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RESEARCH ARTICLE

Experiences on Developing Conceptual Understanding of 3D Shapes through Audio-Visual Aids

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Abstract: Conventional lecture-based methods have often led to student disengagement and superficial learning in mathematics in Nepal. This study examines the experiences of Grade X students and teachers in developing a conceptual understanding of 3D shapes through the use of audio-visual aids (AVAs) within mobile learning frameworks. Employing a qualitative narrative inquiry design, the researchers collected data from February to July 2024 through in-depth interviews with two secondary-level mathematics teachers and two students. Thematic analysis of the narratives reveals that AVAs-such as YouTube, GeoGebra, and Khan Academy-meaningfully enhance student engagement, foster deeper conceptual understanding, and bridge the gap between abstract mathematical concepts and real-life scenarios. The findings indicate that these tools promote active participation, collaborative learning, and deeper conceptual grasp by making mathematical ideas more tangible and accessible. The study concludes that the strategic integration of audio-visual resources can transform mathematics teaching and learning. It recommends that educational policy-makers and school administrators prioritize equipping classrooms with appropriate technological tools and providing targeted teacher training to ensure effective implementation, thereby improving mathematics learning outcomes.

Keywords: audio-visual aids, conceptual understanding, 3D shapes, mathematics pedagogy, narrative inquiry

1 Introduction

Mathematics education in Nepal faces significant challenges for nurturing student engagement and conceptual understanding (Dahal et al., 2022; Maharjan et al., 2022). A common experience for many educators at the beginning of their careers is heavy reliance on textbook-centric and teacher-centric instructional methods (Dahal et al., 2019; Dahal, 2022). As Panthi and Belbase (2017) noted, mathematics teachers in Nepal employ traditional teaching methods, such as lectures and transmission procedures. This pedagogical approach often fails to engage students, resulting in dissatisfaction with their own understanding of mathematical concepts and problem-solving skills. Likewise, Khanal (2011) remarked that the rote memorization of mathematical concepts is a common strategy that contributes to students' misconceptions. This often results in declining interest and low achievement in mathematics, a phenomenon linked to the conventional teacher-centered pedagogy, which is identified as a key factor in diminishing student motivation (Shrestha et al., 2021). These challenges are reflected in a widespread student belief that mathematics is a more difficult subject than others, frequently leading to negative attitudes (Capuno et al., 2019). Consequently, capturing students' attention and interest in the mathematics classroom is a challenging task, resulting in a very low percentage of students passing mathematics each year. This persistent issue raises critical questions: How can mathematics be made more engaging and applicable? How can student engagement in the classroom be increased, and how can mathematical concepts be connected to real life? Thus, experiential observations in the classroom suggest that incorporating audio-visual aids (AVAs) within mobile learning frameworks, such as 3D models in GeoGebra, can meaningfully boost student interest and participation. Such teaching materials provide visual support for both conceptual and procedural knowledge (Manandhar et al., 2022). The effective deployment of teaching materials is known to influence academic achievement (Otieno, 2010). Furthermore, resource materials such as visual aids can help students understand concepts more easily and relate topics to their daily lives, thereby increasing their interest in mathematics learning

(Koparan, 2017). This aligns with the view that mathematics is not just about numbers; it is more than just nurturing learners' critical thinking, problem-solving, and its significance in daily activities (Kelly, 2006). Digital tools, such as virtual manipulatives, can help students address challenges in mathematical concepts within everyday contexts (Kang et al., 2020), underscoring the recognized link between technological progress and a strong societal understanding of mathematics (National Research Council, 2012).

On the other hand, a key issue in Nepali mathematics education is that many teachers lack appropriate training in and knowledge of instructional materials, often neglecting hands-on methods that could make mathematics relatable to real-life applications (Dahal et al., 2022; Lavidas et al., 2022a, 2022b; Papadakis et al., 2023a, 2023b). This contributes to a widespread lack of proper mathematical knowledge among secondary students in community schools in remote areas. Chapagain (2021) noted that 85% of government school students received grades ranging from C+ to E in the 2021 Secondary Education Examination (SEE) math results. Further discouraging data from the National Education Board of Nepal indicates a failure rate in community schools greater than 88%, with 178,595 students receiving a Non-Grade (NG) in mathematics (NEB, 2018). The Ministry of Education, Science and Technology (MoEST, 2021) reported that students obtained GPAs less than 2.0, and the National Assessment of Student Achievement found a disturbing pattern of declining performance across all provinces of Nepal (ERO, 2019), with mathematics results falling below 50% on average. While modern education theory posits that audio-visual aids can enhance students' mathematical understanding (Wei et al., 2015), the conventional teaching approach often makes it challenging to connect abstract mathematical concepts with real-life applications (Lockhart, 2009; Ali, 2011). The persistent problem of poor achievement in mathematics is prevalent throughout the Nepali school system (Acharya, 2017). Therefore, this study focuses on one of the primary difficulties—poor mathematical success—and investigates the role of audio-visual aids in improving learning achievements. For example, experiential evidence from the classroom indicates that students who learn with audio-visual aids tend to perform better (Maharjan et al., 2022). Traditional teaching strategies may be ineffective for helping students easily grasp complex concepts. For instance, students in grades 9 and 10 in Nepali schools often face significant challenges learning the concepts of prisms, pyramids, cones, and cylinders. The application of audio-visual materials, such as GeoGebra, MATLAB, and Khan Academy, to represent these concepts has been observed to increase conceptual understanding. This observation motivates us to research the role of audio-visual manipulation in teaching surface area and volume of 3D shapes. This study aims to bridge the gap between theoretical and practical applications of mathematics pedagogy by utilizing audio-visual elements. Thus, the purpose of this research is to explore how audio-visual aids enhance students' understanding of 3D shapes in Nepali schools, while also identifying the obstacles that restrict instructors from effectively employing these resources. This study guided the following research question:

