Digital content development and their uses in secondary mathematics classroom

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Digital content development and their uses in secondary mathematics classroom

A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy.

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February 2025

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APPROVAL

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DECLARATION

I hereby declare that this thesis has been created in alignment with the university's guidelines on the presentation of a research thesis and conforms to the regulations for the degree of Doctor of Philosophy. The material contained within this thesis is my original work and has not been submitted for consideration for any other degree.

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Pedagogy: Learning Objectives (Photograph used in digital content)

[Shahid Minar Monument; An animated picture of Circumference of the Circle; Area of the Circle; Area of the Circle; Title of the Lesson (Simple Simultaneous Equation); Draw the Graph of the Equation; Parabolic-shaped Pictures; Graphs of Quadratic Equations; Graph of the Parabola; Pictures of Triangle shapes; Pictures of Triangle shapes; Pictures of Triangle shapes; Construction of different Triangles; The text about Infinite Triangles; Pictures of Cone shapes; Definition of Cone; Surface of Cone; Pattern in the Pictures; Definition of Progression; Concepts of Arithmetic Progression; Pictures of Set; Picture of Set; Definition of Set; Finite Set; Infinite Set; Van Diagram; Concepts of Relation; Concepts of Function; Concepts of Function and Relation; Concepts of Function and Relation; Video on Trigonometric Ratios; Concepts of Right-angled Triangle; Concepts of Right-angled Triangle; Pictures of Rectangular Solid; Definition of Rectangular Solid; Total surface area of a Rectangular Solid]

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Pedagogy: Instructional Design (Photograph used in Digital Content)

[Concepts of Pi; Area of Circle; Area of Circle; Four Quadrants and the corresponding points; Four Quadrants and the Coordinates; Graph of the Equation; The Equation and the Solution; Teacher's work with Geo-gebra; Graph of Parabola; Construction 1 (Triangle); Teacher's work on the Smart-Board; Construction 1 (Triangle); Surface Area of Cone; Surface Area of Cone; Surface Area of Cone; Common Difference in Arithmetic Progression; First Term of Arithmetic Progression; General Form of Arithmetic Progression; Concepts of the union of sets and intersection of sets; Venn Diagram; Concepts of Domain and Codomain of a Function; Domain and Range of the Function Concepts of Function and Relation; One-one Function and Universal Function; Concepts of Trigonometric Ratios; Relation among Trigonometric Ratios; Video on Rectangular Solid; Area and Volume of Rectangular Solid; Diagonal of the Rectangular Solid]

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Learning Context: Classroom Culture (Photograph used in Digital Content)

[Group-Work on Circle; Evaluation slide on circle; Group-work on Simultaneous Equation; Individual Work on Graph of Quadratic Equation; Evaluation on Quadratic Equations; Homework from textbook; Evaluation slide on Triangle; Problem on Surface Area of Cone; Group-work on Cone; Homework from the textbook; Formulas of Arithmetic Progression; Problem and the Solution on Arithmetic Progression; Problem and the Solution on Arithmetic Progression; Problem and the Solution on Arithmetic Progression; Individual work on Set; Pair-work on Set; Group-work on Set; Evaluation slide on Set; Individual work on Function; Pair-work on Function; Problem on Function; Group-work on Function; Solution of the Group-work; Evaluation slide on Function; Individual work on Trigonometric Ratio; Group-work on Trigonometric Ratio; Evaluation slide on Trigonometric Ratio; Individual work on Rectangular Solid; Pair-work on Rectangular Solid; Group-work on Rectangular Solid; Evaluation slide on Rectangular Solid]

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[Pictures of circle shapes (Collected from google); Circle (Collected from the new textbook); Making Pi (Collected from the new textbook); Use of Tarsia Puzzle (Collected from google); Connecting Real-life with simultaneous equation (Collected from google); Real-world problem of Simultaneous Equation (Collected from google); Graph activity of Simultaneous Equation (Collected from google); Simultaneous Equation activity (Collected from the new textbook); Simultaneous Equation activity (Collected from the new textbook); Real-world problem on Parabola (Collected from google); Construction of Triangles (Collected from google); Concepts of Arithmetic Progression (Collected from google); Concepts of Arithmetic Progression (Collected from google); Activity on Arithmetic Progression (Collected from the new textbook); Concepts of Set (Collected from the new textbook); Activity of Set (Collected from the new textbook); Finite and Infinite Set (Collected from google); Van-diagrams (Collected from google); Finite and Infinite Set (Collected from google); Van-diagrams (Collected from google); Concepts of Relation (Collected from google); Concepts of Function (Collected from google); Concepts of Trigonometry (Collected from the new textbook); Trigonometric Ratios (Collected from google); Activity on Trigonometric Ratios (Collected from the new textbook); Trigonometric Ratios (Collected from google); Rectangular Solid-shaped Pictures (Collected from google); Surface Area of Rectangular Solid (Collected from google)]

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Figure 149 – 164: 220-238

Learning Context: Classroom Culture (Photograph from Google and New textbooks)

[Tasks about the Area of the Circle (Collected from Google); Activity on Circle (Collected from Google); Pair work on Circle (Collected from the new textbook); Group activity on Circle (Collected from the new textbook); Activity on Graph of Equation (Collected from google); Activity on Graph of Equation (Collected from google); Graph activity on Parabola (Collected from google); Activity on Parabola (Collected from google); Activity on Triangles (Collected from google); Activity on Cone (Collected from google); Group work on Arithmetic Progression (Collected from google); Group activity on Arithmetic Progression (Collected from new textbook); Activity of Set Operation (Collected from google); Activity on Function and Relation (Collected from google); Activity on Trigonometric Ratios (Collected from new textbook); Activity on Trigonometric Ratios (Collected from new textbook); Group work on Rectangular Solid (Collected from the new textbook)]

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LIST OF ABBREVIATIONS

a2i- Access to Information

BEDU- Bangladesh Examination Development Unit

DC- Digital Content

GOB- Government of Bangladesh

FSSAP- Female Secondary School Assistance Project

FGD- Focus Group Discussion

ICT- Information and Communication Technology

MMC- Multimedia Classroom

MMCs- Multimedia Classrooms

MoE- Ministry of Education

MoPME- Ministry of Primary and Mass Education

MQI- Mathematical Quality of Instruction

NCTB- National Curriculum Text Board

NGO- Non-Government Organization

PTK- Pedagogical Technology Knowledge

SESDP- Secondary Education Sector Development Project

SESIP- Secondary Education Sector Investment Program

SEQAEP- Secondary Education Quality and Access Enhancement Project

TIP- Technology Integration Panel

TOT- Training of Trainer

TPACK- Technological Pedagogical Content Knowledge

TTC- Teachers' Training College

TTTC- Technical Teachers' Training College

TRU- Teaching for Robust Understanding

TQI-SEP- Teaching Quality Improvement in Secondary Education Project

UNDP- United Nations Development Programme

USAID- United States Agency for International Development

UNESCO- The United Nations Educational, Scientific and Cultural Organization

UNESCO ICT CFT- UNESCO ICT Competency Framework for Teachers

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ABSTRACT

Digital content in mathematics classrooms has significantly increased in the last few decades. This study aims to explore the existing situation of mathematics teaching and learning using digital content and the integration of pedagogical approaches in secondary mathematics multimedia classrooms (MMCs).

A comprehensive review of past and existing training manuals was conducted to inform the study design. This was combined with the findings from the five selected mathematics teachers' interviews with the insights gathered from three mathematics teacher educators' interviews to gain a deeper understanding of the trained teachers' conceptions of digital content in mathematics classrooms.

A qualitative case study approach was used to facilitate an in-depth exploration and investigation of this topic. This methodology allowed for a rich and nuanced understanding of the complex issues surrounding the integration of digital content in mathematics teaching-learning. Five trained mathematics teachers from five schools were selected using maximal variation techniques to ensure a diverse range of backgrounds. The selection criteria included factors such as training received (national and international ICT training, length of digital content development training), experience, gender, type of school, and location. Eighty students from these five schools were also chosen to participate in the focus group discussions (FGD). The existing multimedia mathematics classroom activities in these five schools were observed and recorded on video, that being facilitated by the five trained mathematics teachers. Field notes were made while paying close attention to listening to the recorded audio and video materials. The researcher then translated and transcribed the audio and video data, and analyzed the connections between the teachers' pre-lesson interviews and subsequent lessons to gain insights into how they utilized digital content. To achieve a more comprehensive understanding of the topic, a triangulation design was used to integrate data from three sources: lesson observations, teachers' post-lesson interviews, and students' focus group discussions. This triangulation approach allowed the researcher to explore the thinking of both teachers and students on various aspects of learning mathematics with digital

content in the classroom, including their perspectives on the benefits, challenges, and effective use of digital tools.

The findings of the study revealed that although teachers were capable of creating digital content, they faced challenges in integrating pedagogy in a way that fostered creative and innovative learning experiences for their students. The trained mathematics teachers believed that digital content kept students engaged and attentive through visual elements like images, animations, and videos. However, they were not aware of the importance of integrating pedagogy. It was noted that the training manuals did not include sessions about in-depth learning and practice of the pedagogy integration using digital content, and it can be inferred that the mathematics classes followed a traditional lecture method using digital content in the form of PowerPoint presentations. The mathematical tasks or activities in lessons that incorporated digital content were often found to be lacking in challenge and diversity, failing to provide opportunities for students to engage in creative and innovative thinking. Additionally, there was no supportive physical space or effective technology infrastructure in the classroom, and the students did not benefit from the multimedia classroom's use of digital content in terms of problem-solving, conceptual development, and critical thinking in mathematics. The recommendations necessitate redesigning the training programs for mathematics teachers to include mathematical digital content and various software with a strong pedagogical alignment. The findings of the study might be helpful to policymakers in focusing on supportive physical space in the classrooms and student-centered technology infrastructure and modifying the mathematics curriculum by integrating mathematical ICT resources along with diversified and challenging mathematical tasks for effective mathematics teaching and learning.

Key Words: Digital content, pedagogical approaches, multimedia classrooms (MMCs), mathematics teaching-learning using digital content, technology-enhanced physical space, mathematical tasks using ICT, effective mathematics teaching-learning.

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Chapter One

Introduction

1.1 Background of the Study

Teaching is becoming one of the most challenging professions in contemporary society (Jung, 2005). Knowledge is expanding rapidly through technology and this vast amount of information is now easily accessible to students and teachers simultaneously. Students use technologies to acquire knowledge and create new things in new ways (Klopfer et al., 2009). But at the same time, Information and Communication Technologies (ICT) have placed more demands on teachers to learn and adapt to these new tools in their teaching-learning process. Innovative technologies have provided various possibilities to teaching professions and there is a big challenge for now how teachers effectively integrate ICT with their subject content (Hennessy et al., 2010). Kilag (2023) explains that integrating ICT into the classroom boosts student motivation, enthusiasm, and engagement, allowing for innovative tools and materials that facilitate interactive learning and simultaneous access to technology. The term Information and Communication Technology (ICT) is a term of different tools of technology that are used to transmit, process, store, create, collect, display, share, or exchange knowledge and information with people and resources by electronic means all over the world (UNESCO, 2007). UNESCO (2018) states that it is essential to have the competencies for teachers to integrate ICT into their professional practice to guide learners in developing knowledge society skills such as critical and innovative thinking, complex problem solving, the ability to collaborate, and socio-emotional competence.

The Government of Bangladesh has planned to introduce Information and Communication Technology (ICT) initiatives to revolutionize the education system. As part of the Bangladesh Government's vision 2021 agenda, the Access to Information Project (a2i) has initiated to reform the traditional education system by introducing 'ICT in Education' to make teaching and learning more fun and engaging in primary, secondary, and madrasah levels in the country (Khanam et al., 2013). The ICT initiatives in education started with introducing 'multimedia classroom (MMC)' and 'teacher-led content development' in 500 primary schools, 15200 secondary schools, and 5300

madrasahs through different projects of the Ministry of Education (MoE) and Ministry of Primary and Mass Education (MoPME). The goal of the teacher-led digital content development training program was to enhance the quality of teaching and learning through the use of ICT in education and also support the professional development of teachers (a2i, 2013).

Imon (2017) describes digital content as combining various digital media types, including texts, images, videos, and audio, which are integrated with pedagogy to create a meaningful, multi-sensory, interactive, and learner-centered presentation for students. A recent study by Viberg et al. (2023) highlights the importance of teachers' thorough understanding of digital tools in mathematics education. The findings suggest that teachers should learn about digital tools and carefully design learning situations to create a more effective and engaging learning environment for students. The ultimate goal of digital content development training programs is to make teaching and learning more effective and enjoyable for both students and teachers through using ICT. In the digital content development training programs, the participant teachers learn computer primary skills, PowerPoint presentation skills, email, internet browsing, and downloading relevant things. During training programs, the trainee teachers learn mostly about preparing and presenting subject-based PowerPoint presentations named digital content using the materials that they found on the internet. The participant teachers have to learn to insert topic-related text, images, and videos, and use animations in the presentation slides; in this way, they make the digital content of PowerPoint presentations for their classrooms. However, the effective integration of ICT with subject content is a challenge. The challenge for schools is not just using these tools but how the tools are used in learning. The ways of using ICT must also be linked to educational goals and objectives. In many developing countries including Bangladesh, most teachers have minimal ICT skills themselves, and therefore they find it hard to develop ICT resources for learners. Hennessy et al. (2010) explains that effective teacher education and continuing professional development are the two of the most important supports for ICT integration into teaching-learning practice. Vandeyar & Adegoke (2024) explain in their recent study that teacher have to adapt their pedagogical approaches to effectively integrate technology into their teaching practices acquiring relevant knowledge and skills.

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In Bangladesh, the secondary level of the education sector is the classes 6 to 10 of the 12-year cycle of formal schooling. For the development of secondary education, the Government of Bangladesh and some NGOs have undertaken several projects named Teaching Quality Improvement in Secondary Education Project (TQI-SEP), Secondary Education Sector Investment Program (SESIP), Secondary Education Sector Development Project (SESDP), Female Secondary School Assistance Project (FSSAP), Secondary Education Quality and Access Enhancement Project (SEQAEP), a2i, ICT, etc. Mathematics at the secondary level can be challenging for students to understand and make progress, as it often appears as an abstract subject. Most students solve problems mechanically by knowing some rules or formulas and will try to apply them when solving problems. Mathematical literacy needs to be visualized to the students to make it concrete. Integrating visualization systems can enhance the learning process in a digital environment, making a more effective and cost-effective way to improve learning quality for the new generation of students (Liu et.al., 2020). Using ICT in mathematics classes can create a fun and engaging environment that can help students to be motivated with excited in solving problems with a clear understanding and enhancing their thinking level. The students can explore mathematical ideas and concepts by using proper ICT tools in learning mathematics, if the teachers can effectively integrate technologies with pedagogy; that would help the students to analyze, create, and make relations of the abstract mathematics problems to the real-life. This task is easier said than done. Abedi's (2023) research reveals that actual technology integration practices and effective implementation of technology in education can lead to more meaningful and impactful learning experiences, ultimately benefiting students' learning and development of modern competencies. The Bangladesh government has stepped up to prepare the teachers for a successful implementation of ICT in education. According to the Education Policy 2010 of Bangladesh, GOB designed with a2i's support a USD 40 million educational transformation program to establish multimedia classrooms (MMCs) in over 23000 secondary schools, madrasahs, and junior colleges and train nearly 70000 teachers by 2014 (a2i, 2014).

1.2 Statement of the Problem

In the development of digital content training programs, teachers employ a variety of multimedia elements including text, images, animations, audio, and videos, which are typically incorporated within a PowerPoint document. However, teachers face numerous challenges when implementing technology-based instructional strategies in the mathematics teaching-learning process. Most teachers may find it difficult to incorporate new technology and they may be unfamiliar with how to apply their existing pedagogical knowledge to the use of ICT, which can lead to difficulties in designing effective learning experiences. a2i recognized that it is important to empower teachers in a different way in the era of digital technology. In the field of education, a2i has introduced a significant change in perspective, emphasizing 'ICT in education' instead of focusing on 'ICT education'. One slogan a2i has been using is 'Content Development by the Teachers, for the Teachers' (a2i, 2014). With this slogan, a2i has developed a model for teacher's empowerment; the model has been expressed as follows: Empowerment (E) = Multimedia classroom (M) × Content (C) × Connectivity (C) × Collaboration (C); that is, $E = MC^{3.}$

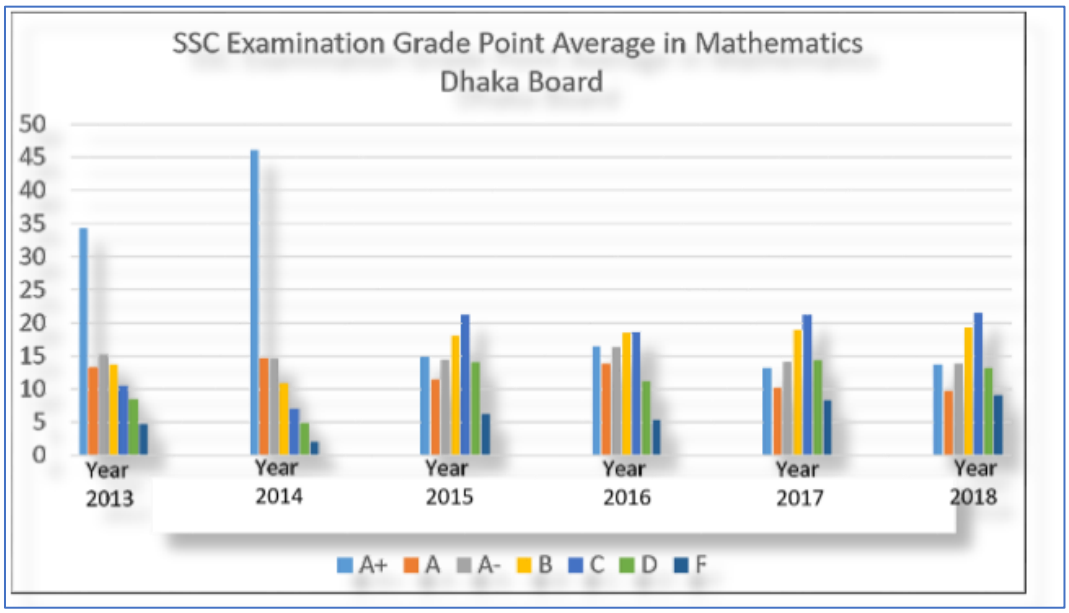
From the very beginning of a2i, the researcher has had first-hand experience in the Digital Content Development Training Program as a trainer of 'Training of Trainers' (TOT) and as a Master trainer. It has been found that the teachers are generally comfortable with practicing basic ICT skills, like using computers or the Internet. However, they find it challenging to combine these ICT skills with their teaching methods and subject content. The a2i project proposal has organized teacher-led digital content development training programs for teachers from various subjects altogether. It has been found challenging to focus specifically on a specific subject, integrating pedagogy into mathematics content and mathematics ICT. Most participant teachers are new to ICT experience in the training program. So, they are eager to learn primary ICT knowledge, instead of pedagogy integration. The participant teachers enjoy learning to write text, insert images and videos, and use animations in their digital content of PowerPoint presentations. They enjoy using PowerPoint presentation software for creating presentations and browsing the internet for relevant content. Most participant teachers find it challenging to recognize the significance of incorporating pedagogy into ICT and content when developing and presenting their digital content in the training sessions. From the researcher's experience as a trainer, most trained teachers show the presentation

slides one by one and explain them to the students in the MMCs at secondary school instead of creating a learner-centered environment. Numerous research studies have revealed that teachers often fail to employ ICT in their classrooms in a pedagogically appropriate way (Mishra, 2018). Teaching will become more meaningful and attractive when teachers interact with the pedagogical and technological knowledge in their classrooms (Vandeyar & Adegoke, 2024).

