retrieved from https://www.nea.org/assets/docs/HE/Technology_Mathematics_Learning.pdf

[21] NCES. (2019). Computer and Internet Use in the United States: 2015. National Center for Education Statistics. Retrieved from https://nces.ed.gov/pubs2017/2017015.pdf

[22] AERA. (2021). Using Technology to Improve Mathematics Learning. American Educational Research Association. Retrieved from https://www.aera.net/Publications/Using-Technology-to-Improve-Mathematics- Learning.

[23] Ozkan, S., Duran, F., & Yildirim, A. (2017). Examining the effects of a digital game-based learning environment on mathematics achievement. Computers & Education, 110, 120-133.

[24] Hwang, Y.-C., Chiang, Y.-T., & Lee, M.-H. (2019). The effects of digital technology on mathematics learning: A meta-analysis. Computers & Education, 133, 25-45.

[25] Leong, Y. H., Yap, W. K., & Looi, C. K. (2020). The impact of digital technology on mathematics learning among students with learning disabilities. Computers & Education, 144, 103377.

[26] Amit, A., & Amia, A. (2020). Case-based games learning strategies to improve conceptual understanding in mathematics. Journal of Physics: Conference Series, 1663, Article 012060. https://doi.org/10.1088/1742-6596/1663/1/012060

[27] Mendezabal, M. J. N., & Tindowen, D. J. (2018). Improving students' attitude, conceptual understanding and procedural skills in differential calculus through microsoft mathematics. Journal of Technology and Science Education, 8(4), 385– 397. https://doi.org/10.3926/jotse.356

[28] Mlotshwa, N., & Tunjera, N., & Chigona, A. (2020). Integration of MOODLE into the classroom for better conceptual understanding of functions in mathematics. South African Journal of Education, 40(3), 1–14. https://doi.org/10.15700/10.15700/saje.v40n3a1570

[29] Psycharis, S., Chalatzoglidis, G., & Kalogiannakis, M. (2013). Moodle as a learning environment in promoting conceptual understanding for secondary school students. Eurasia Journal of Mathematics, Science & Technology Education, 9(1), 11–21. https://doi.org/10.12973/eurasia.2013.912a

[30] Zulnaidi, H., & Syed Zamri, S. N. A. (2017). The effectiveness of the GeoGebra software: The intermediary role of procedural knowledge on students' conceptual knowledge and their achievement in mathematics. Eurasia Journal of Mathematics, Science and Technology Education, 13(6), 2155-2180. https://doi.org/10.12973/eurasia.2017.01219a

[31] Dwyer, L. M. O., Wang, Y., & Shields, K. A. (2015). Teaching for conceptual understanding : A cross-national comparison of the relationship between teachers' instructional practices and student achievement in mathematics. Large-Scale Assessments in Education, 3, Article 1. https://doi.org/10.1186/s40536-014-0011-6

[32] Haji, S., & Yumiati.(2019). NCTM's principles and standards for developing conceptual understanding in mathematics, 1(2), 52–60. https://doi.org/10.32734/jormtt.v1i2.2836

[33] GebreYohannes, H. M., Hadi Bhatti, A., & Hasan, R. (2016). Impact of multimedia in teaching mathematics. International Journal of Mathematics Trends and Technology, 39(1), 80–83. https://doi.org/10.14445/22315373/ijmtt-v39p510

[34a] Mayer, R. E. (2014a). Incorporating motivation into multimedia learning. Learning and Instruction, 29, 171–173. https://doi.org/10.1016/j.learninstruc.2013.04.003

[34b] Mayer, R. E. (2014b). Cognitive theory of multimedia learning. In R. Mayer (Ed.), The Cambridge handbook of multimedia learning (pp. 43-71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005

[35] Sorden, S. D. (2012). The cognitive theory of multimedia learning. In B. J. Irby (Ed.), Handbook of educational theories (pp. 155- 168). Information Age Pub.
[36] Mayer, R. E., & Moreno, R. (1998). A cognitive theory of multimedia learning: Implications for design principles. Journal of Educational Psychology, 91(2), 358-368. https://bit.ly/3YOoP3G
[37] Soewardini, H. M. D., Meilantifa, M., & Sukrisno, H. (2018). Multimedia learning to overcome anxiety and mathematics difficulty. IOP Conference Series: Materials Science and Engineering, 434, Article 012002. https://doi.org/10.1088/1757-899X/434/1/012002