How do teachers and students narrate their experiences of developing a conceptual understanding of 3D shapes through audio/visual aids within mobile learning frameworks?

2 Literature Review

Conceptual knowledge in mathematics is defined as a deep and relational understanding of mathematical concepts, principles, and their interconnections (Manandhar et al., 2022). It transcends rote application, involving the recognition of patterns, the construction of meaningful connections, and an understanding of the underlying "why" and "how" of mathematical operations. This form of knowledge empowers students to perceive broader mathematical structures and flexibly apply concepts across diverse contexts. As defined by Hiebert (2013), such knowledge is characterized by its rich network of relationships.

In contrast, procedural knowledge refers to the ability to execute mathematical procedures and algorithms with fluency and efficiency. It is often associated with the memorization of rules and the sequenced application of steps to solve specific classes of problems. Rittle-Johnson and Schneider (2015) describe it as a series of steps used to achieve a specific mathematical goal. Scholarly discourse posits that both conceptual and procedural knowledge are integral to mathematics education. Wilson et al. (2020) suggest that audio-visual aids (AVAs) can serve as a bridge between these domains, simultaneously supporting procedural fluency and fostering deeper conceptual understanding. For instance, dynamic visual tools such as simulations and animations can render abstract concepts tangible, elucidating both the mechanics and the rationale behind mathematical processes. The integration of audio-visual materials is further recognized for its capacity to stimulate intellectual engagement with information, thereby altering students' comprehension and perspectives on mathematics (Martin & Bolliger, 2018). Such engagement, as noted by Abrami et al. (2011), can manifest when students watch instructional films, interact with multimedia, or seek information independently. Moreover, these tools can enhance pedagogical presence, enabling educators to employ a broader range of methodologies that engage students in substantive mathematical tasks (Begolli & Richland, 2016). The integration of established technologies, such as audio, video, and multimedia, has been shown to improve student engagement by effectively merging course content with technological interaction (Martin & Bolliger, 2018).

Empirical studies have consistently highlighted the contributions of AVAs to mathematical learning. Research by Wibowo et al. (2021) revealed that incorporating digital visual tools in classrooms fosters a better understanding of geometry and spatial reasoning. Similarly, Sun et al. (2022) found that interactive video-based learning in algebra significantly enhanced students' ability to form conceptual connections, indicating that AVAs play an important role in promoting deeper understanding and long-term retention. These tools also help teachers structure mathematical tasks that promote the development of advanced thinking skills, both individually and collaboratively (Dewi et al., 2020). In the post-pandemic landscape, digital tools such as GeoGebra, Desmos, and virtual manipulatives have become particularly supportive aids for student-centered mathematics learning, enabling active learning by allowing students to explore mathematical ideas through direct interaction and experimentation (Kaur & Jamil, 2021).

3 Social Constructivism as a Theoretical Referent

The social constructivism theory served as the foundation for this research. Lev Vygotsky proposed social constructivism in 1978. Social constructivism emphasizes the social aspect of student learning. It assumes that knowledge is not passively acquired but rather generated through active engagement with more knowledgeable persons and the environment (Bruner, 1996; Vygotsky, 1978). Effective arithmetic learning settings go beyond rote memorization. It emphasizes a collaborative learning environment in which students study together, discuss concepts, and think critically to build a deeper understanding and problem-solving abilities (Slavin, 1995). Lev Vygotsky's 1978 proposal of social constructivism provided the foundation for our study on the use of audio-visual resources within mobile learning frameworks. This theory focuses on how knowledge is constructed through social interactions and active collaborations with individuals who possess more knowledge. Thus, by following this theoretical framework, our study focused on how students understand the challenging aspects of mathematical concepts through collaborative learning and active engagement with the aid of audio-visual materials. This encourages us to frame the study in terms of the personal experiences of students and teachers using narrative inquiry methods. This framework captures the comprehensive understanding of the different realities and perspectives of the research participants.

With all of the above, social constructivism shaped the methodology and analysis, providing spaces for active participation and social interaction. This research study was guided by social constructivism, as the role of audio-visual aids provides important insights into the effective learning of mathematics by Nepali secondary school pupils. Social constructivism emphasizes the role of the social environment in the construction of knowledge. Hence, by incorporating social constructivism into this research, we can examine the social and economic parameters that influence students' mathematical learning in mathematics courses, such as area and volume, through this theoretical lens. As a result, the data is expected to be more reliable and trustworthy.