As a teacher educator, the researcher has observed a stark contrast between the initial expectations and the reality in many mathematics classrooms. Instead of actively engaging in learning and developing creative and critical thinking skills, students often passively watch presentation slides, rather than participating in collaborative activities, communicating effectively, or undertaking productive tasks. The researcher has observed in many mathematics multimedia classrooms that, there is a limited presence of interactive and mathematically challenging activities in mathematics lessons, which are not pedagogically aligned. Most students do not engage deeply with mathematical concepts, and they have yet to become creative and productive in multimedia classrooms. Despite this, integrating pedagogy and meaningful mathematical tasks remains a considerable challenge for mathematics teachers. Furthermore, the teachers struggle to create a meaningful learning environment by incorporating pedagogy and ICT. Unfortunately, over the past few years, there has been little progress in the results of public examinations in Bangladesh, indicating a persistent need for improvement (Table 1, Graph 1).

	SSC Examination Grade Points in Mathematics at Dhaka Board										
Year 2013		Year 2014		Year 2015		Year 2016		Year 2017		Year 2018	
Grade	Percent	Grade	Percent	Grade	Percent	Grade	Percent	Grade	Percent	Grade	Percent
A+	34.3	A+	46.1	A+	14.9	A+	16.4	A+	13.1	A+	13.7
A	13.2	A	14.7	A	11.4	A	13.8	A	10.2	A	9.7
A-	15.2	A-	14.6	A-	14.4	A-	16.3	A-	14.1	A-	13.8
B	13.7	B	10.8	B	18	B	18.4	B	18.9	B	19.3
C	10.5	C	7	C	21.2	C	18.6	C	21.2	C	21.5
D	8.4	D	4.9	D	14	D	11.1	D	14.3	D	13.1
F	4.7	F	1.9	F	6.1	F	5.4	F	8.3	F	9

Table 1- Ref: Bangladesh Examination Development Unit (BEDU)



Graph 1

This study investigates the use of digital content at secondary mathematics classes in Bangladesh, exploring its affect in mathematics teaching-learning process. Strijbosch (2017) explains that ICT can enhance mathematics education significantly, as it allows students to delve deeper into the

subject, develop foundational skills, equip students with the necessary competencies, and prepare them for the future world.

1.3 Rationale and Significance of the Study

Vandeyar & Adegoke (2024) explains that the quality of both pre-service and in-service training plays a crucial role in equipping teachers with the necessary competencies to effectively integrate technology into their teaching practices. The Access to Information (a2i) program, supported by the United Nations Development Program (UNDP) and United States Agency for International Development (USAID), was started in 2007 to promote the use of technology in education. Since then, the government of Bangladesh has launched several projects and programs to improve education through technology. These projects have included training programs for teachers to develop digital content and use multimedia classrooms. Teaching Quality Improvement in Secondary Education Project Phase-I and Phase-II (TQI-SEP-I and TQI-SEP-II), ICT for Education in Secondary and Higher Secondary Level Project (ICT Project: Phase-I and Phase-II) and Non-gov College Project have been provided the digital content development training programs in different Teachers' Training Colleges all over Bangladesh. Bangladesh Bureau of Educational Information and Statistics (BANBEIS), Technical Teacher Training Colleges (TTTC), Higher Secondary Teachers' Training Institutes (HSTTI), Bangladesh Madrasah Teachers' Training Institute (BMTTI), many government and non-government colleges, many schools and other institution have organized a similar training program for their teachers, and have been facilitated by the teacher educators. The training programs have been mostly 12-day courses, but some institutions have provided shorter 6-day training programs. The goal of all these programs was to help teachers develop their skills and knowledge in using digital content in the classroom. There was also a special 12-day training program for visually impaired teachers across Bangladesh. All these programs aim to empower teachers with the skills and knowledge they need to use digital content effectively in their classrooms. Additionally, there were distributed twenty thousand and five hundred (20,500) laptops, multimedia projectors, speakers, and internet modems to participating institutions, including Madrasah institutions (moedu.gov.bd). Besides, Banglalink, Intel, Hosaf-Group, and other private partners came forward under the public-private partnership (PPP) approach to implement its 'Multimedia Classrooms' and 'Teacher-led Content

Development' initiative project enhancing the use of ICT in education (Ahmed et al., 2015). A big online collaboration platform has been designed as the teacher's portal named "Shikkhok Batayon" to meet teachers' needs for multimedia content and empower the teachers. The teachers themselves have developed and uploaded digital content in this portal during and after getting the training. They shared their ideas, innovations, and interchange content through this online platform (a2i, 2015). Another initiative has been introduced suggesting a '6CAP' competency profile to co-create a preferred future education learner of 2041 in Bangladesh. The learners will be Communicative, Collaborative, Critical thinkers (and problem solvers), Creative (and innovative), Global citizens (who are active), Changemakers, Adaptive and, Productive (and proactive) (Shovon, 2019).

Over the past fourteen years, the Bangladesh government has undertaken numerous initiatives to integrate ICT into education. The Government has made a tremendous effort to provide training to teachers across face-to-face and digital platforms. The primary objective of these initiatives is not only to enhance the classroom learning experience by making it more engaging, interactive, and effective but also to prepare learners for their future careers. However, despite these efforts, the desired outcome remains elusive in real classroom settings. This is why it is crucial to investigate the use of digital content in mathematics classrooms, particularly in the context of Multimedia Classrooms (MMCs), to better understand the current situation and identify areas for improvement.

After receiving training, teachers have improved their skills in using laptops and creating digital content with ICT resources. The teachers have created digital mathematics content that combines images, videos, animations, and text to make it attractive to students. However, despite these advantages, there is still a significant gap to be bridged to equip students with the critical thinking, creativity, and problem-solving skills necessary for success in the digital age.

So, in this context, the researcher feels that this is a proper time to look at how students and teachers will benefit from all these education programs in terms of applying digital content to acquire competencies in real mathematics classrooms. Moreover, there is a lack of research on how teachers utilize digital content in secondary-level mathematics classrooms in Bangladesh. This is obviously a proper time to know what new technological knowledge of mathematics training is

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needed for the teachers to equip them in the constantly changing and transforming knowledge society. As the researcher is a trainer of digital content development training programs, these are all the reasons that led to the decision to focus on this particular research study. The findings of this study can assist policymakers in identifying the necessary changes to improve the design of digital content development programs and future educational plans for mathematics teachers, ensuring that students are equipped with the skills and mathematical reasoning needed for the world of 2041.

1.4 Purpose and Research Questions

The overall purpose of this study is to explore how mathematics teachers incorporate digital content in their secondary school classrooms after completing digital content development training programs. To fulfill this purpose, the following research questions have been formulated for the study.

1. How do teachers develop their understanding of digital content in mathematics from the digital content development training programs?
2. How do teachers use digital content in secondary mathematics classrooms?
3. How does the use of digital content affect the secondary mathematics teaching-learning process?

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Chapter Two

Review of Related Literature

2.1 Introduction

Education must take the opportunity from the rapidly changing world increasing access to quality learning. In this rapidly changing knowledge society, it is essential to prepare students to be active and collaborative with quality teaching (Garrison, 2017). Active and collaborative students can transform their perceptions and apply their knowledge to real-world problems. This review of the related literature will function as a guideline focusing on the study of mathematics teaching-learning with digital content. The sub-topics ICT in education, Education and technological frameworks, ICT integration in classrooms, Mathematics learning-teaching, Digital content in mathematics classrooms, and Literature in Bangladesh have been considered in this chapter. The review of the literature will inform the development of a conceptual framework, which will serve as the structural foundation for the study. The conceptual framework will provide a framework for the research questions, guiding the investigation and ensuring a comprehensive examination of the research topic. According to Hennink et al., (2020), an effective conceptual framework is essential for facilitating a clear understanding of the research questions and how they relate to other. This framework is typically developed through deductive reasoning, drawing on existing literature and theoretical foundations to provide a logical and systematic structure for the research.

2.2 ICT in Education

ICT stands for Information and Communication Technology, which is an extended term of technology. The term 'ICT in education' refers to the use of Information and Communication Technology (ICT) in educational settings (UNESCO, 2017). In education, technology is a tool used to enhance learning and improve learning outcomes in the classroom. Digital content, ICT, and technology in education are often used interchangeably to describe the development of teaching-learning processes. As UNESCO (2018) notes, "Information and Communication Technology (ICT) can complement, enrich, and transform education for the better". Education

serves two primary functions: education as a means of ensuring continuity and education as a driver of creativity and innovation (Haddad and Draxler, 2002). ICT in education aligns with the latter function, which promotes creativity and innovation in the educational process.

ICT has been used to enhance teachers' professional knowledge, skills, and capabilities, thereby providing students with broader access to learning resources (Lim, 2007). Developing ICT competency is a vital requirement for teachers, as it enables them to effectively utilize various ICT tools and resources. To this end, teachers need to possess more than just subject knowledge, learning theories, and a good understanding of ICT resources (Gu et al., 2013). Instead, they must acquire the skills to harness the potential of ICT to foster problem-solving, collaborative, and creative learners who can apply their knowledge effectively in real-world situations (UNESCO, 2011). Moreover, teachers' innovative abilities play a crucial role in nurturing learners' potential by imparting new knowledge and preparing them for lifelong learning in a constantly changing and transforming world (Devetak et al., 2010). Teachers should create learning environments that foster creativity, innovation, and critical thinking, equipping their learners with the ICT skills needed to thrive in the future workplace (Vandeyar & Adegoke, 2024). By enhancing their ICT competency, teachers can better equip themselves to provide students with the skills and knowledge needed to thrive in an increasingly complex and interconnected world.

ICT is best used as a supplement to normal teaching-learning practices, rather than as a replacement. ICT engages and motivates students, but students will benefit more if technology is effectively aligned with an appropriate pedagogical framework (Higgins et al., 2012). The strategy of using technology can facilitate students' skill development, promoting active collaboration, innovative thinking, and critical problem-solving (Habler et al., 2016). This is crucial for reforming new pedagogical ideologies to engage students in innovative work, project-based learning, and active participation, ensuring effective technology use in education (Almas & Krumsvik, 2008). Technologies can be used strategically and powerfully as a method of learning and teaching in the classroom, helping students develop deeper learning with higher-order thinking skills and prepare for life and work in the 21st century (Debe & Future, 2014). The term '21st-century skills' refers to core competencies such as collaboration, digital literacy, critical thinking, and problem-solving, which are essential for students to fully participate in today's global society (Silva, 2009). Students

need to be able to share their thoughts, questions, ideas, and solutions to succeed in this digital age. According to the Digital Success Program (2016), digital transformation is a vital phenomenon that individuals must prepare for in today's competitive world. Students learning skills should focus on what they can do with knowledge, not just knowing (Silva, 2009). A learner-centered classroom environment that fosters problem-based and project-based learning can help students create, collaborate, and engage with people worldwide (Rotherham & Willingham, 2010). To achieve this, teachers should incorporate critical and creative thinking skills, information and technological skills, communication, and collaborative skills into their teaching practices. By acquiring and applying these skills, students can solve problems in real-life contexts (Marope, 2014).

The future of education will shape what tomorrow's world will look like. Every learner will have the ability to learn from anywhere, at any time, and in different places, thanks to the internet, making them smarter in the future (Hooijdonk, 2019). Learners must be prepared to meet the demands of the era and the challenges of an uncertain future. Project-based learning and working processes are essential for today's students, as they will learn how to apply their skills to various situations in a shorter timeframe. This approach will provide more opportunities for learners to acquire real-world skills that are relevant to their future careers (Henny, 2016).

2.3 Education and Technological Frameworks

2.3.1 The TPACK Framework

There are several different educational frameworks for technology integration in the classroom. One of them is the technological pedagogical content knowledge (TPACK) which focuses on teachers' understanding to integrate technology effectively in their classroom. Mishra & Koehler (2006) introduced the TPACK framework consists of seven domains: content knowledge (CK), pedagogy knowledge (PK), technological knowledge (TK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK) (Figure 1). The TPACK framework has been introduced to support and enhance the changing role of teachers in integrating technology effectively into their teaching practices. Teachers can use technology to employ pedagogical

techniques that leverage students' current knowledge to enhance their understanding and promote the development of new knowledge (McComas, 2014). The way of Integrating ICT with pedagogies should prioritize fostering high levels of interactivity among students, as well as between students and teachers, and between students and the technologies being used (Dzimiri & Mapute, 2013). The development of the TPACK framework offers a valuable theoretical lens through which to explore the knowledge and skills that educators need to successfully integrate technology into their classroom (Hofer & Swan, 2008). Stapf & Martin (2019) explained that the researchers utilized the TPACK framework to gain a comprehensive understanding of how

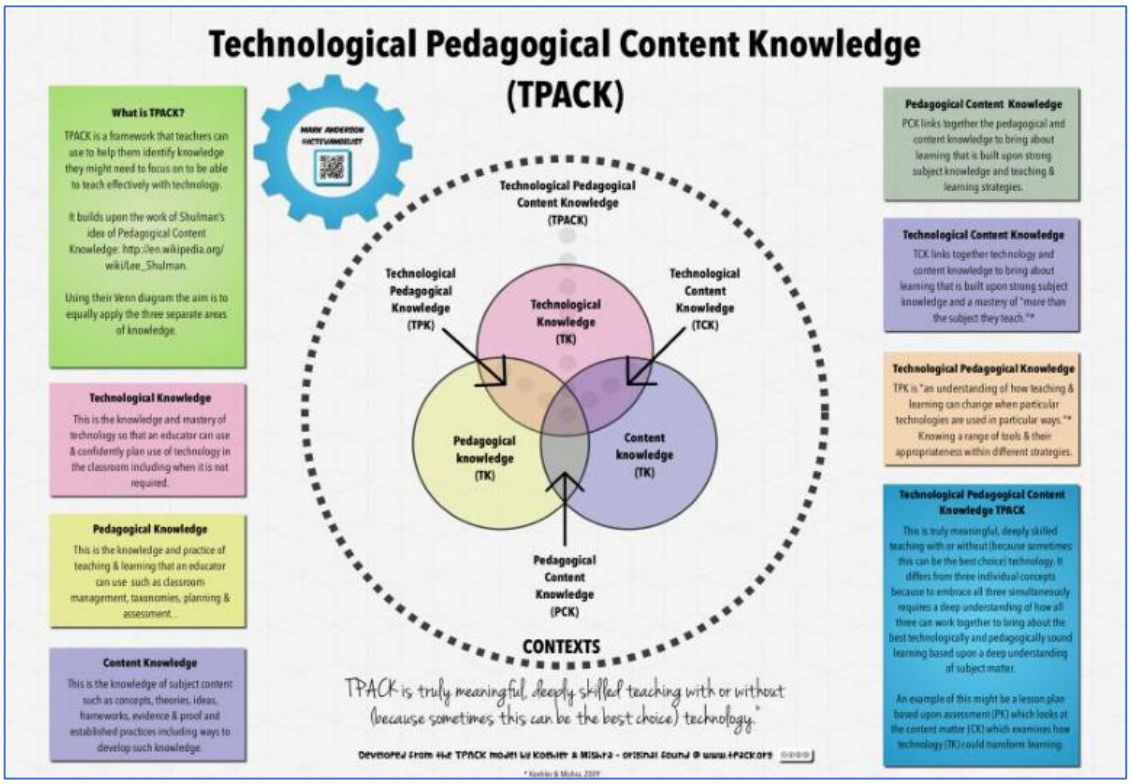


Figure 1 -TPACK Framework by Mishra and Koehler (2009)

technology can be effectively integrated into classroom instruction. The TPACK framework is indeed crucial for teachers at all instructional levels as it provides a structured approach to aligning pedagogy, technology, and content in the teaching and learning process. This framework was important at all instructional levels to help teachers align their pedagogy with technology and content in the teaching-learning process. Teachers should know to integrate powerful technology, appropriate pedagogy, and rich content in their teaching practices to empower learners with

a deeper understanding and develop their higher-order skills. (Mishra, 2018). Muslimin et. al. (2022) found in their study that before the treatment, teachers' confidence in using technology to teach (TPACK) was low because they did not feel confident in their technical skills (TPK), content knowledge (PCK), or teaching methods (TCK). However, after the treatment, teachers' confidence in using TPACK increased significantly, and this was because they had improved their skills in TPK, PCK, and TCK.

2.3.2 The UNESCO-ICT Competency Framework

The UNESCO ICT Competency Framework for Teachers (ICT-CFT) aims to support policymakers and curriculum developers in creating national plans for integrating technology into education by enhancing teachers' digital skills. Educational systems must continually update and refine teacher training and professional development to guarantee that all teachers can effectively use technology to enhance teaching and learning (UNESCO, 2018).

According to the framework, there are three approaches to six aspects of a teacher's work. The six aspects of a teacher's work are understanding ICT in education, curriculum and assessment, pedagogy, ICT/application of digital skills, organization and administration, and teacher professional learning (Figure 2). In the 2018 ICT CFT, the aspect of 'ICT' has been termed as the 'application of digital skills'. The approaches of the UNESCO ICT Competency Framework for Teachers (version 3) represent different stages in the use of ICT in education. The three different levels of teaching are knowledge acquisition, knowledge deepening, and knowledge creation.

