Enhancing the conceptual comprehension of astronomy for grade seventh students using multimedia

Kinga Tshering[1*], Dorji Wangchuk[2], Dil Bahadur Mongar [3], Kelzang Dema[3]

[1]Ministry of Education and Skills Development, Thimphu, Bhutan.

[2]Kengkhar Middle Secondary School, Mongar Bhutan.

[3]Ministry of Education and Skills Development, Thimphu, Bhutan.

[4]Trashigang Middle Secondary School, Trashigang Bhutan

[*]Correspondence: kingat@education.gov.bt

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Abstract

This study was motivated by the absence of studies examining the effectiveness and students' perceptions toward multimedia in learning concepts in astronomy in the Bhutanese context. The study used an explanatory sequential mixed-method research approach with a pre-test and post-test experiment on a single group. The study examined the effectiveness of multimedia in learning astronomy concepts. Additionally, it also explored the perceptions of students toward the use of multimedia in learning astronomy concepts. The participants consist of 44 seventh-grade students. The quantitative data was collected using an astronomy conceptual test. The qualitative data were collected through semi-structured interviews with 12 students. Quantitative data was analyzed employing histograms and paired samples t-tests. Braun and Clarke's thematic analysis was used in the study to generate themes for the qualitative data. The semi-structured interview data were analyzed to gain insights into the students' perceptions regarding the use of multimedia in learning concepts in Astronomy. The quantitative result indicated that the performance on the astronomy conceptual test significantly improved when students were taught concepts using multimedia. Moreover, students' perceptions were positive towards the use of multimedia. However, there were challenges such as time constraints and an ability to discern appropriate information for astronomy concepts. It was recommended that multimedia could be used to learn concepts in astronomy.

Keywords: *Astronomy concepts, Challenges, Grade seventh, Multimedia, Students' perception*

Introduction

The Royal Government of Bhutan initiated several changes to the science curriculum. For instance, in 1986, 'The New Approach to Primary Education was launched to contextualize the curriculum and promote science learning through investigation instead of memorization for classes 4-6 (Childs et al., 2012). Additional changes were implemented in grades seven and eight science curricula, incorporating integrated science along with the 'New Approach to Primary Education' since the academic years 1999 and 2000 (Tshewang, 2019). Recently, with frequent lockdowns due to the COVID-19 pandemic, the erstwhile Royal Education Council (REC) undertook major reforms to develop the National School Curriculum (NSC) and Instructional Guidelines (IG). These documents were reviewed and revised further in the year 2022, which resulted in the minimization of dependency on textbooks while emphasising a greater focus on the learning process.

The REC's significant reform of the science curriculum was not simply a response to intermittent lockdowns caused by the pandemic but rather the culmination of four years of ongoing curricular reform efforts. The reform was based on the premise that students would be equipped with transversal competencies and 21st-century abilities, and it focused on learning 'how' and 'why' rather than the teaching of 'what' (Department of Curriculum and Professional Development [DCPD], 2022). The Science curriculum for grades PP-12 had a significant reform and introduced contents related to astronomy into the latter section of science for grades seven and eight. Further, curriculum changes were also included for the science subjects in the lower classes.

According to Dhendup et al. (2021), teachers in Bhutan encounter challenges teaching astronomy ideas and terminology, and students perceive astronomy topics as complex and challenging to comprehend. On the other hand, Salimpour et al. (2020) suggested that astronomy could spark excitement among students and the general public, potentially fostering interest in STEM subjects and thereby contributing to technological advancement.

Physics as a science subject is considered an abstract and challenging discipline (Ramma et al., 2018; Yunzal & Casinillo, 2020). Therefore, teachers must use various instructional strategies to help students understand abstract concepts (Ndihokubwayo et al., 2020). Ndihokubwayo and colleagues mentioned that effective physics teaching and learning necessitates instructional tools such as multimedia. The curriculum in Bhutan was reformed entirely, particularly the science curriculum, to keep abreast with technological advancements in the world. Moreover, the science curriculum framework for class PP-XII focused on using technology design to

supplement science standards and engineering design whenever possible (National Research Council [NRC], 2014). Thus, this study sets out to investigate the effectiveness and students' perceptions of the use of multimedia in learning astronomy in science subject for grade seven.