4 Research Method

This study employed a qualitative research design, subscribing to narrative inquiry within the interpretive paradigm, to explore the lived experiences of teachers and students in developing a conceptual understanding of 3D shapes through audio-visual aids within mobile learning frameworks. The methodology was carefully selected to align with the research question and the theoretical framework guiding the study.

4.1 Research Paradigm and Design

The study was positioned within an interpretive paradigm that acknowledges multiple realities and subjective epistemologies, focusing on the meanings people ascribe to their experiences (Dahal et al., 2024; Lincoln & Guba, 1985). A narrative inquiry approach was adopted as the primary research design. This approach is suited to capturing the richness of individual, experience-based stories, allowing for a deep and contextual understanding of how audio-visual aids influence the learning of mathematical concepts (Clandinin & Huber, 2006). Unlike quantitative methods, which seek to measure variables, narrative inquiry accommodates the subjective and reflective understanding of participants' personal journeys by examining their stories and broader meanings (Dahal et al., 2024).

4.2 Research Site and Participants

The research was conducted in Kathmandu, Nepal, including participants from two schools (referred to by the pseudonyms ABC School and XYZ School) to capture a variety of perspectives aligned with the lived experiences of teachers and students in developing a conceptual understanding of 3D shapes through audio-visual aids within mobile learning frameworks. A purposive sampling technique was used to select participants who were information-rich and directly relevant to the research phenomenon (Dahal et al., 2024; Patton, 2002). The sample consisted of: (1) Two Grade X students from ABC School: One was a high-performing and active student, while the other was of average academic ability. This selection was designed to capture variation in learning experiences. (2) Two mathematics teachers: One from ABC School with six years of experience in a private school, and another from XYZ School with eight years of experience across different institutions. Although the sample size was small, it was deemed sufficient for a narrative inquiry, which prioritizes depth of understanding over breadth (Dahal et al., 2024). Data saturation was considered achieved when participant responses began to yield recurring themes without new information emerging (Dahal, 2025).

4.3 Data Collection Methods and Tools

Data were collected through in-depth, semi-structured interviews. This method was chosen to elicit detailed personal stories and subjective narratives regarding the role of audio-visual aids in teaching and learning mathematics. Two distinct interview guides were developed—one for students and one for teachers, aligned with the research purpose. The instruments consisted of interview guiding questions, which were developed in collaboration with two experienced mathematics educators. Minor adjustments were made based on their feedback to ensure content relevance and clarity. The interviews featured open-ended questions to encourage participants to express their ideas freely and allowed for probing to explore emerging insights. Interviews were conducted via phone calls and Zoom meetings, audio-recorded with the participants' prior informed consent, and later transcribed verbatim for analysis.

4.4 Data Analysis

The data analysis followed an inductive thematic analysis process (Dahal, 2025). The interview transcripts were manually open-coded, allowing codes and categories to emerge directly from the data rather than being pre-determined. These initial codes were then sorted and grouped into overarching themes that addressed the research question. Key themes that emerged within mobile learning frameworks included "student engagement," "conceptual clarity," "real-world connection," and "teacher motivation." The narratives were analyzed in relation to existing literature, and to ensure confidentiality in accordance with quality research principles and the rigor of the research process, while reporting (Dahal, 2023), all participants were assigned pseudonyms (teachers: Dipesh and Roshan; students: Sangam and Rohit).

4.5 Ethical Considerations and Researcher Reflexivity

Informed consent was obtained from all participants before data collection. The researchers, who also held the dual role of teachers, practiced reflexivity throughout the study by maintaining a research diary to document and critically examine their own biases, assumptions, and influences on the research process and interpretation of the data. This active reflection was vital for enhancing the trustworthiness of the findings.

5 Findings

In the findings section, we analysed and interpreted the research participants' responses, drawing on a relevant review of the existing literature. This section was structured around recurring ideas and themes that emerged from the participants' stories and perspectives, which were organized into distinct findings as follows. These findings collectively address the research question and provide meaningful insights within mobile learning frameworks that align with the purpose of the study.

5.1 Visual Aids and Student Engagement in the Mathematics Classroom

Audio-visual materials also appear to increase students' interest in mathematics classes, especially for students at the secondary level. Audio-visual materials inspire students to engage intellectually with information, which can alter their comprehension and perspectives on mathematics (Martin & Bolliger, 2018). Such materials help bridge the gap between the abstract nature of math problems, such as area, volume, and geometry problems, and real-life scenarios that are more applicable to the students. They can't visualize the concept in a real-life scenario. Therefore, audio-visual materials can help students gain a deeper understanding. Participant Roshan shared his ideas as follows:

Now, while I am teaching, I still presume that students may face the same problems I did in the past; thus, to avoid that, I use a paper model to explain it to them. In the meantime, I am taking help from several videos broadcast by the National Centre for Educational Development (NCED). I present some solid figures of my own, such as the beam balance used to explain the cone, the temple's roof as a pyramid, and the house rooms as different prisms. This is how I believe I can approach students more effectively from my perspective.