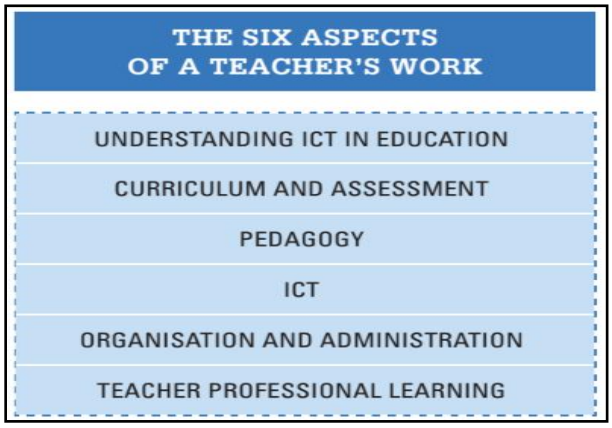


Figure 2- The six Aspects

(UNESCO ICT-CFT, 2011)

The first stage of the process is Knowledge Acquisition (Figure 3), where teachers learn about the effective use of technology and basic digital skills to support specific curriculum topics. At this stage, teachers need to understand the potential benefits of using technology in the classroom. They should be able to identify ways to utilize technology to enhance student learning, foster engagement, and improve their teaching practices. Teachers must be able to use ICT to manage the classroom, support students' lifelong learning. This helps the students to gain a deeper understanding and develop new ideas. By creating new knowledge, students can contribute to making their communities better and more successful. In the 2011 UNESCO ICT CFT, the level of 'knowledge acquisition' was termed 'technology literacy'.

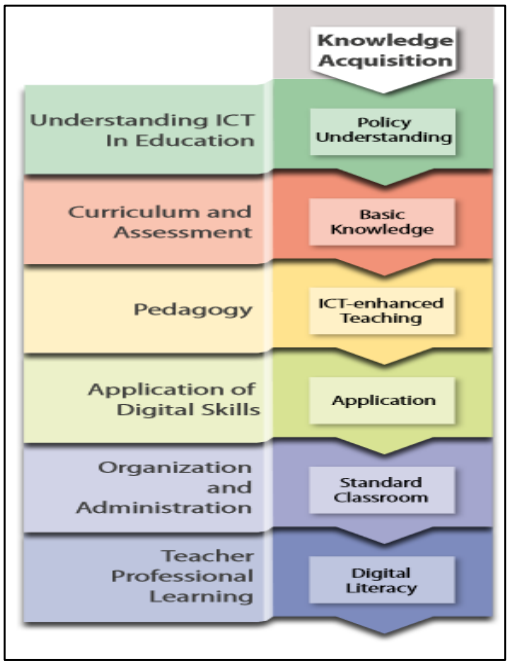


Figure 3- Knowledge Acquisition

The aim of the knowledge-deepening approach (Figure 4) is to increase the ability of students to solve problems in real-world situations. Teachers should also utilize technology to facilitate student-centered learning, including designing and tracking individual and group project plans and collaborating with peers to enhance their professional development. In this approach, the teacher's role is to provide guidance, feedback, and support as needed, as students work together on projects. Teachers assist students in creating, implementing, and monitoring project plans and solutions. The classroom structure becomes more dynamic, with students engaging in collaborative group work for extended periods to enhance learning. To facilitate students' understanding of fundamental concepts, teachers will utilize subject-specific open-ended ICT

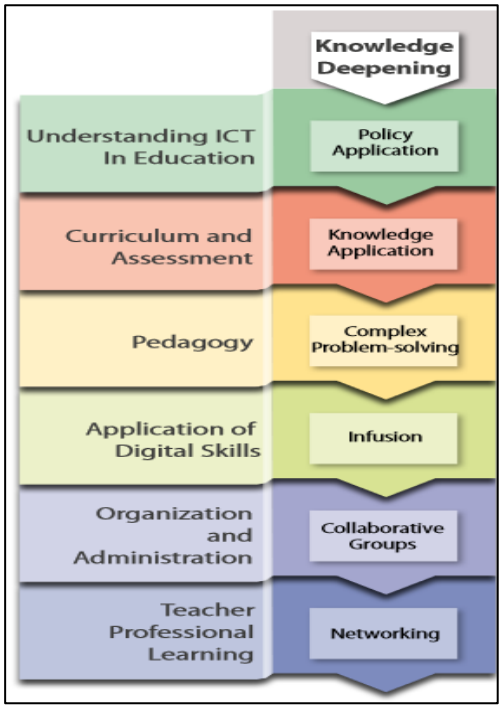


Figure 4- Knowledge Deepening

tools, such as visualizations and data analysis tools in mathematics and role-play simulations in social studies, to promote deeper learning.

According to the framework (Figure 5), the Knowledge Creation approach aims to foster productivity by empowering students to engage in continuous learning, innovation, and lifelong learning. This enables them to participate effectively in the digital society. Teachers serve as model learners and knowledge producers, actively involved in educational experimentation and innovation. They collaborate with peers and external experts to generate new knowledge on teaching and learning practices. By creating a dynamic learning environment, teachers facilitate student involvement in enhancing their and their peers' learning abilities. The primary goal of education is for students to take ownership of their learning by setting their own goals, evaluating their strengths and weaknesses, and developing a learning plan. They must also monitor their progress, capitalize on achievements, and adapt to setbacks. Teachers proficient in the knowledge creation approach can design and develop learning resources and environments incorporating ICT, utilizing technology to enhance critical thinking skills and promote knowledge creation. They facilitate ongoing reflective learning, establish knowledge communities for students and colleagues, and take a leadership role in establishing and implementing a vision for their school as an innovative community focused on continuous learning.

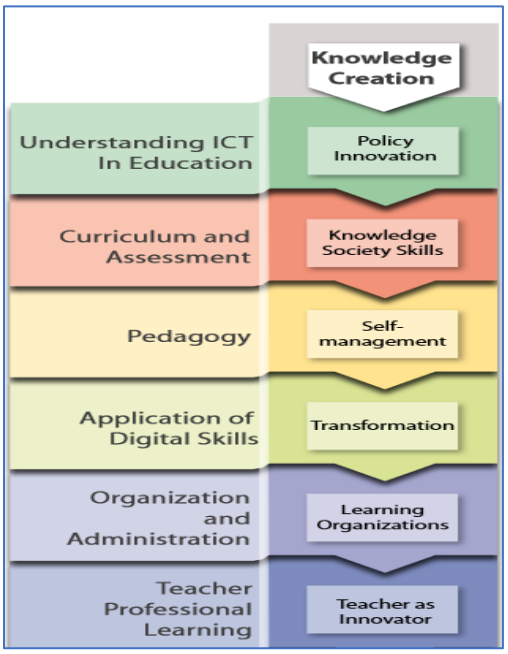


Figure 5-Knowledge Creation

UNESCO published three versions of ICT frameworks in 2008, 2011, and 2018, each reflecting the evolving landscape of technology in education and incorporating popular technologies (as cited in UNESCO, 2018). Teachers should possess the necessary competencies to effectively conduct teaching and learning in an ICT-enabled classroom. The UNESCO ICT-CFT can assist schools in gaining a deeper understanding of how ICT can be utilized for teaching, learning, and assessment purposes. Teachers should possess the ability to guide students in developing collaborative,

problem-solving, and creative skills through the use of ICT (UNESCO, 2011). The framework helps teachers involved in teacher professional development to create a wider range of learning opportunities for teachers and principals. UNESCO strives to assist countries in enhancing and broadening education through SDG4 by harnessing the potential of ICT (UNESCO, 2018). But Rakisheva & Witt (2023) commented that the UNESCO ICT-CFT framework is not entirely suitable for training future teachers because the level of digital skills has increased significantly, and being digitally competent in teaching is now a new requirement for teachers.

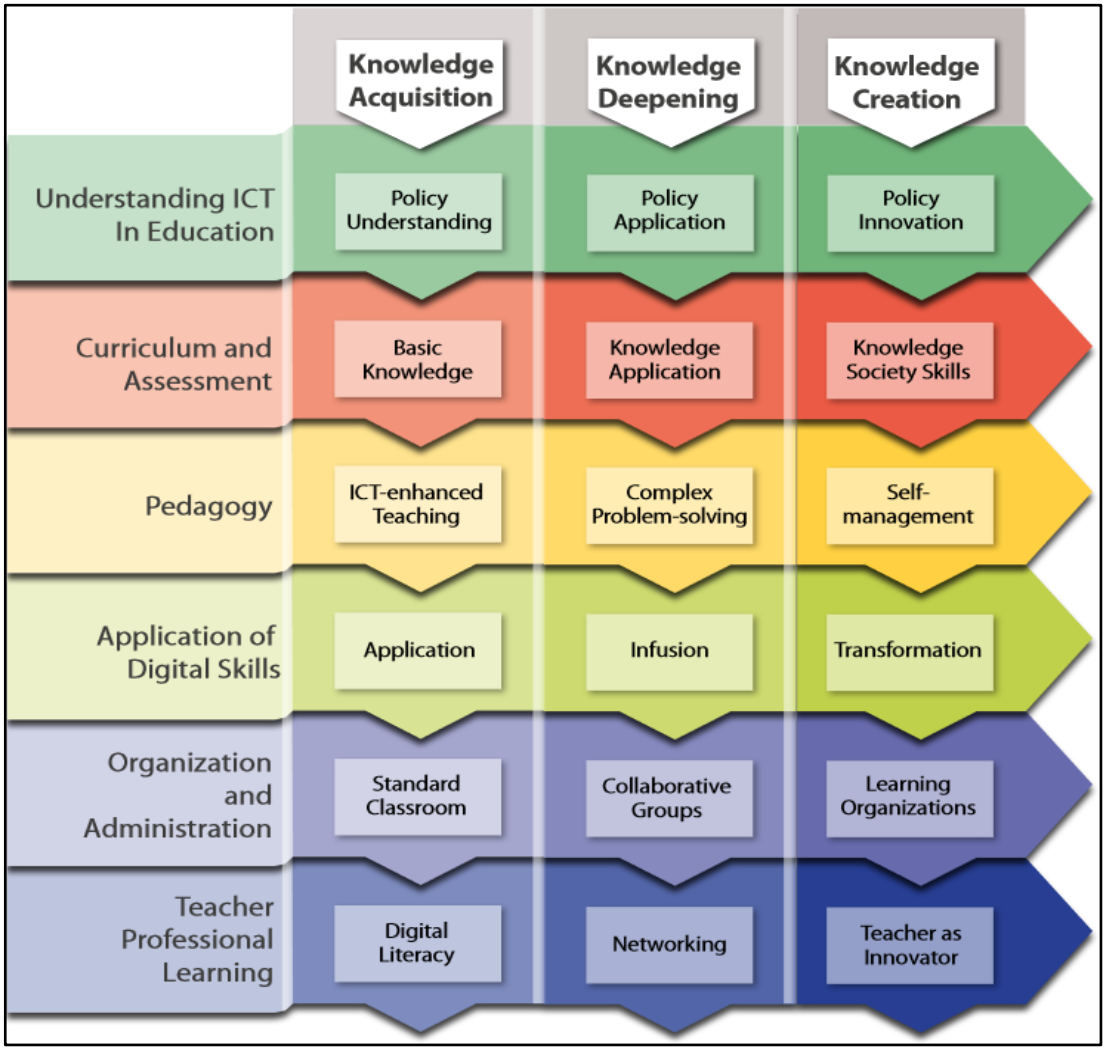


Figure 6- UNESCO ICT CFT-2018

2.4 ICT Integration in Classroom

The integration of Information and Communication Technology (ICT) in education is essential for improving academic performance and providing students with diverse learning experiences. As most teachers and learners are already familiar with the internet, the focus should be on developing their knowledge and skills to use ICT effectively in education (Toma et al., 2023). According to Lim (2007), ICT enables learners to acquire information through active discovery, combination, and application of resources, developing skills in problem-solving and communication.

One of the key benefits of ICT in education is its ability to personalize learning experiences for students. With the aid of digital tools, teachers can create customized learning plans that cater to individual students' needs and abilities (Muhtadi et al., 2018). Additionally, ICT can facilitate collaboration and communication among students, teachers, and parents, promoting a more connected and supportive learning environment (UNESCO, 2017). Studies have shown that teachers' attitudes, beliefs, and confidence towards technology play a crucial role in successful ICT integration (Papanastasiou & Angeli, 2018). Hennessy et al. (2010) also have focused on influencing factors such as teachers' perceptions, beliefs, confidence levels, pedagogical expertise in using technology, and the contexts that allow teachers to adopt technology and apply new pedagogical approaches in their teaching-learning practice. According to Nago & Sang (2024), to effectively incorporate ICTs into teaching, it is crucial to develop teachers' capacities and expertise through Professional Learning Communities (PLCs) to enhance their confidence and competence in integrating ICTs into their instructional practices. Bicalho et al. (2023) reveal in their study that analyzing teachers' use of ICT, specifically how they incorporate technologies into their teaching practices, can lead to a greater focus on pedagogical intentionality. Additionally, teachers require ongoing professional development opportunities to cultivate their skills and competencies (Afshari et al., 2009). The rapid expansion of the knowledge society, driven by the widespread use and accessibility of ICT, requires teachers to skill up and develop relevant knowledge to effectively utilize technology in their classrooms (Vandeyar et al., 2024). ICT tools are valuable resources for improving academic performance and developing important skills such as participation and teamwork (Toma et al., 2023). By providing easy access to learning materials, interactive tools, and multimedia content, ICTs can help students learn more effectively and enjoyably. When used

appropriately, ICTs can also boost students' motivation, broaden their perspectives, and prepare them for the challenges of a globalized world (Rofi et. al., 2024). This necessitates a transformation of pedagogical practices to integrate ICT seamlessly into teaching.

Developing an ICT and pedagogy integration plan is not a simple task, it is a complex and time-consuming process that requires careful planning and collaboration (UNESCO, 2011). The integration of ICT is transforming pedagogy by offering innovative methods to engage learners and empower them. However, teachers frequently encounter hurdles when attempting to successfully incorporate technology into their teaching practices, as highlighted by Buabeng (2012). A multitude of factors, including institutional constraints, limited resources, and individual teacher perspectives, can influence teachers' ability to adopt and integrate ICT into their classrooms (Mumtaz, 2006). This diversity of views and experiences can create challenges for the teachers seeking to effectively incorporate technology into their instruction. According to Levin and Wadmany (2008), teachers should have diverse teaching experiences, allowing them to enter the classroom with a broad range of skills and a positive attitude toward technology integration. Moreover, UNESCO (2018) emphasizes that the effectiveness of ICT integration into the learning environment depends on teachers' ability to effectively structure the learning environment by merging technology with pedagogy, ensuring a seamless and effective learning experience. Habler et al. (2016) emphasize that teacher education programs should prioritize the integration of technology into teaching and learning practices, focusing on developing teachers' pedagogical knowledge and skills rather than just technical skills. Vieira and Pedro (2023) suggest that policymakers should focus on improving the use of technology in their curriculum so that future teachers can master digital tools, pedagogical knowledge, and teaching skills. However, the successful integration of ICT in education requires careful planning and implementation. Teachers must be equipped with the necessary skills and knowledge to effectively integrate ICT into their teaching practices (Kennedy, 2023). Furthermore, schools and educational institutions must provide adequate infrastructure, resources, and support to ensure that ICT is used effectively and safely (Voogt & Knezek, 2008). According to Kennedy's study in 2023, teachers need to be equipped to instruct and facilitate learning in ICT-enabled classrooms, where effective pedagogy is crucial for high-quality teaching and learning practices. The outcome suggests that teacher training programs and institutions need to have adequate ICT infrastructure in place. This is crucial

for empowering teachers to effectively use ICTs in their training. Teachers should possess a deep knowledge of their subject area, along with the ability to effectively integrate pedagogy and ICT knowledge in their teaching practices (Debe & Future, 2014). By incorporating richer content, utilizing powerful pedagogy, implementing valid assessments, and establishing connections between in-classroom and out-of-classroom learning through technology, teachers can enhance the effectiveness of learning and empower learners.

2.5 Mathematics Teaching-Learning

Mathematics is complex and it is more than just computation, it involves a deeper understanding of patterns and relationships, as well as thinking, creativity, and language (Lester, 1995). Despite its importance, mathematics has been taught in the same way for centuries (Strijbosch, 2017). Traditional teaching methods often involve teachers writing solutions to problems on the board, and the students only see the teacher's board work of solving problems rather than develop their own problem-solving skills (Galligan et al., 2010). Capraro et al. (2014) argue that one argument is that mathematics is often perceived as just for academics, but it is actually important and relevant for everyone's benefit, and mathematics learning should focus on developing problem-solving skills, rather than just passing tests. Effective problem-solving approaches in mathematics should aim to cultivate students' ability to think independently and enhance their learning capabilities (Isoda, 2010). According to Uzun (2024), problem-solving has been a persistent challenge in mathematics classrooms, where students struggle to articulate what the problem is about, what it requires, and how to progress to solve it. Fry et al. (2025) explain that active learners are encouraged to explore concepts through inquiry, allowing them to engage in productive struggle, reason mathematically to justify their solutions, and represent the mathematics they are working with. (Lester (2013) emphasizes that students need to consistently work on challenging tasks over time to improve their problem-solving skills. They must also have opportunities to tackle diverse types of problems.

According to Lester (2013), the role of the teacher's approach to problem-solving in mathematics, which involves three steps: translating a real-world problem into mathematical terms, operating on it mathematically, and then translating the solution back into reality, is ineffective. Liljedahl et

al. (2016) note that verification in mathematical problem-solving serves not only to check correctness but also to re-engage with the problem at the level of detail. It allows the solver to examine ideas and concepts more closely, refining their understanding during the unconscious work. Effective mathematics teaching, as emphasized by Hofman (2023), relies heavily on effective classroom management. Mathematics teachers' emotions, such as fear or anger, can significantly impact their teaching style, which is deeply connected to their practice. Ndiaye (2019) suggested that teachers strike a balance between their role and students' autonomy in the classroom, enabling learners to actively construct knowledge rather than just passively receiving information. Teachers empower students to recognize their individual strengths and weaknesses in mathematics learning, which is a critical component of effective mathematics instruction that fosters student growth and development (Alfageh et al., 2024). As noted by Uzun (2024), teachers play a vital role in encouraging students to engage in reasoning, provide justifications for their claims and participate in the argumentation process. To achieve this, teachers must undergo the necessary training and preparation to effectively guide students in this process. Teachers must develop both procedural knowledge and conceptual understanding to create a collaborative learning environment where all students can engage and learn. Using visual and practical approaches in their teaching, teachers can align their pedagogy to motivate and excite students about their learning (Reiter, 2014). Providing incentives to teachers can motivate them to revise their instructional approaches and design engaging, interactive and relevant mathematics lessons, thereby encouraging them to rethink their teaching methods and adopt more effective strategies (Souza et al., 2023).