Problem Statement

Teachers and students hold a negative viewpoint on astronomy. A study conducted by Aydin (2017) found that students in grade seven had a limited understanding of celestial concepts such as the sun, moon, and earth system. It was also discovered that limitations arise from everyday language and textbooks. Similarly, teachers and students in Bhutan are unfamiliar with ideas linked to astronomy, which was incorporated into science textbooks recently. Furthermore, many science teachers did not have formal training in astronomy during their schooling. Also, students are concerned about learning astronomy in grades seven and eight.

Since the contents related to astronomy are abstract (Dendup et al., 2021; Kersting et al., 2020), employing effective strategies for teaching and learning astronomy is essential. Moreover, students have misconceptions about astronomy contents (Aksan et al., 2017; Baybars & Can, 2018; Koca, 2019). Therefore, digital technology effectively contributes to teaching and learning abstract concepts like astronomy (Oktay, 2022). Moreover, adolescents also require educational media about astronomy that can maintain their attention through multimedia. Additionally, with the recent inclusion of astronomy content in the science curriculum in Bhutan, there is a need to conduct empirical studies that determine the effectiveness of employing multimedia for learning astronomy.

Aims and objectives of the study

Based on the global findings and concerns related to the existence of learning difficulties and the abstract nature of the contents related to astronomy, the study intended:

- Explore the students' prior knowledge about concepts in astronomy in grade seven.
- Evaluate the efficiency of learning concepts related to astronomy using multimedia in grade seven.
- Examine the challenges of using multimedia among grade seven students.

To achieve the aforementioned objectives, the study was directed by the following questions:

Research questions

Principal question

How effective are multimedia in enhancing the students' conceptual understanding of the concepts in astronomy?

Research sub-questions

The following sub-questions were utilized to find an answer to the main question.

- What are students' pre-understanding of the concepts related to astronomy?
- Does multimedia have an impact on students' achievement in astronomy concepts?
- What are the challenges of using multimedia while learning concepts related to astronomy?

Literature review

Concepts of astronomy

To make science lessons effective, teachers must pay attention to the constructs that students form as they make sense of the world and bring them to class (Slater et al., 2018). It is critical to pay attention to the concepts that children form. According to Gali (2021), students' previous knowledge combines with information presented in class, resulting in unintentional learning results. This leads to changes in conceptual understanding, remembering, recalling, reasoning, comprehending, problem-solving, and learning new information. Before students enter any informal or formal institutions, they have a fundamental awareness of the natural surroundings and astronomical phenomena (Cardinot & Fairfield, 2021).

Astronomy is one of the earliest disciplines and attracted considerable interest from the people (Baybars & Can, 2018). They also claimed that before the development of writing, people conducted their lives according to the sun and moon they viewed during the day and night. Early civilizations related astronomy with religious and astrological practices, as well as keeping track of time and completing agricultural tasks (Serttaş & Türkoğlu, 2020). As a result, Copernicus developed the heliocentric hypothesis in the 16th century, starting with the Renaissance of astronomy. Though Galileo's invention of the telescope was much credited for the work done in astronomy, the launch of Sputnik I in 1957 accelerated the transformation in astronomy (Baybars & Can, 2018).

Misconceptions on astronomy

To create a platform for studying science, including high-quality physics, five components must be addressed: comprehending concepts, developing competencies, developing attitudes, and integrating into daily life (Azizah et al., 2022). According to Sa'adah and Haryadi (2020), when learning physics, students must focus on developing concepts rather than memorising equations without comprehending them. Memorising without comprehending leads to students having difficulty understanding topics in class. Students' initial conceptions are created by encounters with the environment, hence they are more likely to make mistakes when constructing (Saputra et al., 2019). Similarly, with the recent inclusion of astronomy in Bhutan's science curriculum, students find astronomical contents incomprehensible and abstract (Dhendup et al., 2021).