When I initially taught. I used the same traditional techniques as my teacher did. Provide a formula and find the unknown sides of height, area, volume, etc., and I found that this helps students increase their imagination. While calculating the LSA of the pyramid, we need to find the area of the four triangles. TSA means the base area and the area of the four triangles. Volume means the 1/3 base area times the actual height. I used to analyse the figures, explaining them; there was no more TV and videos like today's children get. Now that the NCED has uploaded videos explaining beautifully, I am seeking help with this before I move forward to exercise. I will also be doing this in the coming years.

Furthermore, Abrami et al. (2011) note that student-to-content contact can occur when viewing instructional films, interacting with multimedia, or looking up material. Audio-visual materials are found to be significant in mathematical achievements. Audio-visual materials increase teachers' visibility, and teachers can employ various teaching methodologies that engage students in mathematical tasks (Begolli & Richland, 2016). This agrees with Martin and Bolliger (2018), who found that AVAs enhance conceptual knowledge by enabling learners to envision real-world connections. Unlike what they discovered in technologically supported spaces, the current study indicates that Nepalese instructors utilize limited digital tools, opting instead for creative uses of locally available materials. Sangam shared his ideas as follows:

When I was a student, my teacher would come with chalk and a duster, tabulate the related formula, and then teach the methods for calculating the answer. This was a purely teacher-centric method. Even though we felt lucky to have such teachers, given the lack of manpower to teach math, I still think they were ideal for them. Later, when I joined Kathmandu University (KU), I realized that math could be taught on a practical basis. Now, when I enter my class, I take all the necessary materials and start building up the concept of how a formula is derived. Even use pieces of paper to fragment them and make the formula clear. The table will be created by themselves, and after that, I will help them with the calculation step by step. This is how I look forward to my lessons.

Initially, our curriculum was designed to enable students to secure more marks. While applying traditional techniques to secure marks, we felt that the students were familiar with them. However, the technique is now different, and the students secure it well. Now the students' level of understanding is far better than before. They appreciate my practical approach to teaching mathematics. This is better than the older one.

Nevertheless, not all students equally benefit from AVAs within mobile learning frameworks. For example, some learners remain isolated despite these measures. Likewise, audio-visual materials enable teachers to provide mathematical challenges to pupils, promoting the development of critical thinking skills both individually and in groups (Dewi et al., 2020). Participants also emphasized the importance of audio-visual tools in the classroom for a thorough knowledge of mathematical ideas.

5.2 Audio-Visual Tools for Developing Concepts in Mathematics

Audio-visual aids help students to think critically and improve their visual concept. They serve as both instructional enablers and cognitive supports, allowing students to interact with shapes, manipulate models, and explore spatial relationships. Several researchers have discovered the importance of audio-visual tools in the mathematics classroom. Visual aids are tools and procedures used to illustrate instructional aims, present knowledge more effectively, provide visual comparisons of common topics, and apply diagrammatic reasoning processes (Malty, 2000, as cited in Schnotz and Lowe, 2003). On the other hand, Bocka et al. (2008) and Rivera (2011) found that employing visuals and interactive devices may be the best strategy for eighth-grade pupils to improve their math skills. Our research participant, Sangam, shared the following ideas:

While teaching using old traditional methods, a few students don't pay attention as they feel math is a boring subject. When I bring these hands-on materials to class, they come to pull one or more solid objects and start to play with them, which makes them engaged in learning new things. I have to search and ask who has taken this shape. Sometimes, they combine different shapes to form new ones, making the learning environment more interactive and sustainable. I observed that the usage of 3D manipulatives in my class not only increased engagement but also facilitated collaborative learning, which is especially helpful for visual learners. There is no doubt that when we use ICT, the students can be clearer. The colourful picture attracts and gives a clear concept of area volume, TSA, etc. I have prepared the materials, but I feel it is challenging to use them, as not all schools have smartboards and the necessary tools to support them. Sometimes the electricity goes out. Despite the challenges, whatever we can visualise is the best of all, so ICT plays a great role in learning.

Additionally, they found that visual aids and interactive technologies are the most effective tools for teaching mathematics during these developmental stages. According to Korthagen (2004), when learning mathematical facts, visual thinkers prefer graphical representations since they can draw connections from holistic representations. Rohit shared his ideas as a student.

Our teacher had used ICT videos for 3D shapes and chapters related to area, volume, TSA, etc. The concept was clearer when we watched those videos than with markers and boards. I was very excited to learn. It enhanced our learning capacity. Sometimes, the teacher used to divide us into groups and teach. This is also a good method. We could share and learn. Sometimes I would teach them, and sometimes I would learn from them too. It is beneficial to both of us to learn in groups. Generally, my friends do not pay attention while reading as our school uses with traditional method, but when ICT classes start, they become active and enthusiastic about learning. They become excited about learning math through ICT and visual aids.