Research suggests that our brain processes mathematical information more effectively when it is presented visually, as students need to develop strong visual pathways to build their mathematical understanding (Boaler et al., 2018). According to a recent study by Wang et al. (2022), mathematics has the potential to foster abstract thinking by engaging visuospatial and semantic networks, which collaborate to facilitate scientific and mathematical processing. These networks rely on the representation of abstract symbols, relationships, and semantic understanding of mathematical concepts, involving generalizing relationships between common properties and creating rules, as well as critical thinking about mathematical ideas and real-world problems (Vale, 2018). Liljedahl et al. (2016) also note that problem-solving and problem-posing are integral parts

of mathematical activity. Although researchers in mathematics education have usually focused more on solving problems, they have also looked closely at creating problems. Many studies have explored how problem-posing relates to student learning and teacher training across all levels of education. According to Baldinger and Louie (2018), teaching mathematics is a complex task that goes beyond simply presenting facts and formulas for students to memorize. Rather, the aim is to foster a robust understanding of mathematics, requiring teachers to employ a range of strategies to promote deeper comprehension. Pedagogies include teaching methods that involve students in meaningful and challenging mathematical problem-solving. These problems are often complex and not straightforward, requiring negotiation and discussion, and they are usually presented within a real-world context (Artigue & Blomhoj, 2013; Fielding-Wells et al., 2014; Makar, 2007, 2012; Makar et al., 2018, as cited in Fry et al., 2025).

2.5.1 The TRU Framework in Mathematics

Schoenfeld & the Teaching for Robust Understanding Project (2016) explain that they have developed a framework for mathematics education that supports the improvement of teaching mathematics in developing deeper understandings and enriching learning environments. The Teaching for Robust Understanding (TRU) framework describes five dimensions of mathematically powerful classrooms that provide a high-quality learning environment (Figure 7). TRU began as a collaborative project between the University of California, Berkeley, Michigan State University, and the University of Nottingham.

Schoenfeld (2014) investigates the connection between classroom practices and student achievement, requiring reliable and comprehensive measures of student performance, specifically in terms of content knowledge, conceptual understanding, reasoning abilities, and problem-solving skills.

The Five Dimensions of Powerful Mathematics Classrooms				
The Mathematics	**Cognitive Demand**	**Equitable Access to Content**	**Agency, Authority, and Identity**	**Uses of Assessment**
The extent to which the mathematical content in which students engage represents our best current disciplinary understandings related to mathematical thinking, learning, and problem solving. Students should have opportunities to learn important content and practices, and to develop productive disciplinary habits of mind.	*The extent to which classroom interactions create and maintain an environment of productive intellectual challenge conducive to students' disciplinary development. There is a happy medium between spoon-feeding content in bite-sized pieces and having the challenges so large that students are lost at sea.*	*The extent to which classroom activity structures invite and support the active engagement of all of the students in the classroom with the core content being addressed by the class. No matter how rich the content being discussed, a classroom in which a small number of students get most of the "air time" is not equitable.*	*The extent to which students have opportunities to "walk the walk and talk the talk," building on each other's ideas, in ways that contribute to their development of agency (the capacity and willingness to engage) and authority (recognition for being a good thinker), resulting in positive identities as thinkers and learners.*	*The extent to which the teacher solicits student thinking and subsequent instruction responds to those ideas, by building on productive beginnings or addressing emerging misunderstandings. Powerful instruction "meets students where they are" and gives them opportunities to move forward.*

Figure 7a- TRU Framework in mathematics (Schoenfeld, 2014)

According to Schoenfeld (2016), the Teaching Works project and the TRU framework are merely a beginning point in addressing the significant challenges the nation faces in rebuilding a teacher workforce that can provide equitable support for students to develop meaningful mathematical knowledge and identities. The TRU Framework was designed to highlight the essential components of teaching and learning mathematics. Alan Schoenfeld and his team over several years suggest that the framework serves as a guide for observing and providing feedback on mathematics learning. This comprehensive framework helps identify powerful mathematics classrooms that support student learning. The core concept of TRU is that students' engagement with content is crucial, and it is essential to consider how they are positioned to benefit from the wealth of knowledge. The main premise of the TRU framework is that a classroom's proficiency in the five dimensions of TRU directly correlates with students' development as informed, adaptable, and skilled critical thinkers and problem solvers.

The TRU Mathematics Conversation Guides provide five sets of reflection questions, each centered on a critical dimension of teaching. These five dimensions, identified by research as crucial for students' mathematics learning, help teachers navigate the complexity of their work and focus on content, instructional practices, and student development as thinkers and learners (Louie et al., 2016).

The Five Dimensions of Mathematically Powerful Classrooms	
The Mathematics	How do mathematical ideas from this unit/course develop in this lesson/lesson sequence? How can we create more meaningful connections?
Cognitive Demand	What opportunities do students have to make their own sense of mathematical ideas? How can we create more opportunities?
Access to Mathematical Content	Who does and does not participate in the mathematical work in the class, and how? How can we create opportunities for each student to participate meaningfully?
Agency, Authority, and Identity	What opportunities do students have to see themselves and each other as powerful doers of mathematics? How can we create more of these opportunities?
Formative Assessment	What do we know about each student's current mathematical thinking? How can we build on it?

Figure 7b-TRU Math Conversation Guide (Louie et al., 2016)

2.6 ICT in Mathematics Teaching-Learning

In today's digital age, teachers need to incorporate digital technologies into their lessons to create interactive, dynamic, contextualized, and motivating learning experiences that allow students to explore new applications of mathematical concepts and transform the classroom environment (Souza & Gonçalves, 2023). Technology can encourage students to explore and think critically about mathematical ideas, providing additional opportunities for learning (Chong et al., 2006). Students can use ICT as a tool to discover things, solve problems, or understand complex concepts; they can use graphing calculators or plotters to solve equations graphically, draw diagrams, and analyze collected data with a deeper understanding (Budhathoki, 2023). GeoGebra is an interactive, web-based software that integrates geometry and algebra. It is created as an educational

tool, it offers diverse resources for learners and teachers alike (Hohenwarter & Jones, 2007). Yildiz & Arpaci (2024) found that participant teachers considered mathematical software such as GeoGebra essential for their professional development, valued it for mathematics instruction, and intended to integrate it into their practice. Furthermore, effective training and support aligned with the TPACK model can enhance their motivation to incorporate GeoGebra into their teaching toolkit. Aggarwal and Bal (2020) emphasize the importance of ICT integration as a necessary tool for both students and teachers and suggest a range of ICT applications that can enhance learning and teaching, including smart classrooms, social media platforms, and specialized software such as MATLAB, Wolfram Mathematica, Maple, Graphmatica, GeoGebra , Math Mechanixs, Math Editors, and Geometry Pad. ICTs are the most powerful tools used for problem-solving, conceptual development and critical thinking in mathematics to spend productive time developing strategies for solving complex problems with a deeper understanding of the various mathematics topics (Das, 2019). Stapf & Martin (2019) comment that technologies paired with mathematical concepts should be chosen strategically, as they could assist students in engaging and understanding often difficult or abstract mathematical content. Dasari et al. (2024) emphasize the importance of a balanced approach, proposing that ChatGPT can be a valuable tool in the learning process when used in conjunction with guidance from teachers. This blended approach can effectively enhance student learning outcomes.

According to Boaler et al. (2018) at Stanford Graduate School of Education, visually representing mathematical concepts and including visual activities can greatly help students learn mathematics with excitement and make it real. Students can explore and make discoveries using games, graphing calculators, puzzles, interactive software, and digital tools (Scharaldi, 2020). To develop mathematical literacy, students should possess fundamental competencies such as communication, mathematizing, representation, reasoning, devising strategies, and using symbolic, formal, and technical language and operations. ICT enables students to productive use of their mathematical knowledge and tackle real-world challenges by achieving these competencies (Turner, 2011). ICT brings learning to life by using videos, animations, graphics, and other interactive software to help students develop skills and understanding in mathematics (Boaler et al., 2018). Drijvers and Sinclair (2024) comment that digital technology in mathematics education has become more comprehensive and interconnected, focusing not only on the digital technologies themselves,

but to consider their relationship with teaching practices, assessment methods, emotional and social impacts, and issues of equity.

Despite the significance of ICT integration, several challenges persist, including difficulties in scanning online materials and limited familiarity with mathematics application software. To address these challenges, it is recommended that special programs be developed to provide hands-on learning experiences for prospective teachers, ultimately enabling them to effectively integrate ICT into learning mathematics (Zamir et al., 2023). Viberg et al. (2023) suggest that schools and teachers should be careful and thoughtful in integrating digital tools into mathematics classes. They should learn thoroughly how the tools work and what they can do, create a learning situation that's right for each student, and set everything up correctly in the classroom. Rather than simply providing technology, it is essential to collaborate with them to foster shared, to promote effective learning. Teachers can become more innovative in their teaching practices and envision themselves as future role models for other teachers and students when using technology strategically to assist students in engaging with often difficult or abstract mathematical content (Stapf & Martin, 2019). The proper use of ICT in mathematics can increase student achievement and motivation and encourage them to become active participants in the classroom (Raines& Clark, 2011).

Technology helps teachers to engage students pedagogically to enhance their thinking and understanding and to reflect more on mathematical results than on producing answers (Jung, 2005). Utilizing digital technologies in classrooms is crucial for mathematics teachers as it serves as a transformative tool in the learning environment, allowing students to engage in new experiences and apply mathematical concepts effectively (Souza & Gonçalves, 2023). Mathematics education should be learner-centered, focusing on inquiry-based learning, problem-solving, or project-based learning that can be done individually or in groups through collaborative activities (Strijbosch, 2017). To enhance mathematics learning, integrating technology in classrooms requires fostering a culture where secondary school teachers are encouraged to combine their knowledge of effective technology integration with the mathematics curriculum and their pedagogical skills. (Yanuarto et al., 2023).

Mathematical content and pedagogy should not be compromised. Liljedahl et al. (2016) suggest that using GeoGebra allows learners to view mathematical tasks as opportunities to engage in activities such as creating dynamic models, formulating conjectures, and always looking for different arguments to support their ideas. Additionally, an online platform enables learners to share their thoughts, problem solutions, and questions on a digital wall, where they can also engage in mathematical discussions that extend mathematical classroom activities. Research suggests that purposeful and well-designed use of PowerPoint presentation software in mathematics classrooms can enhance student learning since it can allow teachers with a variety of learning styles (Raines& Clark, 2011). The classes are made more interesting and exciting with multimedia described as the combination of text, images, sound, video, and animations that offer remarkable opportunities and challenges for teaching mathematics (Ogochukwu, 2010). The PowerPoint presentation provides a fun learning experience for students, they are invited to jump directly into the real world by viewing images, videos, and animations (Kresnadi, 2018). According to Putra and his team (2023), teachers use digital tools like PowerPoint to make learning more exciting. This has been shown to help students learn more effectively, be more creative, and stay focused. The interactive content makes lessons more enjoyable and keeps students from getting bored. Jerika & Lestari (2022) explain that although the results were not statistically significant, the interviews with teachers and students revealed that the interactive PowerPoint learning materials used in mathematics classes during the pandemic were effective in capturing students' attention and boosting their motivation to learn. Aminah and Wahyuni (2018) suggested that by using PowerPoint in mathematics class teachers should create varied and interactive slide designs to enhance interaction and not fixate on PowerPoint throughout the learning process. The use of PowerPoint should be designed to help achieve these goals rather than act as a barrier. The question also raises what mathematical skill means in today's ICT world and what changes are needed to be made in learning mathematics content incorporating pedagogy and ICT to prepare students for tomorrow, world and make them future human resources (Gravemeijer, et al., 2017).

2.6.1 The PTK Framework in Mathematics

The researcher has looked at another mathematical framework, which is Pedagogical Technological Knowledge (PTK) what is related to using ICT in the mathematics classroom (Figure 8). Thomas and Palmer (2014) proposed a new theoretical framework Pedagogical Technological Knowledge (PTK) that is parallel to the TPACK defining teachers' knowledge of integrating technology in the mathematics classroom including the MKT (Mathematical Knowledge for Teaching) factor which relates to pedagogical and mathematical content knowledge (Anabousy & Tabach, 2022).

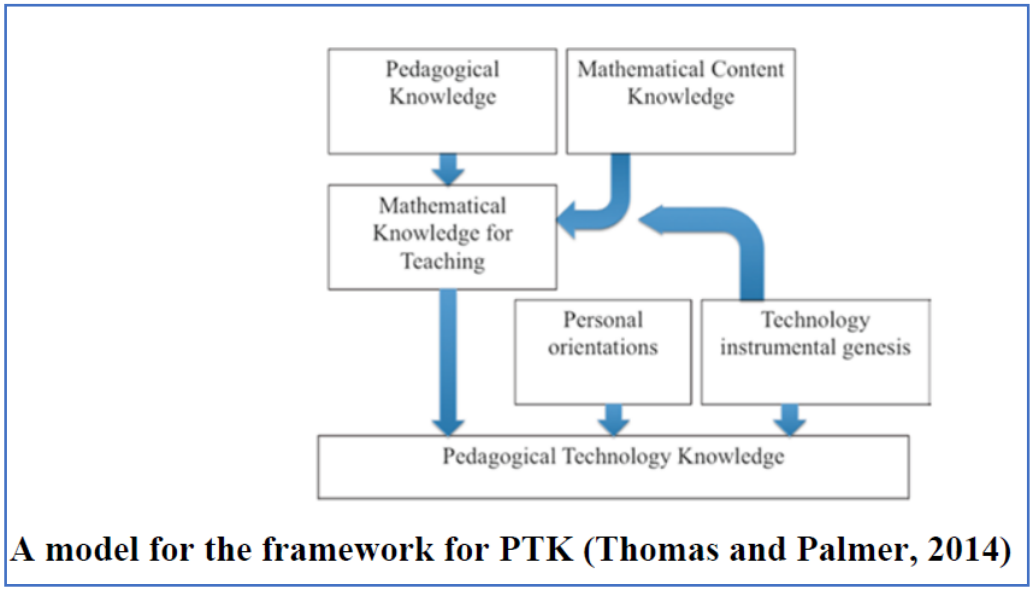


Figure 8- PTK Framework in Mathematics (Thomas and Palmer, 2014)

2.7 Literature in Bangladesh

Numerous studies have been conducted on the integration of Information and Communication Technology (ICT) in education in Bangladesh. Islam (2020) explains that the use of digital content is more effective than the traditional way of teaching because it could make the lesson attractive to the students and reduce their boredom. Khanam et al., (2013) also find the same in their study of the MMC (Multimedia classroom) approach. They pointed out that MMC approaches help the students (a) to understand the lessons easily, (b) to increase their eagerness towards learning, (c) to retain learning, (d) to reduce monotony and cramming in learning, etc. They also suggest that incentive mechanisms for the teachers should be established to ensure better quality digital content for use in the classrooms. The researchers propose that the 'Teachers Training Course' should be designed based on the needs of teachers, so they can learn the skills and knowledge they need to make their mathematics classes more interactive and effective using technology. Additionally, an advanced training course should be designed for teachers to learn how to create their multimedia content. Integrating Information and Communication Technologies (ICTs) in the classroom enables teachers to enhance the learning experience in a manner that was not feasible with traditional technologies (Chowdhury et al., 2011). Banu (2012) recommends, intensive in-service training programs providing content-based teaching material as the teachers were unable to conduct their classes with confidence and competence. Hansson et al. (2018) also find that teachers are motivated to use the teachers' portal 'Shikkhok Batayon' to upload and download digital content. They state that the Teachers' Portal 'Shikkhok Batayon' empowers teachers and has become a key driver for changing Bangladeshi education with quality education. Raiyan (2017) emphasizes the importance of focusing on teachers' basic ICT skills and their application in classrooms, regardless of subject area. Additionally, providing students with opportunities to use computers and ICT materials can help them develop their digital literacy skills and become comfortable using technology for learning purposes. According to Sarowardy and Halder (2019), insufficient resource constraints, the lack of teacher motivation, the absence of expert human resources, inadequate digital tools, and the lack of a multimedia-enabled classroom environment are the barriers to effective teaching. According to Kamal's research in 2019, Information and Communication Technology (ICT) has the potential to transform the education system, but this potential has not been successful due to a lack of appropriate educational strategies. A recent study

by Jahangir et. al. (2021) find that Bangladeshi educational institutions heavily rely on traditional methods and written examinations, despite the potential of digital technologies to enhance learning. However, poor infrastructure and affordability pose challenges. Additionally, Zubairi et. al. (2021) indicate that there is a need for teacher professional development to improve digital content creation skills, as well as a lack of understanding of how to use technology to manage diverse classrooms.

2.8 Conceptual Framework of the study

According to Hennink et al. (2020), a conceptual framework is a visual map that shows the main ideas and connections in the study. It is typically portrayed as a diagram comprising interconnected boxes or nodes, with arrows indicating the potential relationships between the concepts. This diagrammatic representation helps to clarify the researcher's intentions and provides a framework for further exploration and analysis. The conceptual framework for this study on "Digital content development and their uses in secondary mathematics classroom" was developed by synthesizing existing literature, theoretical perspectives, and previous research findings in the field of ICT in mathematics education. This framework incorporates multiple models, including TPACK, UNESCO's ICT competency framework, and the TRU of Mathematics framework. These frameworks serve as a guide for formulating research questions, defining clear objectives for the research process, and mapping out a path to draw coherent conclusions based on the relationships and patterns identified in the research findings.