As a science, astronomy entails the development of a complex and dynamic mental model; as a result, students may develop astronomical notions that contradict their present scientific beliefs, leading to misconceptions (Yıldız Tezer, 2022). The field of astronomy is marked by a significant degree of misunderstanding, leading to widespread misinterpretation of its concepts among students (Serttaş & Türkoğlu, 2020). Furthermore, in the field of astronomy students have alternative conceptions starting from elementary schools (Slater et al., 2018). For example, Saçkes (2015) investigated the notions of day and night with 46 kindergarten students (aged 5-6 years). The most common alternative conceptions in this study were the distance model, in which the sun goes closer and further away, and the model in which the sun moves straight up and down.

Multimedia as a strategy for teaching and learning astronomy

Gali (2021) recommended that to remediate the alternative concepts in astronomy, educators must select teaching strategies and classroom activities that consist more of visualization, graphs, concept cartoons, and explanations to make the lesson understandable. Further Visual, sensory, and kinesthetic integration can help people grasp concepts in space better (Shaikh et al., 2020). Since astronomical concepts should be accessible to both adults and children alike, educational media such as multimedia visuals should be effectively integrated (Abdillah et al., 2020). Hence multimedia technology includes not just cutting-edge IT innovations like high-tech digital equipment, but also common objects like short video clips, text, PowerPoint presentations, graphics, and more (Rigzin & Chalermnirundorn, 2021). Similarly, in Bhutan, the Department of Curriculum and Professional Development (DCPD) designed an IG for teaching content, and it recommends integrating different multimedia such as video clips, simulations, and mobile apps for teaching and learning astronomy concepts (DCPD, 2022).

Dahal (2021) studied the effects of multimedia on astronomy and geology and noted that by integrating multimedia there were significant differences between the control and experimental groups. Likewise, the use of web-based instructional methods such as simulations and online multimedia links has exhibited a significant increase in students' performance in astronomical achievement tests. Additionally, students have responded positively to the integration of multimedia resources (Nthimbane & Kazeni, 2019). Further, employing digital lessons such as animations and digital games such as AstRoamer improved the student's understanding of basic astronomy concepts and yielded positive changes in attitude toward science and astronomy (Shaikh et al., 2020).

Methodology

Research design

The primary goals of this study were to examine the impact of multimedia on seventh graders' mean scores in astronomy and gather students' perspectives on multimedia as a learning strategy. The study used the Explanatory Sequential Method where the research approach with a pre-test and post-test experiment on a single group was implemented (Nthimbane & Kazeni, 2019). First, quantitative data were collected and analyzed. Subsequently, qualitative data was collected and analysed. The final phase consisted of data interpretation.

Moreover, with the premise that students' perceptions of the learning strategy employed have a sufficient impact on their performance, a semi-structured interview was conducted. Semi-structured interview as a component of the qualitative approach of the research design was used to elicit students' views on multimedia as a learning strategy.

Research method

Data related to students' pre-understanding of astronomy concepts and the effectiveness of multimedia as a strategy in enhancing students' conceptual understanding of astronomy concepts were collected quantitatively using *Astronomy Conceptual Test (ACT)* items. Likewise, through a semi-structured interview process, students' perspectives regarding learning through multimedia were gathered qualitatively. To address the main research questions, the data were analyzed independently.

A pre-test was administered before the intervention to determine the students' previous understanding of astronomy concepts. The participants were taught astronomy concepts using multimedia as PowerPoint, video clips, Edpuzzle learning videos, quizizz, TED talks, articles, and journals as learning strategies after the pre-test. Following the

intervention, participants were administered a post-test to determine the students' conceptual understanding of astronomy concepts based on the use of multimedia as a learning strategy. Finally, students' perceptions regarding multimedia as a learning strategy were acquired from participants through a semi-structured interview.

Research sample

There were two sections of grade seven students at the research school during the academic year 2022. The participants of the study consisted of 44 seventh-graders from one of the middle secondary schools in eastern Bhutan. Grade seven students were chosen because astronomy concepts are taught in the seventh grade as per the Bhutanese science curriculum. Indeed, basic concepts such as "The Earth and Heavenly Bodies" are taught starting from pre-primary schooling. For the semi-structured interviews, 12 students were selected, comprising 3 participants each from low achievers, middle achievers, and high achievers to provide authentic data representing all levels of student performance.