The researcher found that when visual aids within mobile learning frameworks were used to teach mathematics, students were able to relate mathematical ideas to real-life situations, utilizing their imagination. Some studies have found that children's early years are dominated by a visual-mathematical thinking approach (Ball, 1992, as cited in Sutton & Krueger, 2002). Throughout researchers' teaching careers, they have found that most students use visual relationships between numbers as a means to represent shapes or objects. To illustrate mathematical ideas, teachers employ manipulatives (ICT) like shapes and symbols. Participant Roshan shared his ideas as follows:

ICT plays a crucial role in fulfilling the needs and curiosity of individuals. For example, we may not have sufficient resources to create any objects that we desire, but via ICT, we can visualize them with a clear view and concept. Regarding our facilities, we have smartboards with high-definition images and videos to display, making them an ideal tool for those situations where real resources for modeling are not available. This is also an interesting area for students.

According to Ferri (2012), children in the eighth and tenth grades often employ visual thinking approaches, even though they are well into their formal operational stages. The use of visual aids in the classroom enhances students' memory, enabling them to better link, organize, reflect on, and apply what they have learned in real-world settings (Dewi et al., 2020). Also, Luawo and Nugroho (2018) found that visual aids will enhance the learning environment and increase student interest and motivation. Further, Dipesh shares his ideas as follows:

It has a positive influence on student performance. I have two examples to justify this. One of them is that when I started modelling, they practically knew the dimensions of the object. On the other hand, when they were visualised, they gathered to compare their modelling with the picture. This helps them memorise the formula and get a clearer concept, too. Having said this, there are a few lazy students who do not like to come ahead in either practical work or visualization. These students remain a challenge for us to improve.

Furthermore, Yusantika et al. (2018) found that audio-visual media offer a variety of non-monotonous lessons that help students develop and improve their independent learning comprehension. On the other hand, the study found that audio-visual resources that convey the material's authenticity can provide students with real-life experiences that promote self-directed learning (Agustini et al., 2016; Utami et al., 2019). To increase students' interest in the learning process and make the message simpler to absorb and understand, visually engaging audio-visual media is used to convey the teaching and learning process (Setiawan & Bezaleel, 2019). As a result, audio-visual aids appear to be quite significant in mathematical education.

5.3 Empowering Mathematics Through Audio-visual Dynamics

The use of audio-visual resources within mobile learning frameworks in mathematics education appears to improve conceptual understanding. Many researchers attest that AVAs possess the ability to enhance students' math comprehension by approximating abstract ideas into concrete and interactive representations. They discovered that difficult mathematical concepts can be easily understood through audio-visual dynamics. Kinder (2015) defines audio-visual resources as tools that can be used in the classroom to enhance learning outcomes and make the learning process more dynamic, relevant, concrete, and effective. Similarly, Rather (2004) describes audio-visual resources as any instructional instrument used in the classroom to assist learning and make it easier and more entertaining for students to understand, including charts, maps, models, projectors, televisions, and others. Sangam presented his opinions as follows:

As much as possible, I make my own materials. There is less chance of error. I recommend selecting only the necessary materials from reputable sources. They should be prescribed by the curriculum so that it becomes better for students. Personal bias materials should not be included. The evolution of students using ICT is better than the traditional methods; students have greater clarity in concepts. They cannot understand much better by saying that learning is better using ICT. Visual aids help make concepts clear, which in turn increases students' knowledge. The calculation can be taught using the board, too. As far as I know, the students increase their calculation abilities.

A significant amount of research has been conducted in the field of audio-visual dynamics and its impact on mathematics. Martin and Bolliger (2018) state that the use of audio-visual materials helps to empower mathematical understanding in students. On the other hand, this empowerment is further enhanced by research showing that learners become more engaged and focused on the material presented (Lalian, 2018). Research has found a positive correlation between the use of audio-visual materials and their impact on empowerment in mathematics learning. In the context of mathematics education, audio-visual learning materials are believed to support the online mathematics learning process more creatively and enjoyably (Setiawan & Oka, 2020). In addition to this, these materials combine sound and images in an interesting and fun manner (Kusuma, 2018; Wahyudi et al., 2003), providing students with instant access to simulations and demonstrations reflecting real-world situations, thus helping them understand concepts and apply them to their daily lives correctly and accurately (Kania & Arifin, 2020; Nomleni & Manu, 2018). In these ways, audio-visual materials are found to be significant tools for mathematical conceptual understanding.

Students can replay the video if they feel they missed something or if certain concepts remain unclear, allowing for effective repetition of the content (Salaberry, 2001). One of the notable advantages of audio-visual media is the ability to revisit material when needed. Supporting this line, audio-visual materials enhance students' critical thinking abilities (Anggraeni et al., 2019). Audio-visual aids are the most important tools for math learning. Nwachukwu (2006) emphasizes the importance of audio-visual aids in enhancing teaching effectiveness and improving student academic achievement in schools. The use of audio-visual aids is one of the most important tactics for successful mathematics learning with real-world applications. Access to and use of audio-visual aids are crucial when teaching mathematics, as they create an engaging and interactive learning environment that facilitates students' improvement in problem-solving abilities in this subject (Abubakar et al., 2021). In this way, the research found that the use of audio-visual materials boosts students' mathematical understanding.