Digital content development and their uses in secondary mathematics classroom:

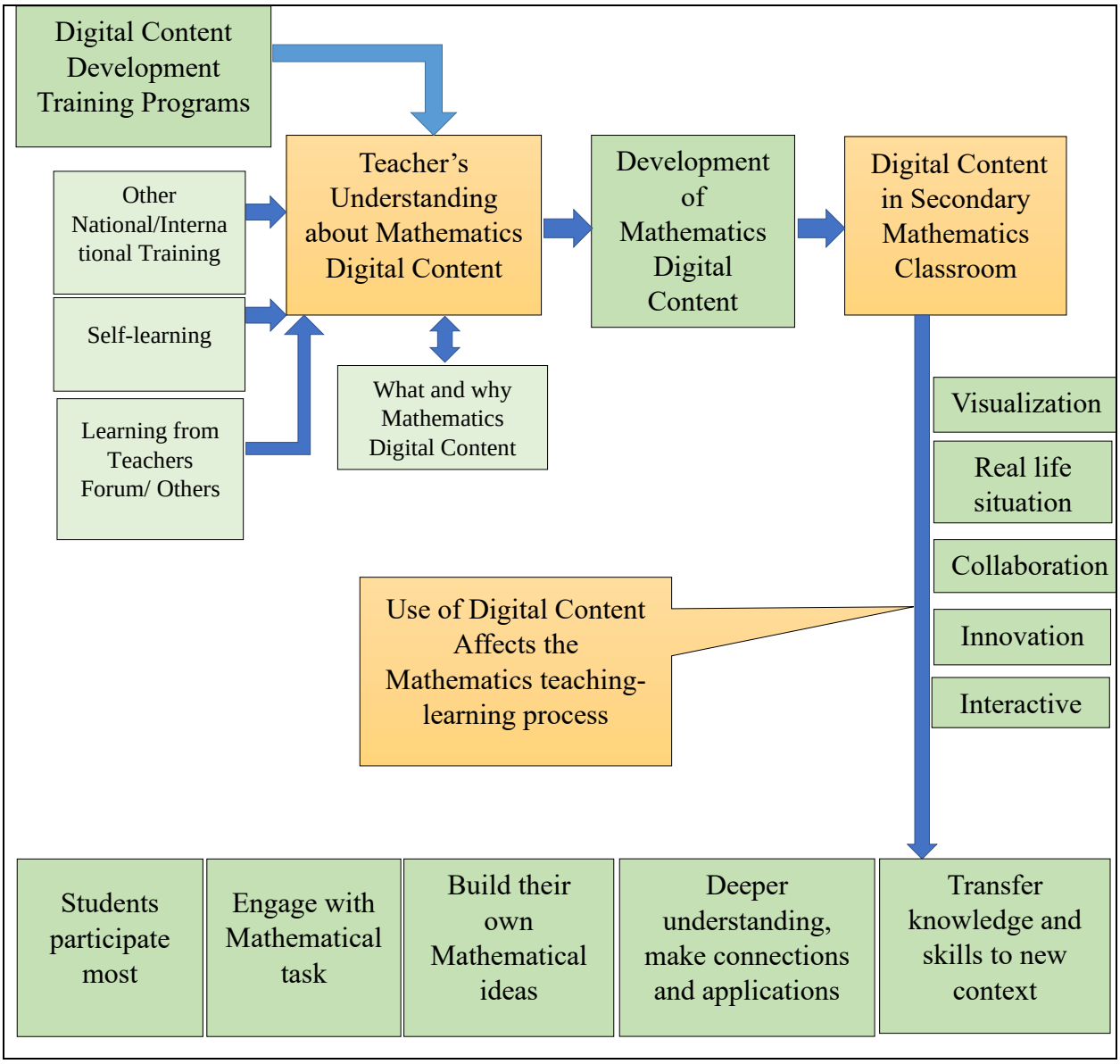


Figure 9- Conceptual Framework

2.9 Research Gap

There is a lack of studies in Bangladesh that provide detailed information about how mathematics has been taught in schools. Most of the existing studies are either purely quantitative or use a mix of both methods. These studies have shown that teachers are motivated and students benefit from multimedia classrooms using digital content. The researchers suggested incentive mechanisms for the teachers to ensure better quality digital content and for using it in the classrooms. However, there is limited evidence about what happens in real mathematics classrooms when digital content is used. In particular, there are no studies that focus on how teachers utilize digital content during mathematics lessons. Therefore, a research gap exists, and my research aims to investigate in-depth how teachers use digital content in their mathematics classrooms in Bangladesh.

Chapter Three

Methodology

3.1 Introduction

This chapter outlines the methodologies and strategies employed to carry out the research activities. This study will explore the practices of mathematics teachers who have undergone digital content development training programs, focusing on how they utilize digital content in their secondary mathematics classrooms. A comprehensive understanding of the research topic requires investigation in depth of the trained teachers' use of digital content in mathematics classrooms and their approaches. This study aims to investigate the understanding of mathematics teachers regarding digital content and their use of digital content in teaching and learning mathematics at the secondary level, as well as the subsequent effects on student views and achievements in the classroom. This kind of in-depth exploration and investigation demands a qualitative approach; hence this study is qualitative in nature using the case study approach. According to Luthfiandana et al.'s (2024) study, case studies are closely related to qualitative research. The authors argue that the case study research approach, which focuses on a few cases, in-depth analysis, and specific conclusions, is well-suited for qualitative research because it allows for a deep understanding of the situation, considers the social context and involves careful interpretation and analysis of the data. The article 'Exploring Qualitative Research: A Comprehensive Guide to Case Study Methodology' by Nasri (2023) offers an in-depth exploration of qualitative research methodologies, with a particular focus on case studies. The researchers can triangulate data by using multiple data collection techniques, including interviews, classroom observations and document analysis (Vandeyar & Adegoke, 2024). According to Koster & Fernandez's (2023) study, in the context of qualitative research using a case study approach, the phenomenon is explored and interpreted through methods such as individual interviews, focus groups and classroom observations. The scope and depth of qualitative research conducted through a case study approach can be significantly enhanced by collecting more detailed and nuanced data, thereby providing a more accurate and meaningful understanding of the phenomenon under investigation.

3.2 Selection of the Respondents

According to Hennink et al., p. 17 (2020), "Due to the in-depth nature of qualitative research, few study participants are needed, as the purpose is to achieve depth of information by "mining" each participant deeply for their experiences of the research topic. Data are textual and generated through different methods such as interviews, focus group discussion or observation". Three mathematics teacher educators, who worked as the Trainer of Training (TOTs) of the digital content development training programs were selected conveniently from three different Teachers' Training Colleges in Bangladesh to gather their opinions on the training program, the development of digital content, and the trained teacher's understanding of ICT use in mathematics classrooms. The Training Documents (Training Manuals) were also examined to explore the ways how participant mathematics teachers developed their understanding of creating and utilizing digital content.

Vandeyar et al. (2023) conducted a study employing maximal variation sampling, selecting schools with varying levels of technology access and infrastructure. In this study, the researcher selected five trained mathematics school teachers using a maximal variation technique, considering diverse backgrounds such as national-international training received, experience, gender, expertise in ICT, and location of the five different schools (Table 2). Five trained mathematics school teachers from five different secondary schools in Bangladesh were selected as the cases for this study. The teachers were chosen for their diverse backgrounds and varied experiences, ranging from 8 to 30 years of teaching. Three of the teachers received 12-day digital content development training from Teachers' Training Colleges, while two received 6-day in-service training in their institutions. Additionally, two teachers attended the international ICT-based training program of fifteen days, one in Korea and the other in Thailand. Two teachers of them were chosen from the top-ranked list compiled by a2i (personally collected the list from a2i). One of these two teachers, who was also awarded as the best teacher in the teacher's portal, had particular expertise in developing digital content and incorporating it into their lessons.

The schools where these teachers work are located in urban, semi-urban, and rural areas of Bangladesh. Specifically, three schools are from urban areas, one is from a semi-urban area, and one is from a rural area. The urban schools are split between two girls' schools and one boy's school, while the semi-urban and rural schools are co-education.

The schools' multimedia classrooms also vary. One urban school has only one multimedia classroom, and it was unused for days. Another urban school has a multimedia classroom in its college section, but teachers must request permission to use it. The third urban school has three multimedia classrooms and is actively working to establish more. They used their multimedia classrooms by rotation. The rural school has four multimedia classrooms, and the teachers also use digital content by rotations. Conversely, the semi-urban school has different arrangements. They have multimedia in all their classrooms with a Smartboard, while the teachers must use digital content in their every lesson.

Eighty students were selected purposively from five different schools (5x16=80) for ten focus group discussions (FGDs). Eight students from each mathematics class were chosen to explore their thoughts on various aspects of learning mathematics with digital content in their lesson. Zhao & Chen (2023) revealed in their recent study that the impact of ICT in education on students' achievements is primarily attributed to the enhancement of teachers' efforts and enthusiasm, increased student involvement, and positive responses.

3.2.1 A summary of maximal variation sampling in the selection of five trained mathematics teachers:

Sex and their Schools	Age Yrs.	Exp Yrs.	Educational Qualification	Trainings	No of MMCs and its usability	Use of Digital Content (DC)
Female Govt girls' school- urban.	44	16	BSc (Hons), MSc, BEd	14 days of national training. 15 days of international training in Korea.	No-Three (3) Use by rotation	Own made DC
Female, One of the best teachers awarded by a2i Private school-boys- unban.	35	8	BSc (Hons), MSc, Med	6 days In-house training,	No-Zero (0) But one (1) was in the College section. No uses	Own made DC
Male Army-ruled school, co-ed, Semi-urban	36	10	BSc (Hons), MSc, BEd	6 days of in-house training	No- all the classrooms Use in every lesson.	Own made DC GeoGebra and Smart-board
Male Govt co-ed school- rural	47	23	BSc, Med	14 days of national training and 6 days of follow-up training	No-4 Use by rotation	Downloaded DC from Teachers' Portal Content
Male, One of the best teachers awarded by a2i. Non-govt girls' school, urban	59	30	BSc, Med	14 days of training, 6 days of follow-up training, and 1 month of advanced ICT training. 15 days of international training in Thailand.	No-1 Use occasionally	Own made DC

Table 2 – Summary of the Selected Respondents

3.3 Data Collection Procedures

In qualitative research of the case study approach, it is essential to employ robust data collection techniques and the documentation of the research procedure, as highlighted by Bowen (2009). Data for this study has been collected through interviews, document analysis, observations, FGDs and pre-and post-lesson Interviews.

According to the Research Questions, the data collection procedure is presented below:

First stage [Research question 1]	Interview with five (5) trained mathematics school teachers Interview with three (3) mathematics trainers (Teacher Educators) Document (two training manuals) Analysis
Second stage [Research question 2]	Pre-lesson Interview with the five (5) trained mathematics teachers Twenty (20=5x4) classrooms observation
Third stage [Research question 3]	Ten (10) Focus Group Discussion for ten lessons with eighty (8x10=80) students Ten (10) Post-lesson Interviews/debriefing with the five (5) trained mathematics teachers

3.3.1 Stage One: Interviews and Document Analysis (Training Manuals 1 & 2)

In the first stage, the researcher wanted to see how the teachers develop their understanding of mathematics digital content for teaching-learning practice.

Interviews

A semi-structured interview tool was used to gather insights from five trained mathematics teachers on their understanding of developing and using digital content in mathematics classrooms, particularly in the context of digital content development training programs. A separate interview tool was used to collect opinions from mathematics teacher educators on the training programs and manuals, to identify the way of teachers understanding about developing and using mathematics digital content for the classroom. The researcher conducted five individual interviews with the trained mathematics teachers using face-to-face meetings and three individual interviews with the teacher educators through virtual conversations. The researcher organized and printed the question sheet in a semi-structured manner and recorded audio to capture the nuances of the teachers' perspectives on how they develop their understanding of digital content in mathematics. Maxwell, J. A., & Reybold, L. E., (2015) explained that recording interviews is now a common practice, which allows researchers to capture the details and nuances of what's being said. The interviews were conducted throughout in a cordial spirit, relaxed mood and without hampering their class hours. Field notes have been taken through listening to the recorded audio attentively and those will be used to triangulate with the data of analyzing the training manuals, ultimately informing the final analysis of the findings.

Document Analysis (Training Manuals 1 & 2)

Two training manuals were selected, one being the original 2009 manual provided by the a2i project, and the other being a modified version of the same manual, which was delivered by the ICT project in 2019. The contents of these two manuals have been analyzed to make a triangulation with the teacher educator interviews and trained mathematics teacher interviews. This aims to find out how teachers develop their understanding of digital content from the training.

3.3.2 Stage Two: Pre-lesson Interviews and Classroom Observation

At this stage, the researcher wanted to see how the teachers integrate ICT and pedagogy in their mathematics teaching-learning practice.

Pre-lesson Interviews

A pre-lesson in-depth interview tool was used to gather detailed information from the five trained mathematics teachers about their approach to developing digital content for their lessons, as well as how they utilized this digital content in the Multimedia Classroom (MMC). The researcher conducted five individual pre-lesson interviews with the five mathematics teachers through in-person and recorded audio to capture the nuances of the teachers' perspectives about using digital content in their lessons. The interviews also explored the teachers' strategies for creating a meaningful learning environment, promoting student engagement, and facilitating collaborative learning opportunities for students integrating ICT and pedagogy. Field notes have been taken by listening to the recorded audio, again and again, which will help to make a linkage with the data of the classroom observation guideline.

Classroom Observation

The data collection process involved observing the teaching-learning practices of the five mathematics teachers in their five schools. The researcher observed and recorded twenty lessons from five teachers, capturing videos to identify how they incorporated digital content into their teaching-learning practices and the benefits it provided to their students. However, due to the similarity in teaching styles, the researcher analyzed only two lessons per teacher, resulting in a total of ten lessons being analyzed. An observation guideline was used to investigate the incorporation of digital content into mathematics lessons, with a focus on the ten lessons of the five teachers while viewing and listening to the videos attentively to what happens in every step of teaching-learning practices. The field notes have been taken on the following aspects of student and teacher activities: attitude and behaviors, problem-solving situations, strategies used by teachers to incorporate digital content, and critical points and incidents. These detailed field notes

will help make the link with the pre-lesson interview data as well as facilitate the post-lesson debriefing and ultimately, the final analysis of the data.

3.3.3 Stage Three: Focus Group Discussion and Post-Lesson Interviews

At this stage, the researcher aimed to explore the impact of digital content on mathematics teaching-learning practices from the students' perspective, examining how their views and experiences with digital resources shape their understanding and engagement with mathematics.

Focus Group Discussion

Data was collected from a sample of students in each of the five schools through a focus group discussion (FGD) technique. A total of 10 FGDs were conducted, with each FGD corresponding to one of the 10 lessons observed. A total of eighty students were selected for FGD in the ten lessons, each FGD consisted of 8 students, who participated in a group discussion to share their experiences and perspectives on their meaningful participation and performance in mathematics lessons. The FGDs took place in face-to-face meetings and were audio-recorded to capture students' thoughts on various aspects of learning mathematics with digital content. The discussions focused on the benefits of learning with digital content, including problem-solving, conceptual development, and critical thinking. The field notes from the FGDs will be used to triangulate data collected from lesson observations and in-depth post-lesson interviews, providing a comprehensive understanding of students' experiences. This data will inform the final analysis and interpretation of the findings.

Post Lesson Interviews

Post-lesson interviews with five mathematics teachers were conducted using an open-ended and flexibly structured interview tool. The researcher conducted 10 in-depth interviews, with each teacher participating in two interviews, focusing on their experiences with the 10 lessons observed. The interviews were conducted in person and audio recorded to gain insight into teachers' thought processes and attitudes towards their lessons. The interviews aimed to explore teachers' approaches to teaching and learning, identify areas for improvement, and gather recommendations for challenging and diverse mathematical activities downloaded from the internet that align with student perspectives. The researcher also collaborated with teachers to ensure alignment with new curriculum textbooks and developed experiential learning activities that integrate ICT, pedagogy, and hands-on learning. The interviews also provided an opportunity for teachers to share their strategies for designing lessons that take into account students' interests, pedagogical limitations, and opportunities for improvement. According to Hennink et al. (2020), the interviews served as a means to gather participants' perspectives on the problem and potential solutions, allowing for a comprehensive understanding of the issue and its potential remedies. The field notes from the interviews were taken by listening to the recorded audio attentively and will be used to triangulate data from lesson observations and FGDs, informing the subsequent analysis and interpretation of the findings.

3.3.4 The Methodology Matrix- Sources of data, number and types of respondents, selection of respondents, and methods of collecting data are shown against the research question at a glance in the following matrix:

Research Questions	**Sources of Data/ Respondents**	**Selection of data source /respondents**	**Methods/instruments for data collection**
How do teachers develop their understanding of digital content in mathematics from the digital content development training programs?	Five (5) Trained Mathematics Teachers	Maximal variation techniques	Interview
	Three (3) Trainers (Mathematics Teacher Educators)	Conveniently	Interview
	Two (2) Document (Training Manuals)	Purposively	Content Analysis
How do teachers use digital content in secondary mathematics classrooms?	Five (5) Trained Mathematics Teachers (previous teachers)	Maximal variation techniques	Pre-lesson Interviews with the five (5) Mathematics Teachers Classroom observation (5 x 2 = 10) Lessons
How does the use of digital content affect the secondary mathematics teaching-learning process?	Students eighty (80) (8 from each class)	Purposively	FGD with students (10x8=80) 10 groups Post-lesson interviews and debriefing with the (5) mathematics teachers

Table 3 – Methodology Matrix

3.4 Tools Development Procedures

In the context of research, a research tool is an instrument designed to measure the intended variables of a study. A qualitative research tool of the case study approach encompasses a wide range of methods, techniques, and strategies used in the inquiry process to gain a deeper understanding of the research topic (Shahi, 2015). In qualitative research, common methods used to collect data include in-depth interviews, focus group discussions, and observation. Throughout the inquiry process, qualitative researchers utilizing a case study approach must recognize that research tools serve as both for discovery and for clarity and focus (Agee, 2009).

As a mathematics teacher educator with over 25 years of experience, the researcher has developed a deep understanding of mathematics teachers and their classroom practices. When designing the research tools, it was initially focused on the research questions that guided the researcher's inquiry. Building on this foundation, the researcher created semi-structured interview tools for school teachers and another for teacher educators to unable respondents to discuss their points and aimed to collect information about trained teachers' understanding of digital content in mathematics classrooms. The interview tool for the school teachers included the teacher's qualifications, ICT knowledge, training received, learning contents in training, challenges faced, curriculum content, and ICT facilities. The questions were designed in a simplified format keeping the language simple, easily understandable, focused and considering the ethical standards. Through an iterative process, the researcher refined and modified these tools multiple times, ensuring that they were robust, effective, and responsive to the needs of the study. An in-depth interview is a qualitative research method of case study approach that involves collecting data, aiming to uncover the rich, detailed and personal experiences of participants to gain a deeper understanding of an individual's perspective, perceptions, and meanings related to a specific topic, issue, or process (Rutledge & Hogg, 2020).

3.4.1 Framework and Rubrics for Developing Tools

After a thorough search, the researcher found a novel research-based classroom observation tool, the Technology Integration Panel (TIP) (Figure 10), which focuses on the capacity of teachers to

utilize technology to support students' learning experiences in the classroom. Yaron Li and Lisa Dawley (2019) introduced the TIP framework, which is a comprehensive tool for evaluating technology integration in student-centered learning environments. This framework is divided into three main parts: Pedagogy, Learning Context, and Technology, and provides a comprehensive approach to assessing the variation in student-centered learning approaches combining theoretical foundations, practical guidelines, and specific questions.