Data collection

Two instruments were used for data collection: ACT and Semi-structured Interviews. The interventions extended over three weeks, after which the post-intervention data was collected. The pre-test was conducted before the intervention using an astronomy conceptual test and followed by a post-test using the same test items after the intervention. In addition, as a part of post-intervention data, 12 students were interviewed.

Astronomy Conceptual Test

The conceptual test consisted of 15 multiple-choice questions that were developed to examine conceptual comprehension of astronomy. The questions were competency-based and it was further contextualized. Moreover, most of the questions were framed involving high-ordered thinking to challenge and engage students meaningfully. The test items were based on an instructional guide designed by the DCPD of the Ministry of Education and Skills Development of Bhutan. Finally, the test was assigned as the *Astronomy Conceptual Test (ACT).*

Pre-test and post-test data from participants were gathered in two periods. The pre-test was administered before the intervention to assess the student's prior knowledge of astronomy concepts. Students' conceptual comprehension development and the effectiveness of multimedia as a learning strategy were assessed using the same test questions as a post-test. The test items were reshuffled in the post-test to discourage students from attempting to answer questions in the post-test without

sufficient knowledge, ensuring that students do not answer questions just by rote learning.

Interventions

Before the intervention, lesson plans were developed on astronomy concepts for different topics for seventh grade. For different topics in astronomy science teacher designed a lesson incorporating different multimedia such as PowerPoint, video clips, Edpuzzle learning videos, quizizz, TED talks, articles, and journals from the internet and Google Scholar.

The intervention using multimedia was carried out for the participants after the pre-test. The intervention lasted for three weeks. Most of the science classes as an intervention were conducted in ICT labs where students explored information on related topics employing TED talks, articles, and journals. However, Edpuzzle learning videos and Quizizz were assigned by tutors and provided with the link and URL for the classes assigned. The lessons on astronomy were focused only on the contents prescribed by the instructional guide designed by the DCPD for grade seven. Further, the lesson employing different multimedia consisted of 40 minutes for each class.

Semi-structured interview

Because of its versatility and flexibility, the semi-structured interview is still the prevalent data-collecting method, quality semi-structured interviews in qualitative research contribute to the objectivity of the research and make the result reasonable (Kallio et al., 2016) however, methodological research on the development of a semi-structured interview guide is sparse.

Validity and reliability

The study's instruments must be reliable and valid to produce authentic results. An essential part of the research instrument is the accuracy and consistency of the equipment (Taherdoost, 2016). The pilot study was carried out before the study to determine the reliability and validity of the pre-test and post-test of the study. Those 15 multiple-choice questions were evaluated by a panel of experts (N=4) who had extensive knowledge and experience in teaching middle secondary schools. As a result, the study's content validity was established and approved. In addition, the credibility of the semi-structured interview questions was ensured by inviting suggestions and feedback from 3 qualitative research experts.

Data analysis

ACT was used to obtain quantitative data, while semi-structured interviews were used to acquire qualitative data. The pre-test was used to assess students' pre-understanding of astronomy concepts, while the post-test was used to assess the effectiveness of multimedia as a learning approach. In addition, the result of the pre-test and post-test was analysed using the statistical package for the social sciences (SPSS, version 26) and confirmed the impact of multimedia strategy on the students' performances. A histogram and paired sample t-test were used to compare quantitative data from pre-test and post-test scores. For the t-test, a statistically significant difference was considered as one with a level of significance equal to or lower than 5% ($p \leq 0.05$).

The semi-structured interview data were analysed to get the students' perceptions of multimedia as a learning strategy. Through a non-verbatim approach, students' comments were recorded and transcribed independently for each participant. The transcriptions were then analysed using Braun and Clarke's (2019) theme analysis method. The theme was organised into perspectives of multimedia by students when learning astronomy concepts.

Ethical consideration

Considering the code of ethics, written approval and permission for this study were sought from different stakeholders. The written approval was granted by the school action research committee which was spearheaded by the Principal as the chairperson. Further, the written consent form was also sought from student participants. Before the data collection of this study, student participants were informed and briefed about the purpose of the study, and the time commitment they will have to provide during the data collection. On completion of data collection, the individual participants were assigned pseudonyms in the written portrayal to protect their confidentiality.