5.4 Bridging Mathematical Abstract Knowledge with Real-Life Scenarios

Results show that AVAs within mobile learning frameworks enable abstract mathematical ideas to be transformed into representational modes familiar to students, improving comprehension and memory. This truth has been established after extensive research. For example, the audio element comprises sound, which helps students to hear learning messages, whereas the visual aspect includes moving visuals that may be understood through visualization (Lalian, 2018). Furthermore, Osokoya (1987) highlights that the use of audio-visual materials in teaching and learning extends beyond textbooks to other instructional methods that enable students to visualize the conceptual implications of what they are learning. In addition, Apte (2014) describes the chalkboard as an important and commonly utilized audio-visual aid in mathematics training. Teachers use it to illustrate diagrams and help pupils understand them. Sharing the ideas by the participants, Roshan, as follows:

Visual aids help make concepts clear, which in turn increases students' knowledge. The calculation can be taught using the board, too. As far as I know, when they have a clear concept, their calculation ability also increases. Few students can learn effectively only by hearing, as in the traditional method; some students learn by touching and feeling, which involves them more actively. In my view, visuals or animated videos could make a greater impact on a wider variety of students. This helps to strengthen their learning and makes it more sustainable.

Furthermore, visual aids play an important role in helping students develop mathematical imagery when they see and hear correctly (Stokes, 2002). Additionally, the combination of sensory inputs is crucial for effective learning. Moreover, Bagila et al. (2019) reported that audio-visual materials facilitate the processing of a greater amount of information. Notably, when students listen to a native speaker for a short period, they retain and remember 65% of the information, compared to 25% when they watch a video (Goh, 1999). This demonstrates the exceptional effectiveness of audio-visual elements in the learning process. Rohit says,

Our teacher used a 3-D model of special chapters, such as menstruation, and sometimes in trigonometry as well. This enhances our understanding significantly and makes it more sustainable. So, it is a better mode of learning. In my opinion, visual aids, books suggested by the curriculum, and videos related to them are better than practice books.

Various research studies also signify this. According to Dale (1946), the 'Cone of Experience', audio-visual materials contribute significantly to improving students' understanding. This supports the argument that multi-sensory inputs like AVAs can result in improved learning outcomes than single-mode teaching. Figure 1 illustrates Dale's Cone of Learning model.

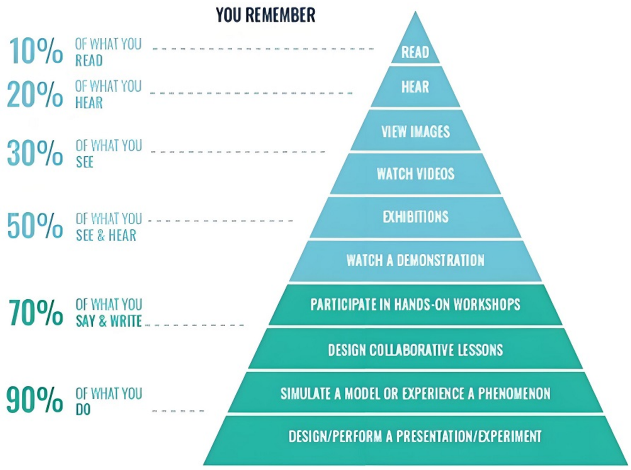

Figure 1 Dale's Cone of Learning Model (Source: Edgar Dale, 1946)

This figure indicates that there is less learning, specifically only 10% through reading. Then hearing is a little bit much, i.e., 20%. However, the capacity to remember increases by 30% when viewing images and by 50% when watching videos and demonstrations. This highlights the significance of audio-visual aids in mathematics instruction.

5.5 Visual Aids for Addressing Learning Diversity

Visual aids within mobile learning frameworks appear to help make Math more inclusive, as they address the varying learning styles and performance levels among students. For example, several researchers discovered that visual aids are critical tools for addressing student learning diversity in the classroom and gaining a deeper comprehension of conceptual knowledge in mathematics. Students with varying learning speeds learned readily and effectively after employing audio-visual elements in the classroom to create a conceptual grasp of mathematics (Dewi et al., 2020). On the other hand, Shin et al. (2017) define visual materials as web-based graphics displayed on a computer monitor that enable students to edit a three-dimensional visual model. This visualization helps students gain insight into mathematical concepts across their diverse capabilities. Additionally, audio-visual materials offer an interactive environment, enabling students to pose and solve mathematical problems. Sangam shares the ideas as follows:

It makes the concept clear and reduces the time limit for drawing the figure. It gives a real-life scenario so it can be observed slice by slice. It is a more conceptualized format than the traditional approach to teaching. Generally, not many students like that in our class, but we cover the same topics frequently, which can lead to boredom. Knowing that our teachers have some other refreshing items helps us regain our concentration.