Another framework called the Teaching for Robust Understanding of Mathematics (TRU), is a research tool that allows researchers to measure the effectiveness of mathematics teaching and learning practices along five key dimensions (Figure 7). In the context of mathematics education, teachers must carefully consider the principles of Teaching for Robust Understanding (TRU), which emphasizes the importance of the classroom's proficiency in the five dimensions that are strongly linked to the development of students as informed, adaptable, and skilled critical thinkers and problem solvers (Schoenfeld et al., 2014). Furthermore, Adkins (2017) utilized the rubric of Mathematics Quality of Instruction (MQI) to examine the instructional strategies employed by mathematics teachers in school classrooms, with a focus on assessing the quality and effectiveness of their teaching practices. The Mathematics Instrument Development Group developed the MQI rubric at Harvard University Graduate School of Education. The MQI described mathematical teaching through three relationships: how the teacher relates to the students, how the teacher relates to the mathematical content, and what the teacher does to help students understand the material (LMT Project, 2011; LMT/Mathematics Instrument Development Group, n.d.; NCTE, 2012) recited by Anna Adkins (2017).

By combining the TIP framework with the TRU rubric and the MQI rubric, the researcher developed a set of research tools that include in-depth pre- and post-lesson interviews with teachers, a classroom observation guideline, and a focus group discussion tool for students (Appendix III to VI). The in-depth interviews and FGD tools were designed as open-ended and flexibly structured along with the TIP framework and TRU rubric to enable respondents to discuss and explore their thoughts on various aspects of learning mathematics with digital content in their lesson. The classroom observation guideline was developed based on the TIP framework, TRU framework, and MQI rubric. The researcher utilized the MQI rubric to analyze the teaching and

learning activities observed in the classroom, assigning scores based on the TIP dimensions and the use of digital content. Integrating these three frameworks, aimed to create a comprehensive set of research tools that would provide a detailed understanding of teachers' practices and their impact on student learning. In-depth interviews require the researcher to be able to create a comfortable and open environment, establish trust with the participant, and ask thoughtful questions to encourage honest and detailed responses. The interviewer needs to have strong skills in building rapport and conducting conversations to get high-quality information (Maxwell & Reybold, 2015).

3.4.2 The TIP Framework

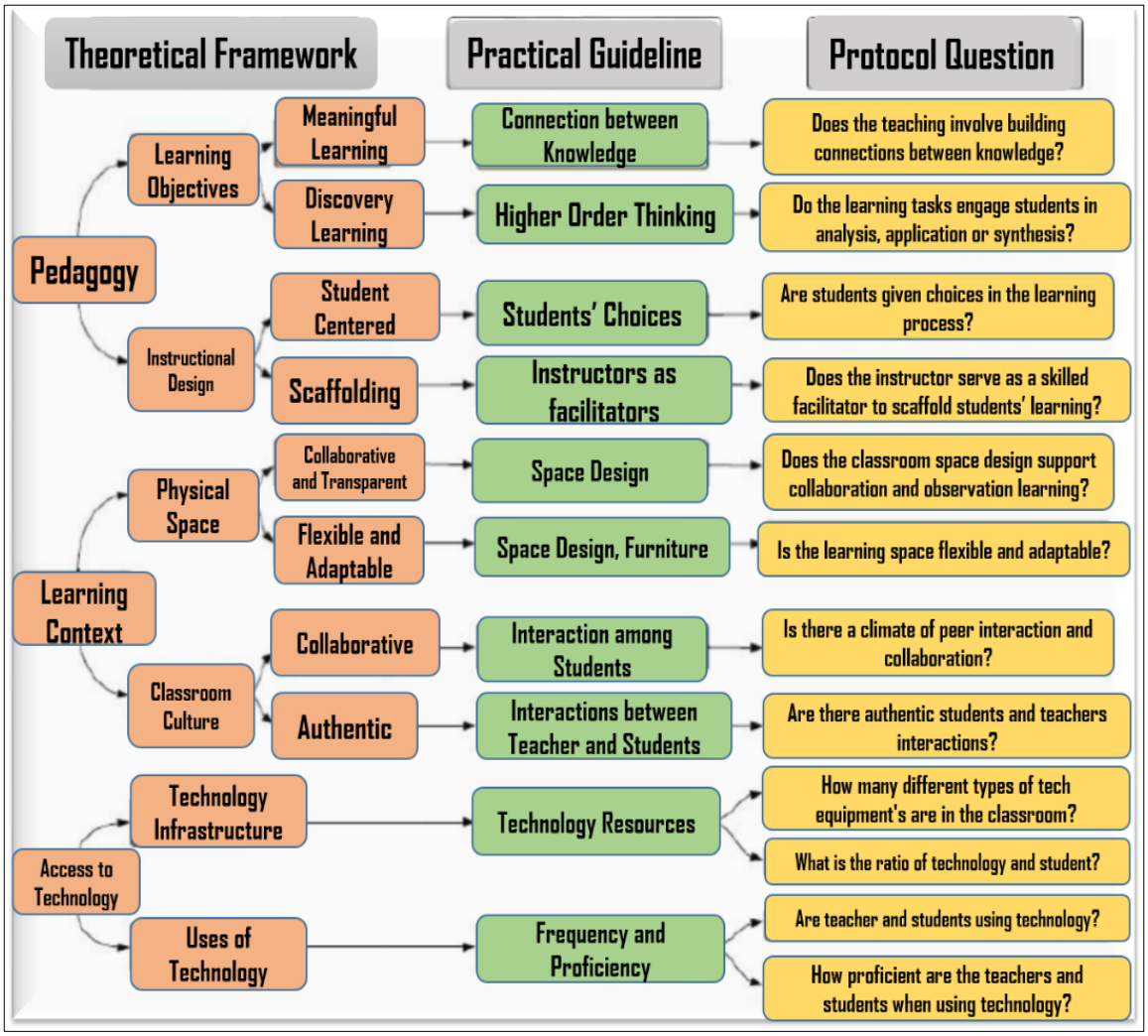


Figure 10- TIP Framework (Yaron Li and Lisa Dawley, 2019)

The Technology Integration Panel (TIP) provides a clear guide to help researchers understand teachers' thoughts regarding where they are now, what they want to achieve, and how they can get there. TIP is made up of both theoretical guidelines and practical rubrics to help researchers and practitioners understand the various factors that affect the ability to use technology to support student-centered learning. The framework is designed to consider the different ways a classroom can be set up by looking at three key areas that intersect with each other: (a.) pedagogy (b.) learning context, and (c.) access to technology and usage of technology tools. This observation tool illustrates the alignment between the theoretical framework, practical guide, and the observation protocol questions. It is composed of 4 items measuring pedagogy, 4 items measuring learning context, and 4 items measuring the access and use of technology.

3.4.3 Description of TIP Framework- The Dimensions and the Strategies:

Pedagogy: Pedagogy is the approach of teaching that considers interaction during learning through discovery learning and acquiring knowledge. This factor is a combination of Learning Objectives and Instructional Design.
Learning Objectives: Learning Objectives define the goals and expectations of a lesson which are a combination of Meaningful Learning and Discovery Learning.
Meaningful learning: The students will connect their prior knowledge to new ideas. The teachers will create an environment where the student extends their ideas connecting between knowledge and real-world examples.
Discovery learning: learning objectives are more likely to design learning activities that involve high-order thinking. The students will be engaged in learning tasks by applying, analyzing critically, and innovating ideas. Students will be asked to explore information and create new knowledge.

Instructional Design: Instructional design will be constructed by pedagogical approaches in a technologically-enhanced environment which are combination of both Student-Centered and Scaffolding.
Student-Centered: Students have a choice in the learning process to express their sense of mathematical ideas. Students have the opportunity to struggle with important mathematical tasks with their strategies. The teachers help students to engage as decision-makers in their learning in a technologically-enhanced environment.
Scaffolding: Instructional scaffolding is a process where the teachers systematically build on student's experience and knowledge when they are learning new skills. The teachers create a climate where students make mistakes and offer support to them as they learn and develop a new concept or skill in a technologically enhanced environment.
Learning Context: Learning context must be designed to help the students learn increasing their engagement and having a good understanding of their needs and preferences. This factor is a combination of Physical Space and Classroom Culture.
Physical Space: This section addresses space designs and flexibility to fit between pedagogy and physical settings.
Collaborative and Transparent: This code focuses on designing spaces. The classroom space design supports collaboration and observation learning.
Flexible and Adaptable: The furniture and space designs are flexible and adaptable for students learning.
Classroom Culture: The classroom culture addresses collaborative and authentic learning.
Collaborative: This code focuses on forming groups of students that learn together, solve problems, build strategies, and ideas, and create tasks. The environment requires joint intellectual effort by the students among themselves and also with the help of the teacher.
Authentic: This code includes an environment of peer interaction, teacher-student interaction and collaborative learning through a variety of activities. This includes pair work, group projects, and interactive inquiry-based learning by using educational technology. There is an opportunity to capture other students' thoughts and characterize them.

Access to Technology: This dimension focuses on students and teachers having access to technology in class, their proficiency with available technology, and the frequency of technology use.
Technology Infrastructure: Different types of technology are in the classroom for teachers and students.
Uses of Technology: The teachers and students have opportunities to access technology and they are proficient in using technology. Technology access may vary between content areas, stages of a lesson, and student needs.

Table 4- Description of TIP Dimension

3.4.4 Pilot Study

The researcher conducted a pilot study aimed at constructing effective tools for conducting interviews with teachers, facilitating student focus group discussions (FGDs), and executing classroom observations. This process took place in locations outside of the proposed study area to minimize bias and ensure that the observations were not influenced by the specific context of the study (Anderson, G., & Arsenault, N., 2002). By implementing the pilot in a different setting, the researcher sought to achieve a more objective evaluation of the tools before their deployment in the primary research context. During the pilot phase, the researcher observed some lessons and engaged in interview discussions with participants, focusing on both teachers and students. This interactive process provided valuable feedback regarding the clarity, relevance, and appropriateness of the items included in the instruments. Upon completion of the piloting phase, the researcher undertook a thorough process of item deletion, carefully evaluating each question and observational category for its effectiveness and relevance. After the piloting work and item deletion were completed, the next step was to administer the tool to sufficient sample size to enable exploratory factor analytic techniques to be performed. This will allow the researcher to analyze the data collected through the refined tools and identify patterns and relationships within the responses, which will provide valuable insights into the tool's validity and reliability (Kumar, 2015). By meticulously piloting the teacher's interviews, student FGDs, and classroom observation tools, the researcher has taken significant steps towards ensuring the robustness of the

research methodology. This systematic approach not only enhances the quality of the tools but also sets a solid foundation for gathering insightful data in the main study, ultimately contributing to a better understanding of educational practices in diverse contexts.

3.5 Data Analysis Procedures

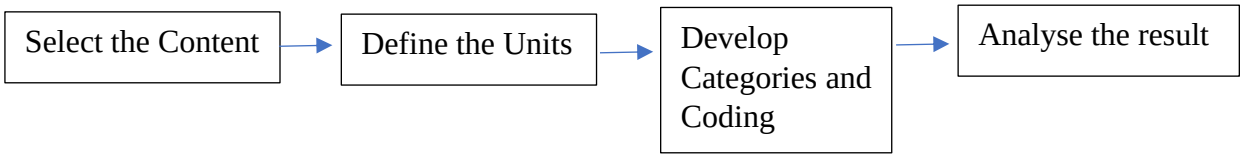
As noted by Hatch (2023), data analysis is widely regarded as the most mysterious and most difficult part of the qualitative research process. According to Hennink et al. (2020), qualitative data analysis is an interpretive process that involves seeking to understand the meanings that participants themselves assign to their experiences and views. Anderson, G., & Arsenault, N. (2002) explained that qualitative data analysis could involve using strategies from in-depth interviews and focus group discussions to identify concepts and themes within the original notes and transcripts. By analyzing qualitative data thematically, valuable insights can be extracted and a better understanding of the complexities of classroom practices.

This study employed a case study approach to collect qualitative data from various sources. The researcher conducted in-depth interviews with teachers, teacher educators, and students, as well as classroom observations and focus group discussions. During these sessions, video and audio recordings were made, accompanied by reflective field notes that captured the nuances of participants' interactions (Creswell, 2009). The recorded data from classroom observations, pre- and post-lesson interviews, and focus group discussions were analyzed thematically. Furthermore, all data collected through interviews, focus group discussions, and lesson observations were transcribed and recorded for further analysis. The researcher conducted a thorough review of the audio and video data, including description, transcription, and color coding to facilitate analysis. This thorough process enabled the researcher to identify potential areas of interest and prepare the data for analysis using a specific framework or approach. In this case, the researcher used a sequence of seven interacting stages developed by Powell et al. (2003) to study the mathematics teaching-learning practices using digital content. This framework likely involved a systematic and structured approach to analyzing the data, allowing the researcher to identify patterns, themes, and relationships within the data that shed light on the development of mathematical thinking in the multimedia classroom.

- Viewing and listening attentively to the data
- Describing the data
- Identifying critical events/potential areas
- Transcribing
- Coding
- Constructing Themes
- Composing narrative

During the writing process, the researcher was involved in a form of data analysis, as they continuously revisited the data and refined their earlier interpretations (Powell et al., 2003). This ongoing analysis helped the researcher to enhance the clarity of the findings and a comprehensive understanding of the research topic and its underlying themes.

Triangulation was done by combining the evidence of multiple sources of data, including the content analysis of the training manual, to increase the validity and reliability of the findings. Two documents (training manuals) of the digital content development training programs were analyzed following the steps adopted by (Luo, 2019).



3.5.1 MQI Rubric for Measuring the TIP Dimensions

In the classroom observation, video data capturing teaching and learning activities that involved digital content were thoroughly analyzed using a combination of the TIP framework, the Teaching for Robust Understanding (TRU) framework, and the Mathematical Quality of Instruction (MQI) rubric. These combined tools serve as a structured framework designed to assess the complex relationships among the teacher, the students, and the mathematical content being taught.

To analyze the teacher's actions and interactions during the observed sessions, the researcher employed the dimensions outlined in the TIP framework, which includes Pedagogy, Learning Context, and Access to Technology. When documenting the observations, the researcher categorized the scores into four distinct levels: high, mid, low, and not done, following the guidelines of the MQI rubric used in the observation guideline. Each level was assigned a corresponding label for clarity and ease of interpretation. Specifically, 'H' was used to denote high performance, indicating that the teacher effectively engaged students and utilized digital content to enhance understanding. 'M' represented medium performance, suggesting that the teacher met some instructional goals but may have areas for improvement. 'L' indicated low performance, highlighting significant shortcomings in instructional practices or student engagement. Lastly, 'N' signified 'not done', meaning that certain expected teacher actions or instructional elements were either absent or not observed during the segments.

3.5.1 Integration of the five (5) Cases

The researcher used the same tools in these selected five cases of maximal variation techniques and looked for similarities and differences to find out the common findings. This involved in-depth observations of two lessons from each case, as well as two focus group discussions with students after each lesson. Additionally, individual pre-lesson and post-lesson interviews were conducted to gather more in-depth information. Guest and Fleming (2015) note that connecting and merging data are two types of data integration techniques used in exploratory data analysis. In this study, the researcher used a single observation guideline to record and analyze the video data of the

observed lessons and assigned the scores using the MQI rubric, which was then merged and integrated into a table for comparison of the total ten observed lessons (Table 6 to 10). The researcher also made a linkage to the transcripts of the teacher's pre-lesson interviews and the classroom observation guideline. A triangulation approach was used to combine and integrate data from three sources: lesson transcriptions, teacher post-lesson interviews, and focus group discussions with students. The data was analyzed by linking and combining the findings from each of the five cases under the three dimensions of the TIP framework, and then all the dimensions were integrated using the systematic method developed by Strom and Fagermoen (2012) (Figure 11).

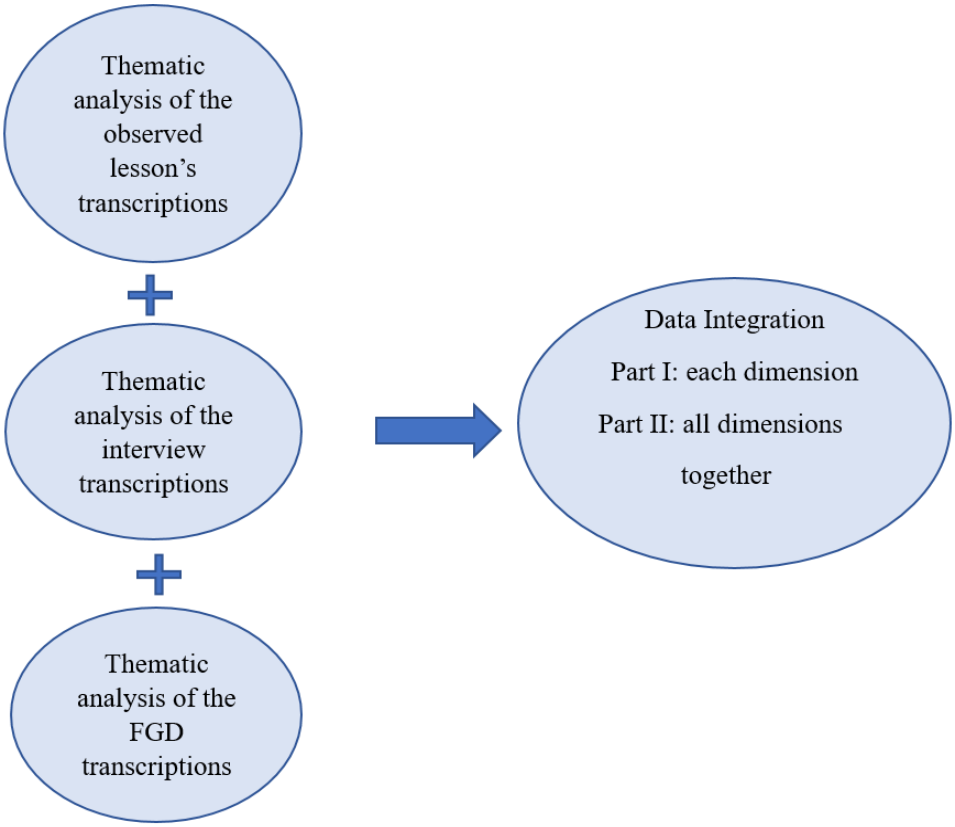


Figure 11-Systematic Data Integration Method

(Strom & Fagermoen, 2012)

3.6 Consideration of Ethical Issues

During qualitative data collection, a multitude of ethical issues can arise, requiring that researchers ensure participants are thoroughly informed about the study's purpose, procedures, and potential risks and benefits before or during the interview or discussion process (Hennink et al., 2020, p. 78). The researcher must show respect to the respondents of their studies to create a healthy environment for mutual respect, understanding, and growth (Khan, 2015). When a researcher acknowledges the significance of someone's experiences, those experiences become more important to that person too. The strong connection between a researcher and a participant, built on trust, intimacy, and mutual understanding, doesn't disappear when the research project is finished (Swift, 2022). The recruited respondents must be fully informed about the procedures of the study (Ferguson et al., 2004). Briggs (2019) explains, 'Formal ethical processes require informed consent for research'. The consent process has been formalized through a requesting letter to the principal by the supervisor that outlines the purpose and the process of the research. The principals of the schools and colleges, the teacher educators, the teachers, and the students have been fully informed of the intents and procedures of the study and their rights to participate. The discussion of the benefits of the study has been explained in realistic terms for the teachers and future students. Confidentiality of research data is based on the principle of respect for the dignity and autonomy of research participants (TCPS2, 2022). The teacher educators, teachers, and the students have been participating in the research study offering voluntary informed consent as per the aspects of the research ethics. The confidentiality and anatomy of the study have been maintained and the researcher did not link the data to any specific individual. The researcher has discussed the reasons for the ethics in regard to the research and explored some of the issues, so the participants would not feel any potential pressure in that respect.