Result

The study results are presented in two sections: The first section consists of quantitative data with histograms and paired-sample t-test. The second section consists of qualitative data obtained from the semi-structured interview collecting perspectives of students on the use of multimedia on astronomy-related concepts.

Quantitative data

The quantitative data pertains to the research questions "What are the students' pre-understanding of the concepts related to astronomy and how does multimedia

affect student's achievement on astronomy concepts? The pre-test and post-test scores were initially compared using the histogram, and the results are depicted below in Figure 1.

Figure 1

Histogram comparing pre-test and post-test scores

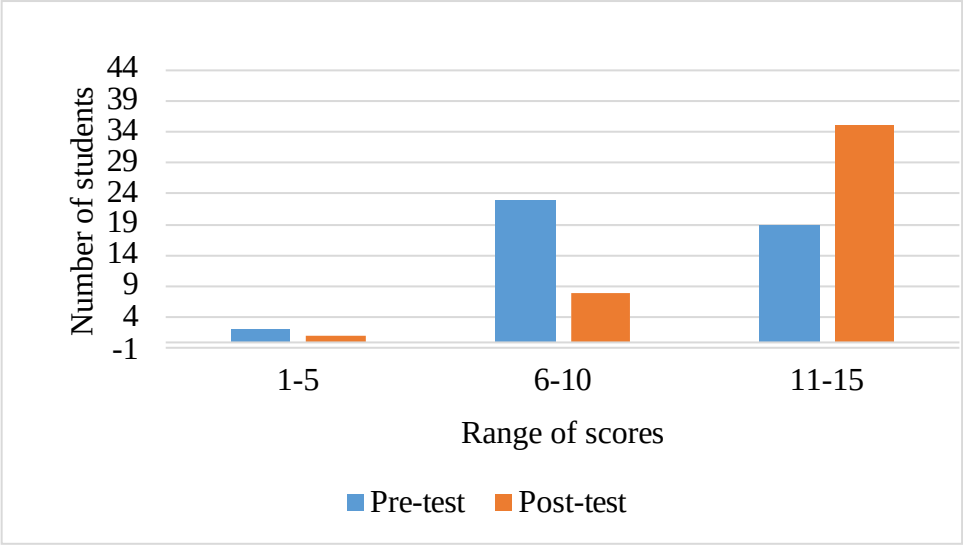

Figure 1 depicts the maximum number of students (42 students out of 44 students) scored between the range of 6 to 10 and 11 to 15 in the pre-test. The mean score of the pre-test was 9.8. After the intervention with the use of multimedia, the majority of the students (43 out of 44) scored between the range of 6 to 10 and 11 to 15 with a mean score of 11.9. There was an increase in the mean score of 2.1 in the post-test compared to the pre-test. The significant difference in students' pre-test and post-test mean scores was determined using a paired sample t-test, and the result of the comparison is displayed in Table 1.

Table 1

Paired Sample t-test Comparison of the Students' Performance in the Pre-test and Post- tests Assessments

Assessment	N	Mean score(%)	SD	Mean score difference (%)	T	Df	p-value	Cohen d
Pre-test	44	9.75	2.52	2.18	-5.75	43	.000**	0.9
Post-test	44	11.93	2.43					

**p<0.000(critical value)

The result of the paired sample t-test revealed that students' performance in the post-test (mean = 11.93, SD = 2.43) was significantly higher than the pre-test (mean = 9.75, SD = 2.52) with t (43) = -5.75, p = 0.000<0.5 (see Table 1). Quantitative results suggested that students' performance in astronomy conceptual tests improved significantly after multimedia interventions. From Cohen's d value of 0.9, it was noted that approximately 90% of students' performance in astronomy conceptual test is accounted for by the multimedia intervention.

Qualitative data

Other research questions were how does multimedia affect students' achievement in an assessment of astronomy concepts? And what are the challenges in using multimedia while learning concepts related to astronomy? To answer these two questions, two themes were considered. The study employed Braun and Clarke's thematic analysis to generate themes for the qualitative data. According to Scharp and Sanders (2019), Braun and Clarke's thematic analysis approach consists of six steps, which include familiarization with the data, developing coding categories, producing themes, reviewing themes, defining and labelling themes, and locating examples.