This type of practice enables a diverse range of learners to connect mathematical concepts, providing them with immediate feedback that facilitates reflection on their conceptual understanding (Durmus & Karakirik, 2006). According to Reimer and Moyer (2005), audio-visual tools helped students of various grades learn more about mathematics by delivering immediate and detailed feedback, which also increased student enjoyment. Furthermore, integrating audio-visual resources into the teaching-learning process has considerably enhanced students' diverse learning abilities (Setiawan et al., 2020). Teachers should conduct visual classes only when the relevant subject matter is covered in the curriculum in an organized manner. Students shouldn't make visual classes in random order for irrelevant objects. Irrelevant and unnecessary context can harm learning. Dipesh shared his ideas as follows:

We have had that bitter experience, as we have been working in areas where the electricity can be off for up to 5 days, even when poles or trees fall down. Or the internet may not work well. Sometimes students remain absent during the lesson. These problems are very common to us. To solve this issue, we just don't depend on ICT or visual classes. We also make our reading materials using local resources, so that it may not create as huge a problem as you imagined. We have been doing that in the past as well. Once the materials are made, they will remain for many years, so the hard work must be done only once.

In these ways, we have different significant applications of visual aids in mathematics teaching and learning activities. The major applications of 3D shapes within mobile learning frameworks, as highlighted by the participants, include imagination, real-life applications, durability of learning, empowerment, and conceptual understanding among secondary school students.

6 Discussion

This study found that audio/visual aids are crucial in increasing student engagement and understanding of mathematical subjects. Martin and Bolliger (2018) highlight that these materials encourage intellectual interaction with content, changing students' perspectives on mathematics. Participants like Roshan utilize paper models and videos from the National Centre for Educational Development (NCED) to illustrate geometric concepts, enabling students to visualize real-life applications and grasp abstract ideas more concretely. This shift from traditional teacher-centric methods to modern, interactive approaches is crucial. Dipesh noted that his initial rote learning techniques were less effective than the practical, hands-on methods he adopted after his experience at Kathmandu University. This transition aligns with Begolli and Richland (2016), who found that integrating audio-visual materials into teaching methodologies significantly enhances student engagement and learning outcomes.

This research finding highlights the important effects of audio-visual aids on various aspects of secondary school students' mathematics learning. Audio-visual aids have been found to enhance students' active engagement and help them gain a deeper understanding of mathematical content. A deeper understanding and engagement of students in mathematical learning activities transforms their understanding and perspectives, and improves their critical thinking and problem-solving skills. Using visual aids also gives teachers advantages. Teachers can develop the ability to employ various teaching strategies, utilizing audio-visual aids, and engage students actively in the mathematics classroom.

Furthermore, audio-visual tools significantly contribute to students' conceptual understanding of the high school mathematical curriculum (Lampropoulos & Papadakis, 2025). Incorporating 3D tools, audio, visual tools, and manipulatives in the classroom delivers effective mathematical concepts and value, which can be applied to real-life circumstances and build vital 21st-century skills in students, such as creativity, teamwork, critical thinking, and problem-solving. Audio-visual aids empower students, making the learning process more dynamic and concrete. Students develop their focus on concrete understanding with excitement. Teachers utilize ICT tools such as projectors, smart televisions, and computers to present mathematical concepts using audio-visual aids, thereby enhancing access to simulations and demonstrations that facilitate the practical applications of mathematical concepts and connect them to real-life applications. Visual aids also cater to students' diverse learning needs by creating an interactive learning environment that addresses various learning dimensions and encourages mathematics learning that is more engaging and precise for a diverse range of students.

This research project suggests that audio and visual materials significantly enhance students' engagement and imagination, empowering a deeper understanding of mathematics. The use of audio-visual resources also addresses the diverse learning needs of secondary school students in mathematical learning. The findings also emphasize the multidimensional impacts of integrating audio-visual aids, such as various technologies. ICT tools and technology provide a comprehensive and detailed approach to enhancing the learning experiences of students. Integrating ICT resources into secondary school mathematics learning environments enables students to develop 21st-century skills such as critical thinking, problem-solving, creativity, and collaboration, making the learning experience more dynamic, engaging, and effective. Graphical representations, audio-visual manipulatives, and visual thinking styles in the mathematics classroom help students develop a creative and collaborative understanding of mathematical concepts. This also bridges the learning gap between abstract mathematical knowledge and its real-world applications. This research also highlights positive correlations between audio-visual materials and student engagement and empowerment, enhancing the conceptual understanding of mathematical understanding and providing instant access to simulations and visual demonstrations. Overall, audio-visual aids within mobile learning framework in mathematics teaching and learning activities for secondary school students effectively create an enriched, inclusive, and transformative learning environment that promotes student engagement, imagination, critical thinking, and collaboration in mathematical learning environments.