The research work was conducted throughout considering ethical issues. These are summarized below:

- Before commencing the data collection, a formal letter from the supervisor of the research was submitted to the head of the Institutes and interviewee teachers. The work was initiated with the prior consent of the Principal/Headteacher.

- The data collection processes (Interviews, FGDs) were conducted in Bangla.
- The all-through data collection was done considering the religion, language, culture, patriotism, gender equality, etc.
- In the data collection events, there are three (3) interviews with the three teacher educators, five (5) pre-lesson interviews and ten (10) pre-and post-lesson interviews with the five (5) teachers. The researcher humbly requested them to assist her in conducting the study.
- During FGDs researcher talks in such a manner considering special needs children and ethnic groups.
- The Interviews and FGDs were arranged at the time and places convenient to the participants and to school authorities.
- Classroom observations have been video recorded, and the interviews and FGD conversations have been recorded audio with their consent ensuring that their responses are only for research purposes to avoid embarrassment, shame, or anxiety in their teaching-learning relationships with faculty and others.

Sim &Waterfield (2019) explain in their research about focus group discussions that the researcher should stay vigilant for signs of distress, confidentiality breaches, or excessive sharing, and aim to redirect the conversation. It can be helpful to conclude the discussion on a more neutral or positive note, responding appropriately. There are ten focus group discussions (FGDs), two FGDs were done in the mini-conference room after the lesson observed. One FGD has been done at a corner in the library room. The remaining seven FGDs have been completed in the multimedia classrooms, as there were no more classes left to attend. The purposively selected eight students have been kept in the room to guarantee their comfort, address their desires, and maintain confidentiality. The researcher has made judgments during the discussion, ensuring that everyone's voice is heard without excluding any participants.

Chapter Four A

Data Analysis and Findings

The analysis phase of qualitative research is often considered the most mysterious and most difficult part aspect of the process. Research questions serve as a framework for guiding the analysis, with each question typically becoming a major coding category that is further decomposed into subcategories (Ngulube, 2015). Seidel (1998) developed a qualitative data analysis model comprising three stages: noticing, collecting, and thinking about relevant data. This approach enables researchers to leverage multiple sources and methodologies, thereby enhancing the reliability of their findings, which is crucial for deriving accurate and meaningful insights into the research topic. By constantly revisiting the data and critically examining their interpretations, researchers can ensure that their work accurately represents the complexity and richness of the information they have gathered.

Data was collected from a variety of sources, including:

- Interviews with Teacher Educators
- Interviews with trained Mathematics Teachers
- Analysis of documents (Training Manuals)
- In-depth Pre- and post-lesson interviews with Teachers
- In-depth Classroom observation
- Classroom observation guidelines
- Focus Group Discussions (FGDs) with students

4A.1 Teacher's Understanding of Digital Content in Mathematics

According to the Cambridge Dictionary, understanding means knowledge about a subject, situation, or how something works. Here teacher's understanding means teachers' knowledge about what and why digital content is in the mathematics lessons especially what they learn from the 'Digital Content development training' programs. The teacher's understanding of the digital content has been developing through the 'Digital Content Development training' programs initiated by a2i in 2009. Additionally, this understanding has developed through various ways, including self-learning, national and international training programs, teacher portals, and others. a2i has continued this Digital Content Development Training program up to 2013 and then handed it over to other Ministry of Education projects, continuing it all over Bangladesh.

This section involves conducting interviews with trained teachers and trainers (teacher-educators) to explore the trained teachers' understanding of digital content in mathematics classrooms. Additionally, a document analysis of two training manuals has been conducted to investigate how trainers create opportunities for participant teachers to enhance their understanding of mathematics digital content. Data from the teachers' interviews, the teacher-educator interviews, and the contents of the training manuals have been analyzed, synthesized, and triangulated. By integrating multiple data sources, the researcher seeks to uncover insights into the participant teachers' perceptions and understanding of digital content gained from the digital content development training programs in their mathematics instruction.

Data from five (5) Teacher Interviews, three (3) Teacher Educator Interviews, and two (2) Document Analyses (Content of Training Manuals) have been analyzed thematically below:

4A.1.1 Teacher's Interviews

The researcher engaged in nearly three months of interaction with the five selected teachers. Each face-to-face interview lasted approximately 25 to 30 minutes.

Four teachers claimed that they usually used digital contents of PowerPoint presentations in their mathematics lessons. Teacher T2 affirmed that he sometimes used the software GeoGebra and Smartboard in his lesson. He used the digital content and software as per the textbook's content needs. Other teachers did not use any other mathematical software in their lessons. T3 claimed that she used the digital content of PowerPoint presentations in her mathematics classroom but not regularly. Because they had no multimedia classroom (MMC) in the school section, there was only one MMC classroom for making Zoom classes in the college section. The teachers have to address the college authority for access to the MMC in order to use their digital content.

T1 to T4 informed that they usually searched Google, YouTube, and different websites for learning material to learn and develop digital content that they have learned from the training. They asserted that they used their own created digital content of PowerPoint presentations in their lessons. They also claimed that there was no quality content in the teacher's portal and not easy to find good content there. T5 asserted that he read newspapers, and used Facebook and the internet. He collected the digital contents of PowerPoint presentations from the teacher's portal and edited those to use in his lessons. Among the teachers, three individuals (T3, T4, and T5) acknowledged that they had no prior knowledge of Information and Communication Technology (ICT) before joining the training. On the other hand, two teachers (T1 and T2) mentioned that they had some ICT knowledge before joining the training program.

All five teachers explained that the objectives of the digital content development training programs were to make the lesson enjoyable and interesting to the students using the digital content of PowerPoint presentations. They also defined that digital content meant basically a PowerPoint

presentation. 3 of them (T1, T2, and T3) added that websites, software, images, videos, and soft textbooks were also called digital content. The other two teachers (T4 & T5) argued that only an image or a video could not be digital content.

They all confessed that they had learned a lot about ICT and digital content from the training and remarked that they have learned how to make digital content with PowerPoint presentation software. The teachers' main takeaways from the training were about how to insert images, and videos, write text in slides, use animations, conduct online search, as well as download the relevant learning materials from internet. T2 argued, "Videos are not fruitful for mathematics lessons". He added that the pedagogy integration in the digital content was about how to start a lesson using digital materials. T1 also commented the same as T2, pointing out that, 'there will be a motivational starter in the lesson'. However, they both were not able to mention more about pedagogy integration. Two of them, T4 and T5 professed that there was no pedagogy integration session in the training program. The teachers also reported that all the participant teachers from different subjects were together in the training, and it was not mathematics-based.

All five teachers described a similar teaching approach regarding one of their most effective mathematics lessons that they liked the most. None of them could provide a detailed example of how students had learned from their effective lesson using digital content. They explained about their effective lessons in general and that when they showed the students images or videos on the screen, the students enjoyed it a lot and loved watching it and understood well the learning facts. T4 explained without mentioning any specific lesson, 'I was watching a game with the students, so they enjoyed a lot'. She added, 'The students understood the topic 'Function & Relation' easily by watching the images on the digital slide'. T2 asserted, 'The students understand well watching the Co-ordinate Geometry & Logarithm on the digital slide'. T3 remembered, 'I showed a video of a cricket game in the statistics lesson and the students enjoyed it a lot'. T1 remarked, 'I evaluate the students through questioning, eye contact, visually and orally'. But he was not able to explain about any specific lesson. All the teachers stated that they have learned to incorporate the following steps into their digital content: welcoming, teacher introduction, topic presentation, learning outcomes, lesson delivery, individual work, group work, evaluation, and homework. They explained that they have developed their digital content of PowerPoint presentations following

these steps what they learnt in the training. They also learned that they could use the whiteboard as necessary in their lessons. T1, T3, and T4 narrated that they felt comfortable following the steps of the lesson plan in their digital content lessons because it was easy to present the mathematical content consistently. T1 added, “Sometimes I pause when students ask questions while I'm presenting my digital content, and then I answer them”. He suggested, “The pattern of digital content needs to be changed as per experiential learning as per the new curriculum”.

All teachers agreed that digital content in mathematics classrooms was important for effective teaching because the students showed interest in attending the multimedia classrooms and their presence has been increasing. The students have become attentive and attracted by watching the images, animations, and videos of the digital content of PowerPoint presentations. The teachers clarified that the digital content training program was designed for all subject teachers together, which made it difficult to understand how to integrate subject content and ICT with pedagogical strategies specific to each subject. T1 and T5 claimed that they experienced a six-day follow-up training, but it occurred only once and almost two years after the initial training. Meanwhile, the other three teachers did not receive any follow-up training whatsoever. They all also complained that they were never monitored, mentored or observed by their trainers after getting the training. However, all teachers wished that they needed mathematics-based digital content training and they wanted to learn about mathematical software for their lessons.

Based on the information provided by the trained mathematics teachers, it seemed that the teachers’ attitudes were positive about developing and using digital content in their mathematics lessons. Moreover, three of them did not have any ideas about computer basic skills before receiving the digital content development training. However, they all successfully learned about MS PowerPoint presentations using basic ICT skills and the internet. The teachers have become empowered and confident in developing digital content after receiving the digital content development training. However, in these five cases, they all lacked ideas about pedagogical alignment in the lessons. The teachers were not able to explain about pedagogical strategies of their mathematics lessons and students’ meaningful activities, and innovative and interactive mathematical tasks using digital content. Furthermore, all five teachers indicated that after

receiving the digital content development training, they were never monitored, mentored, or observed by their trainers.

4A.1.2 Teacher Educator's Interviews

The researcher conducted online conversations with five selected teacher educators. Each online interview lasted approximately 20 to 25 minutes.

The selected three Teacher Educators have experienced almost 13 to 14 years as a Trainers of digital content development training programs. They all have worked more or less as the trainers of different projects such as a2i, TQI-SEP1 & SEP2, ICT project-phase 1, ICT project-phase II: Basic Teacher's Training (BTT), 70 Govt College projects, Madrasa TTC, ICT application in Higher Secondary, in-house training and 1500 College projects since 2009 to 2021.

The selected three Teacher Educators claimed that the main objective was to use digital content in the multimedia classroom to make the lessons attractive and enjoyable to the students. TE2 notified, "The objectives are to digitalize the classroom environment and to expand student engagement". TE3 reported, "The objectives are to empower the teachers developing and using the digital content of PowerPoint presentation". He added that the teachers have been becoming capable of conducting the lessons effectively using digital content.

TE3 explained that at the beginning stage of the training programs, a full PowerPoint presentation was named as the digital content. But later, the digital content was named not only the PowerPoint presentations, but the digital content could also a picture, a video, or any online learning material that was relevant to the subject content. He added that they as the trainer have made a rule to split the learning time regarding using the digital content in the classrooms. So, 1/3 of the lesson time is for using the digital content while the rest of the time (2/3) is reserved for other activities such as relating mathematics content to real-life things, hands-on activities, use of the board, etc. TE1 & TE2 reminded that the basic concept of digital content was a PowerPoint presentation with images, videos, and texts through ICT knowledge and the internet.

The three Teacher Educators claimed that the training was very effective for all the education sectors. TE1 argued, “The participant teachers who do not know the computer, have learned a lot. They have learned about ICT knowledge and made the presentations of digital content and have become an empowered teacher in Bangladesh”. TE1 declared that the teachers were becoming capable of putting animations and adding images, audio, and videos in the PowerPoint presentation slides by using the internet and digital learning materials. TE2 announced, “Some trained teachers also have achieved the capabilities to make videos themselves”. TE2 shared his experience that the students were enjoying very much and have become attentive to watching the digital content in their lessons. TE3 informed that the situation about the teacher’s use of ICT was much better at present than in the year 2009. About 50% to 60% of teachers have been becoming capable of conducting their lessons by using digital content. They have become more confident now about developing and using the digital content of PowerPoint presentations in their instructions. The teachers have learned to upload their content in the teachers’ portal, have joined the competition for the ‘best teacher of the week’, and are awarded as the best teacher in Bangladesh. Some teachers have attended the video competition provided by UNESCO, and they have made excellent innovative videos there.

TE3 disclosed, “Pedagogy integration such as TPACK model is not included in the manual from the beginning but it has been introduced later in the ICT project manual-2019 only in one session. He expressed his frustration, “We actually could not adopt the TPACK model until now”. He added that at the beginning, the mindset was that the digital content meant a full PowerPoint presentation only. In order to integrate pedagogy, TE3 remarked that they have instructed the participating teachers to create slides that align with pedagogical principles. The participating teachers were encouraged to include topic-relevant images or videos and to ask questions pedagogically before declaring the title of the topic. TE1 and TE2 claimed that they had discussed the pedagogy integration during the training sessions on developing digital content although it was not in the manual. TE2 pointed out that there was a session where the teacher educators demonstrated a lesson on how to effectively incorporate images, videos, and texts into their PowerPoint presentation slides with pedagogical alignment. He also remarked that the teacher educators have provided feedback through pedagogical alignment to the participant teachers while the participant teachers have practiced their presentation through simulation. However, he

commented that most participant teachers were curious to learn about basic ICT skills more than pedagogy integration. He added that the participant teachers have argued that they have learned the pedagogy integration at their BEd program but not consistently applied it in their classrooms. TE2 also commented that the teachers usually have used the traditional methods and have not practiced the pedagogy integration in their everyday lessons what they have learned from B.Ed. degree. TE1 and TE2 added that there were 13 instructions only in bullet form about how to conduct a lesson pedagogically using digital content.

TE2 acknowledged that pedagogy integration was the big challenge in developing and delivering digital content during the training sessions. TE3 highlighted that the training program manuals have not been prioritizing in-depth pedagogy integration in developing and using the digital content. Additionally, TE3 revealed that at the outset, there was a need to provide only basic ICT knowledge as the teachers were new to the era of ICT. TE3 also commented, 'The trained teachers are now confident enough about incorporating ICT in their lessons, even though they may not be fully capable at the moment". He added that they have the basic ICT knowledge but need further support in pedagogical integration that was in the model of TPACK. TE3 remarked, "Basic ICT skills and in-depth pedagogical alignment in ICT with learning content have made it difficult for the participant teachers to learn both at a time". He added that this was understandable, as mastering both areas simultaneously could be overwhelming. All teacher educators also complained, just like the mathematics teachers, that the digital content training program was designed for all subject teachers collectively. This made it challenging to understand how to integrate subject content and ICT with pedagogical strategies specific to each subject, particularly in mathematics. It was important to approach this kind of education with a clear understanding of the participants' needs and capabilities. The teacher educators acknowledged that they conducted six days refreshers courses for the trained teachers, however, no programs were provided for them to monitor, mentor, or observe the trained teachers to support them after training. They all suggested that the mathematics teachers' training should be mathematics-focused and centered on in-depth learning of pedagogy integration in ICT, and it might be aligned with the new curriculum emphasizing 'inquiry and experiential' learning.

From the perspective of the Teacher Educators, the digital content development training program has been an effective program across Bangladesh. This training has empowered and boosted the confidence of participating teachers in creating digital content using fundamental computer skills and the internet. As a result, these teachers are now capable of integrating their own developed digital content into their lessons. However, the teacher educators themselves acknowledged that there has not been enough focus on pedagogy integration with ICT in the training manual, which could have helped the teachers to better understand how to integrate technology, pedagogy, and content knowledge in developing digital content and using it in their mathematics lessons. They also noted that it is challenging to learn basic ICT skills and integrate in-depth pedagogy simultaneously, especially when all subject teachers are involved together. They all acknowledged that they had never monitored, mentored or observed the trained teachers to support their use of digital content in lessons.

4A.1.3 Document Analysis (Training Manuals)

The aim and objective of the Training

- To enhance the quality of education in the process of teaching and learning through the use of information and communication technology (ICT) in education and supporting the professional development of teachers. (a2i, 2009).

4A.1.3.1 Training Manual 1

The Training Manual has been developed with a focus on classroom learning activities, ensuring that the learning materials are easily understandable for students and that digital content is effectively utilized in a multimedia classroom (Training Manual, 2010). Manual 1 was originally published in 2009 and reprinted in 2010, 2012 and 2013.

The Units: The major topics of the 48 sessions are the following:

- Use of ICT in education

- Introduction to computers, its uses, and exercise for the use of ICT in education
- Use of MS PowerPoint and exercise in preparing Digital Content
- Introduction to the internet, its use in education, download of image-audio and video download from YouTube
- Planning for making Digital Content preparation in team
- Presentation of planning for preparing Digital Content in the team
- Preparing Digital Content using MS PowerPoint and the Internet in the team
- Develop and present Digital Content using MS PowerPoint and the Internet individually
- Correction of individually developed Digital Content, development, and presentation of digital content-3
- Opening an email account, managing the Teacher's Blog, 'Shikkhok Batayon', installing necessary software, and providing ideas about educational websites.
- Discussion about Multimedia Classroom Management.

The activities with MS PowerPoint presentation software were about making the MS PowerPoint file folder, slide management, writing text with Bangla (Avro) and English font, using font, shapes and color, inserting shapes, tables, charts, and smart art, inserting image and videos, use of PNG-GIP format image, practice image-video editing (clipping, cutting, joining and converting), screenshot, use of animations and use of trigger animation.

A session was conducted by the trainer using sample digital content in session 16. There was a part in chapter 7 of the manual that was about the ideas of how to develop effective digital content by using the principle of learning. There were also 13 instructions in the bullet form about how to conduct a lesson pedagogically by using digital content.

4A.1.3.2 Training Manual 2

This training manual was originally published in 2019 and reprinted in 2024. The topics of Manual 1 were mostly the same as in Manual 2. In Manual 2, there had been added some new topics such as Muktopaath, cloud storage, Google Classroom, the practice of UNESCO Toolkit, Microsoft Word, Microsoft Excel, file transfer through the apps Shareit and Bluetooth, and the website of Kishore Batayon.

At session 20 on day 5, there was a sample of standardized digital content and a guideline of 11 instructions in the training manual. The sample digital content was not about Mathematics. The participating teachers had to emphasize the analyzed digital content and the guideline points while correcting their developed digital content within a 60-minute session. The points have been focused on: how to make the digital content of PowerPoint presentations learner-centered, student's exploration in a new situation, contextualization, and 4C; which means creativity, communication, collaboration, and critical thinking.