Students' perceptions towards the use of multimedia for learning concepts in astronomy

Items from the semi-structured interview sought to determine different forms of multimedia used and whether the use of multimedia helped in understanding concepts in astronomy. The finding indicated almost all the students had used only basic forms of multimedia like text, audio files, images, video materials, and animations. For instance, when asked about different forms of multimedia used in learning concepts in astronomy, student 2 mentioned: "To learn about concepts in astronomy we get articles from Google, videos materials from YouTube, animations, free version of Edpuzzle learning videos coordinated by science teacher".

Regarding the understanding of concepts in astronomy when using multimedia, students agreed that they get additional information in the forms of texts, audio, videos, etc. Getting additional information on concepts of astronomy resulted in improved learning and understanding. Student 11 asserted, "In our textbook, there is limited information, and from the use of multimedia we get more information leading to understanding more about the particular topic". Obtaining additional information from multimedia also aided in correcting students' mistakes.

Further, students mentioned that the use of multimedia like Quizizz and Edpuzzle learning videos with embedded quiz questions in the multimedia content was fun and easy to understand.

Challenges when employing multimedia in learning concepts in astronomy.

We attempted to study the challenges faced by students when using multimedia to learn concepts in astronomy. The majority of the participants mentioned time constraints as the major challenge, stating that they didn't get time to gather adequate information on the related concept. For instance, student 12 stated, "A major challenge is that we don't get enough time to browse all information needed for the particular topic within a short duration". Furthermore, most of the participants mentioned that they didn't get enough time to watch videos related to the particular topic. As a result, students are unable to fully comprehend the essential concepts of a particular topic.

Discovering accurate online information was another challenge students faced while utilizing multimedia to learn astronomy concepts. As a result, students struggled to select the accurate and pertinent material for the given topic. Stressing on abundant information available on the internet, student 10 stated, "As there was a lot of information from the multimedia and internet, we got confused from which to select for the particular topic assigned by teachers". Students who were unable to choose pertinent information for the given topic were unable to comprehend it. Consequently, when asked how students handled this difficulty, they mentioned that they browsed the material hastily and then selected the information that they perceived was the most appropriate.

Discussion of the result

The quantitative results revealed that using multimedia for learning astronomy enhanced seventh graders' achievement in certain topics. This improvement in students' achievement was evident since the use of multimedia in learning astronomy concepts provided students with control over the things learned. It signifies that students actively participate in learning. Furthermore, multimedia aided in comprehending abstract concepts when presented in the form of images, audio, and videos. Multimedia such as web-based instruction provided authentic visualization of astronomical phenomena by making abstract concepts concrete to students, which was not provided by the text (Nthimbane & Kazeni, 2019). Additionally, a study by Abdillah et al. (2020) found that the use of visuals in the form of photos and videos for astronomical education 'eight planets' was a particularly effective form of communication for millennials.

The qualitative data indicated that students mostly use basic forms of multimedia such as like text, audio files, images, video materials, and animations. Text is a simple and most basic aspect of multimedia content (Sulisworo et al., 2020). Furthermore, students mentioned that they got additional information in the forms of texts, audio, videos, etc. Hence accessing the additional information that was absent in the textbook helped students to learn, understand, and rectify their mistakes for the particular topic. A study by Gali (2021) suggested that the direct transfer of knowledge from textbooks without prior knowledge involves students memorizing abstract concepts. Additionally, the study also suggested that it is not adequate to simply provide concepts from the textbooks to achieve a greater conceptual understanding of astronomical phenomena. Using animations and games like AstRoamer helps students learn fundamental astronomy concepts and develop favorable attitudes toward science and astronomy (Shaikh et al., 2020).

Despite students accomplishing greater conceptual comprehension of astronomy concepts, students encountered numerous challenges such as time constraints to locate additional information for a particular concept. Furthermore, students faced difficulty in determining the accuracy and authenticity of information while browsing a wide range of sources on the internet for a specific topic. This finding is consistent with the study by Blown & Bryce (2022), which discovered that time constraints and timetable structure hindered children from conducting direct observational astronomy. The finding also corroborated the findings of Chi and Churchill (2016), which stated that students faced difficulties in filtering a large amount of information. Thus, we conclude that the lack of time makes it difficult to fully understand astronomy concepts in the Bhutanese context although students can find adequate information online.