In situating findings within the global landscape of mobile learning framework in resource-constrained contexts, several parallels and distinctions emerge that merit consideration. Studies from similar low-resource environments in Sub-Saharan Africa (Traxler & Kukulska-Hulme, 2016) and rural India (Kam et al., 2009) demonstrate comparable patterns where mobile technologies and audio-visual aids compensate for limited physical infrastructure and trained teaching personnel. Like Nepal's experience, these contexts reveal that mobile learning initiatives succeed when they leverage locally available technologies—such as basic smartphones and offline video content—rather than requiring high-bandwidth internet or sophisticated devices. However, Nepal's integration of culturally contextualized materials from the National Centre for Educational Development (NCED) distinguishes it from many African mobile learning programs that often rely on Western-developed content (Valk et al., 2010). Furthermore, while studies in Indonesia and the Philippines show similar transitions from rote learning to interactive approaches through mobile technologies (Tancredi & Clifford, 2018), Nepal's teacher-centered professional development model at Kathmandu University appears more systematic in preparing educators for pedagogical transformation. This comparative analysis suggests that Nepal's mobile learning framework, though operating within resource constraints typical of developing nations, demonstrates a more holistic approach by simultaneously addressing content localization, teacher capacity building, and technological accessibility—factors that collectively enhance the sustainability and effectiveness of audio-visual integration in mathematics education beyond what has been documented in many comparable global contexts.

7 Conclusion and Implications

This study examines the lived experiences of teachers and students in developing a conceptual understanding of 3D shapes through the use of audio-visual aids in the mathematics teaching and learning context in Nepal. The narrative inquiry, grounded in social constructivism, reveals that the integration of AVAs—ranging from digital tools like GeoGebra and YouTube to physical models and locally sourced materials—fundamentally transforms the mathematics learning environment. The findings demonstrate that these aids are merely supplementary and are central to fostering deeper, more meaningful learning experiences. The conclusion drawn from this research is unequivocal: audio-visual aids serve as a powerful vehicle for enhancing student engagement, bridging the gap between abstract mathematical concepts and tangible real-world applications, and promoting a collaborative, student-centered learning culture. Thus, by making complex ideas related to 3D shapes visually and interactively accessible, AVAs move learning beyond rote memorization of formulas towards a genuine, relational understanding. This shift is crucial in a context like Nepal, where traditional, teacher-centric methods have often led to student disengagement and superficial learning. The stories of the participants feature that when students can see, manipulate, and discuss mathematical concepts, they become active constructors of their own knowledge, leading to improved long-term retention and problem-solving abilities.

Likewise, the study carries significant and multidimensional implications that extend across classroom practices, teacher development, and educational policy. For classroom pedagogy, teachers are encouraged to transition from traditional chalk-and-talk methods to more interactive approaches. The integration of AVAs in lesson plans, such as those in geometry, can enhance conceptual understanding and engagement. Moreover, while digital tools are highly effective, the study also highlights the value of using creative, low-cost, and locally available materials such as paper models and real-life objects. These resources help foster inclusive and resilient learning environments in regions with limited technological infrastructure. Teachers are also advised to design collaborative learning activities that utilize AVAs to promote group work and discussion, aligning with social constructivist principles and catering to diverse learning styles, including visual, auditory, and kinesthetic modalities. In terms of teacher professional development, the study highlights the importance of systematic and ongoing training programs that enhance teachers' technological pedagogical content knowledge (TPACK). Such programs should empower educators to effectively select, create, and implement audio-visual resources in their teaching.

Additionally, the formation of professional learning communities is recommended, where teachers can exchange best practices, share successful lesson plans, and curate digital resources such as YouTube channels and GeoGebra files for mathematics instruction. From a policy and administrative perspective, the study calls for substantial investment in educational infrastructure. Equipping classrooms with stable internet access, projectors, smart boards, and computers is essential for the widespread adoption of digital AVAs. Curriculum developers and textbook designers are urged to formally incorporate audio-visual activities and digital resources into the national mathematics curriculum, thereby providing a structured framework and reducing the burden on individual teachers to source materials independently. Furthermore, for community schools in remote or resource-limited settings, policies should support the development and distribution of "low-tech, high-impact" AVA kits. These kits, containing physical manipulatives for teaching 3D shapes and other concepts, ensure that all students—regardless of geographic location—can benefit from visual and hands-on learning experiences.

With all of the above, this study posits that the strategic integration of audio-visual aids is a foundation for revitalizing mathematics education in Nepal. Thus, by empowering teachers with training, equipping schools with resources, and embedding these tools into pedagogical practice, stakeholders can transform mathematics from a perceived difficult and abstract subject into an engaging, accessible, and understood discipline. The ultimate implication is clear: embracing audio-visual dynamics is essential for nurturing the critical thinkers and problem-solvers needed in the 21st century.

Ethics Statement

The Research Committee at Kathmandu University School of Education granted approval for this study on January 12, 2024.

Author Contributions

Shankar Bhatt: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Validation, Writing – original draft, Writing – review & editing.

Niroj Dahal: Formal Analysis, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Indra Mani Shrestha: Conceptualization, Formal Analysis, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Generative AI statement

The authors declare that no GenAI was used in the creation of this manuscript. However, we would like to acknowledge the use of Grammarly Edu for this article. Grammarly Edu was used to refine the language and ensure consistent flow and cohesion throughout the sentences and paragraphs. Thus, we wish to recognize and record the application of Grammarly Edu, as well as our cognitive and evaluative abilities, in the formulation of this article.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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