Conclusion

The study found that the use of multimedia during the learning of astronomy concepts promoted higher learning achievements in grade seventh science. Additionally, students had a favorable perception of the use of multimedia. Students held views that the use of multimedia provides access to astronomy-related content more than textbooks which aided in their learning, comprehension, and acquisition of new information. However, students faced difficulties in managing time and filtering relevant information on the internet. Hence, our study concludes that multimedia can serve as an effective tool for teaching and learning astronomical concepts among seventh graders, provided that students are equipped with adequate skills in time management and information filtration.

Recommendation

Findings from this study showed that the use of multimedia is effective in enhancing the learning outcome of astronomy concepts. Teachers teaching science domain are encouraged to adopt multimedia as an alternative to the lecture method especially for concepts related to astronomy. Although the effectiveness of multimedia on learning astronomy concepts and perceptions of students towards multimedia is widely studied in the global context, there is very limited research conducted on the subject in the context of Bhutanese schools. Therefore, there is a need for further studies on this subject in Bhutan. While the scope of this study was limited to grade 7 students, there are opportunities to investigate its effectiveness across different grade levels in Bhutanese schools. In addition, while this study focused solely on the perspectives of students, future research could also explore the perspectives of teachers.

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About the Authors

Kinga Tshering is currently a teacher at Trashigang Middle Secondary School and has Master's degree in Education (Physics). To date, he has published 3 research articles. "Exploring Physics teachers' reflective practices and the challenges" in Vietnam Journal of Educational Science. "Physics Teachers' Reflective Practices in Middle and Higher Secondary School: A Case Study" in Asia-Pacific Journal of Educational Management Research. "Use of Edpuzzle learning videos for class 9 Biology and its impact on academic performance" in International Research Journal of Science, Technology, Education, and Management **(IRJSTEM).** The e-mail id is kingat@ education.gov.bt

Dorji Wangchuk is a teacher at Kengkhar Middle Secondary School. He teaches Economics and English to middle school students. As an aspiring writer, he published two non-fiction books: Mysterious Journey of My Education: A U-turn to School (in 2020) and What a Bull Said: Why I Wish I Had Bunked Classes (in 2021). In 2022, he published a case study, 'Challenges of Emergency eLearning in Rural Bhutan: A Case of Kengkhar Middle Secondary School during the COVID-19 Pandemic' in the Asian Journal of Education and Social Studies. He is collaborating with Professor Rene Adrin Villano of the University of New England Australia on research, 'COVID-19 and Emergency eLearning in Rural Bhutan: Challenges, Opportunities, and Policy Implications'. In addition, he wrote a few chapters for the grade 11 and 12 Economics textbooks initiated by the REC. In 2024, he received the Fulbright Scholarship to pursue a master's degree in Sustainable International Development at Brandeis University in Waltham, MA, USA. His e-mail id is dorjiwangchuk571@educationgov.bt.

Dil Bahadur Mongar is a dedicated academician with a Master's degree in Education, specializing in Chemistry, from the Samtse College of Education under Royal University of Bhutan. He currently serves at the Bhutan Council for School Examinations and Assessment (BCSEA) under the Ministry of Education and Skills Development. In this role, he contributes to the development and evaluation of examination and assessment

protocols, ensuring that they are fair, comprehensive, and reflective of Bhutan's national curriculum. Dil Bahadur began his career as a teacher, where his passion for education and innovative teaching methods stood out. He created engaging and interactive learning environments, making complex chemistry concepts accessible to his students. dbmongar2022@education.gov.bt.

Kelzang Dema is a teacher at Trashigang Middle Secondary School. She holds a Bachelor of Education(General). She published one research article. “Use of Edpuzzle learning videos for class 9 Biology and its impact on academic performance” in International Research Journal of Science, Technology, Education, and Management **(IRJSTEM).** The e-mail id is kelzangdema2020@education.gov.bt