4A.1.3.3 Content Analysis (Training Manuals 1 & 2)

Aspects	No of Sessions (48)		Duration (62.4hours)	
	Manual 1	Manual 2	Manual 1	Manual 2
Basic ICT skill and PPT skills	21 sessions	25 sessions	25.2 hours	32.5 hours
Develop Digital Content by the teachers individually (2) and in groups (1)	6 sessions (no of digital contents 3)	3 sessions (no of digital content 2)	7.65 hours	3.9 hours
Practice presentations with their developed digital content by simulation	7 sessions (3 times by one teacher)	7 sessions (2 times by one teacher)	8.95 hours	9.1 hours
Edit and correct their digital content with Pedagogical Alignment	1 session	2 sessions	1.15 hours	2.6 hours

Table 5 – Content Analysis (Training manuals)

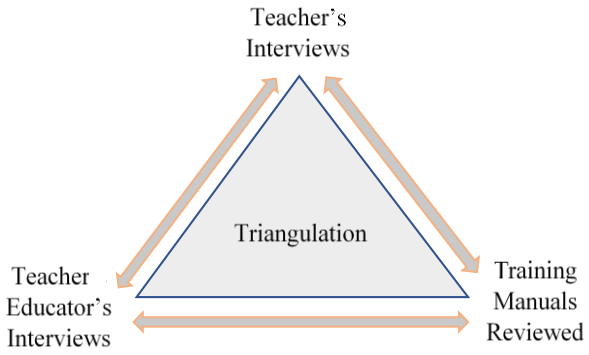
It is noted that Manual 2 was reprinted as a corrected version in 2024. A 90-minute session was added on the use of the TPACK model to develop digital content. Additionally, sessions on Photoshop, Illustrator, Camtasia, artificial intelligence in education, and Smart TV operation were also included in the corrected version.

Upon analyzing the contents of the two manuals, it has been observed that the training manuals primarily have been focused on providing information about basic ICT skills, particularly in developing MS PowerPoint Presentations using the internet and fundamental computer skills. The corrected version of the manual in 2024 also added more ICT skills for the participant teachers. Additionally, a 90-minute session on the use of the TPACK model was included, instructing the participant teachers to apply the TPACK model while developing their own digital content and practicing their presentation skills. The training manuals have focused on integrating ICT knowledge and subject content, but have not placed sufficient emphasis on pedagogical strategies. There were no in-depth pedagogy integration sessions in the manuals for developing and using digital content in the classrooms concerning the TPACK framework. So, the objective of the training can be partially achieved. While the training has empowered the teachers professionally in using ICT, the development of the process of teaching and learning by using ICT might still present a challenge.

The digital content development training programs were designed collectively for all subject teachers in accordance with the training manuals, rather than being tailored for specific subjects. The training manuals mainly focus on basic ICT skills and internet resources. There is a lack of in-depth guidance in the training manuals on the pedagogical integration of developing and using digital content within specific subject, specifically regarding the development and effective implementation of PowerPoint presentations in the classroom, which are crucial for effective teaching and learning processes.

4A.1.4 Synthesizing and Triangulation the data from Trained Teacher's Interviews, Teacher Educator's Interviews and Document (Training Manuals) Analysis

To comprehensively understand trained teachers' perceptions and utilization of digital content in mathematics classrooms, a triangulation was conducted of data gathered from three distinct sources: interviews with trained teachers, interviews with teacher educators, and the analysis of training manuals. By triangulating multiple-faceted approaches and synthesizing insights, it became evident that the teachers could incorporate online materials into PowerPoint presentation software and develop digital content tailored to their mathematics lessons. However, they lacked the opportunity to develop their understanding of the effective digital content for their mathematics lessons with pedagogical alignment, primarily due to the absence of comprehensive and detailed practice sessions focusing on in-depth pedagogy integration in the training programs. The digital content development training programs have empowered the confidence and capacity of participating teachers in creating digital content using fundamental computer skills and the internet. As a result, the teachers have gained the ability to integrate their own developed digital content into their lessons, although they often lack pedagogical alignment. Furthermore, there were no monitoring, mentoring, or feedback programs in place to assist the trained teachers in using digital resources and changing the mindsets they had developed through years of personal experience in classroom practice.



Chapter Four B

Data Analysis and Findings

4B.1 Use of Digital Content in Secondary Mathematics Classrooms

The study involved a series of interviews with the selected five trained mathematics teachers, each lasting approximately 45 to 60 minutes. After pre-lesson interviews with the teachers, their mathematics lessons using digital content were observed and recorded on video. The video data were collected from a total of ten (10) video lessons, which consisted of two lessons from each of the five participating teachers. An observation guideline was used to analyze the video lessons and assign the scores with a description of the teacher's actions. The scores for each segment were coded using the MQI rubric that assigns the following ratings: N (not done), L (low), M (medium), or H (high). The audio and video data were carefully reviewed and transcribed, with potential areas identified and coded using color codes. The data was then analyzed thematically and compose a narrative that captured the essence of the findings.

The uses of digital content strategies in mathematics lessons were analyzed through the lens of three components, as outlined by the TIP (Technology Integration Panel) framework (Figure 10, Page 44).

The three components of the lens:

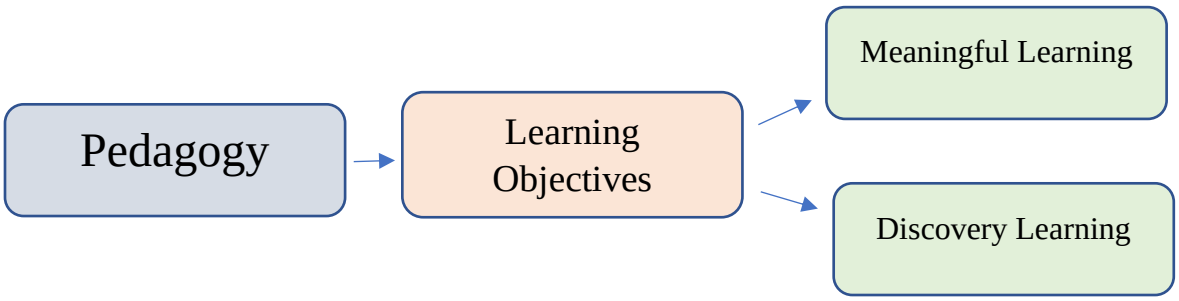
- **Pedagogy** (**Learning Objectives**: Meaningful Learning, Discovery Learning;

  Instructional Design: Student-Centered, Scaffolding)
- **Learning Context** (**Physical Space**: Collaborative and Transparent, Flexible and

  Adaptable; **Classroom Culture**: Collaborative, Authentic)
- **Access to Technology** (**Technology Infrastructure, Uses of Technology**)

In this section, the pre-lesson interviews of the five teachers and the identified potential areas from the transcribed field notes of their ten mathematics lessons were discussed under each dimension. A detailed summary analysis of the ten observed lessons was integrated into an observation guideline, which included assigned scores and descriptions of the teachers' actions within the same dimension. Subsequently, a link was made between the pre-lesson interviews and the transcribed field notes from the ten lessons, and these findings were synthesized into a summary note under the corresponding dimension. Finally, data from all dimensions were integrated into the overall summary note. All activities were carried out using the systematic method developed by Strom and Fagermoen (2012) (Figure 11, Page 51).

4B.1.1 Pedagogy: Learning Objectives (Meaningful Learning and Discovery Learning)



This section delves into the concepts of meaningful learning and discovery learning in the dimension of pedagogy, highlighting their significance in educational settings. The researcher begins by examining how the teacher facilitates students to connect their prior knowledge to new ideas. The teacher fosters an environment that encourages learners to extend their ideas connecting between knowledge and real-world examples. To accomplish this, the researcher highlights the alignment between teachers' reported practices regarding their instructional methods and the evidence gathered from actual observed classroom lessons. In particular, the researcher looks at how the teacher encourages the students to ask questions in connecting their knowledge,

and whether the students are engaged in the learning activities with higher-order thinking of applying, analyzing critically and innovating ideas in the lesson. Through this analysis, the researcher aims to uncover the effectiveness of the teacher's pedagogical approaches in nurturing a classroom atmosphere where students engage in learning tasks by exploring and creating new ideas. The findings from this evaluation will contribute to understanding the interplay between teaching strategies and student learning in the context of meaningful learning and discovery learning.

4B.1.1.1 Teacher's Pre-lesson Interviews

The teacher (Case 1) said that he usually asked questions showing relevant real-life-based images at the beginning of the lesson. He stated that he generally builds meaningful connections between students' prior knowledge and new knowledge using relevant pictures in the digital content. He used easy questioning techniques with three aspects of what, why, and how; so that the students could think critically and create new ideas about the mathematical concepts while watching the digital content. He confessed that he usually did not make situations using digital content where students could develop their own mathematical ideas. He should explain the facts and the procedural method first to the students because very few students were capable of solving the mathematical task with their own mathematical ideas and understanding. He added that the classrooms were still traditional and it was not possible to apply mathematical tasks in real-life situations. However, some mathematical rules could be made by the students by showing them videos or images using digital content.

The teacher (Case 2) disclosed that he usually asked 2 or 3 questions to the students from the previous lessons to start a mathematics lesson. He added that he normally showed the questions as the text on the screen using digital content. However, the teacher reported that there was no need to check the student's prior knowledge at the beginning lesson of a new chapter, it needed to be checked at the 2nd and other lessons of that chapter. He informed that he generally showed the text of the mathematical definitions on the multimedia screen and recited it to help the student better understand. He argued, "Digital content or the pictures could not help to explain the definition".

He added that sometimes he asked the students to underline the definition in their textbook as the important line for their examination.

He argued that it was not possible to create a meaningful connection between the lessons. He added, “There are many things to explain within a short time in the lesson and the main target is to finish the syllabus”. He confessed that he usually did not go from concrete to abstract to evolve a mathematical concept and did not relate it to real-life things. He said that he usually explained the mathematical concepts by showing images and text on the screen using digital content. He shared about applying mathematics in the real-world example that:

> “There were no opportunities to use tiles in solving mathematics, so I explained to the students how to solve tiles problems in the procedural process without using tiles”.

He explained about creating the environment of critical thinking as some students came to him to know about some critical questions and he explained it to them.

The teacher (Case 3) said that she sometimes told stories to the students, showed them relevant pictures or learning materials that she could have in her hands to relate mathematics to real life, and sometimes described the formula in algebraic lessons. She added, “I use the images and videos and ask questions to the students to make the relation between student’s prior knowledge and new knowledge using the digital content”. She also confessed, “I sometimes try to relate the mathematical concepts with the real-life examples using digital content to make it more attractive to the students”. She asserted that it was not possible to make the critical thinking environment in the lessons due to her overloaded classes. She stated, “Actually, this is not easy to take the classes in the way that we have learned at the training due to our overloaded classes”. She explained that she had to take 5 classes out of 6, and it took more time to make digital content for the lesson. However, the use of digital content made the class comfortable for the teachers because the students loved to watch it, the teachers could show things to the students, and the teachers did not need to talk more to the students. She said, “Sometimes I took the students outside to apply mathematics in a real-life situation, the students measured the things and went to the formula”.

She also remarked, “Few students want to explain their own ideas, but they felt interested in exploring and creating new ideas by watching the images or videos in the digital content”.

The teacher (Case 4) said that she usually started the lesson with chalk and talk, and told the student stories sometimes. She narrated that there was no need to check the student’s prior knowledge of the beginning lesson of a new chapter, it was needed for the 2nd and other lessons of that chapter. She generally tried to start showing real-life-based images or pictures to the students using digital content at the beginning of the lesson. She disclosed that it did not usually happen to apply mathematical concepts in real-life situations in her lessons. She noticed that she usually used relevant images to relate the mathematical concepts to real-life examples using digital content to help the students understand the facts. She usually explained the mathematical concepts to the students showing images in the digital content to deepen their understanding.

She pointed out, “The students can develop mathematical new concepts, they can create ideas about the mathematical facts watching the digital content”. She added that the students could understand many things more than the teachers, they asked many creative questions to the teachers.

The teacher (Case 5) said that he usually related the mathematical concepts to real-life things. He confessed, “I usually check student’s prior knowledge at the beginning of the lesson. I ask the student about the formula in algebra lessons showing the formula on the screen of the digital content”. He shared that he did not usually offer challenges for critical thinking and did not create opportunities for the students to apply in real-life situations. He recounted, “Sometimes a few students like to explore the mathematical ideas watching the image and video in the digital content, but they mostly want to receive information from the teacher”.

4B.1.1.2 Classroom Observations

In these five cases, there were opportunities to enhance the lessons through Meaningful and Discovery learning approaches. Field notes have been compiled from a review of the data collected from the ten videos provided.

Observation One – Grade Eight

T1_Lesson 1: Area and Circumference of a Circle

Meaningful Learning and Discovery Learning

The teacher started the lesson by opening a PowerPoint presentation of the digital content. The students were seated and settled, with their bags nearby. The screen displayed a picture of the Shaheed Minar monument with three flower buckets in front of it (Figure 12). The teacher asked the students, "What is the picture behind the Shaheed Minar"? One student said, "It is a red circle". He asked, "How does it look, to whom it looks like"? They said, "Round, circle". The teacher was talking about if they needed to make the circle, and how they could understand the cost. He added if someone were to ask for the cost of a circle, they would need to measure its area. The students were listening silently and one was making yawns. He pointed out the three rectangular-shaped structures indicating the screen and said that measuring the area of a rectangle is straightforward, as it can be calculated by multiplying the length and width. However, he asked the students how they would go about measuring the area of a circle. The students were silent and the teacher did not wait for the reply.

Figure 12: Shahid Minar Monument

The teacher pointed out the animation and began to explain the concept of ‘Pi’ (Figure 13). He then asked the students a series of questions, “How does the circumference of a circle become a straight line? Which one is the circumference of the circle? If we take a plastic shape and straighten it, does the circumference remain Pi? How can we get Pi”? The teacher then walked over to the whiteboard and wrote the equations of ‘Pi’ and he spoke. “If we divide the circumference of a circle by its diameter, then we get ‘Pi’. The students looked at him with a mix of curiosity and confusion but remained silent. The teacher continued, “So, Pi is found when we divide the circumference of a circle by its diameter, if we have a big circle, its diameter will be large, and if we have a small circle, its diameter will be small. But here’s the important thing: no matter what size circle we have, if we divide its circumference by its diameter, we will always get the same value and that value is called Pi”.

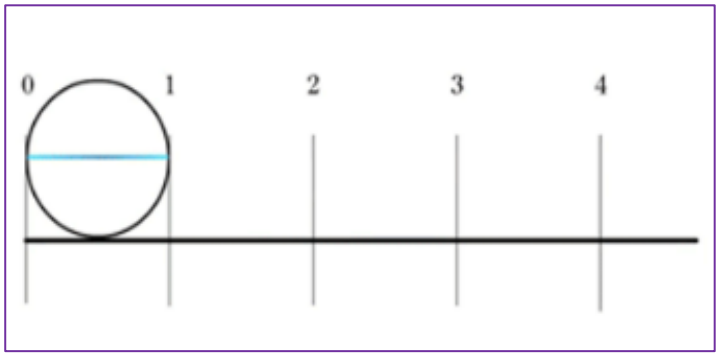


Figure 13: An animated picture of Circumference of the Circle

The teacher moved on to the other slide and began to explain by pointing to the screen that half of the circumference of the circle was equal to the length of the rectangle (Figure 14). Two students were quietly chatting with each other, while another two students were whispering to each other. The majority of the class looked tired. He said that they could do it by actually cutting out a circle.

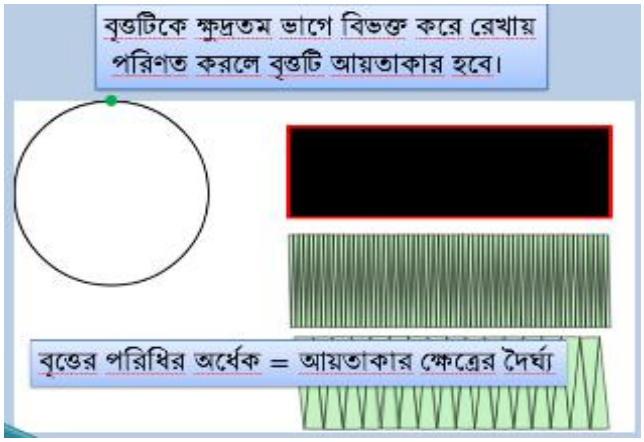


Figure 14: Area of the Circle

He continued to explain by pointing to the screen, “The area of the circle is equal to the area of the rectangle”. He asked to the students, “What is the area of the circle”? Some students replied all together, “πr^2”. They looked like they were trying to memorize the formula. Then the teacher went back to the screen and repeated the words from the screen about the formula of the area of the circle (Figure 15). The texts appeared one by one on the screen and he was explaining the length, width, radius, and the formula of the area of the circle. Four students were chatting quietly with each other, three were fiddling with their fingers.

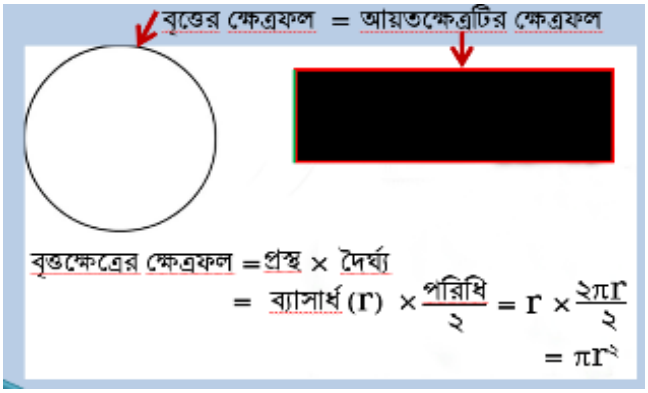


Figure 15: Area of the Circle

Observation Two – Grade Eight

T1_Lesson 2: Graph of a Simple Simultaneous Equation

Meaningful Learning and Discovery Learning

The teacher moved on to the other slide of the digital content and some texts appeared through animation on the screen (Figure 16). He uttered the text that ‘the sum of two numbers was five’. He asked a student directly, “How do we algebraically express this”. The student replied that x+y=5 and the teacher wrote it on the board. The teacher explained, “Here, one number is represented by x and the other number is represented by y. These two numbers are unknown”. Then he clicked on the mouse pad and the same text reappeared on the screen. He asked, “If I ask you to take a value for x and a value for y, so that the sum is equal to 5; so then what would be the values of x and y”. He asked a student directly, and the student stood

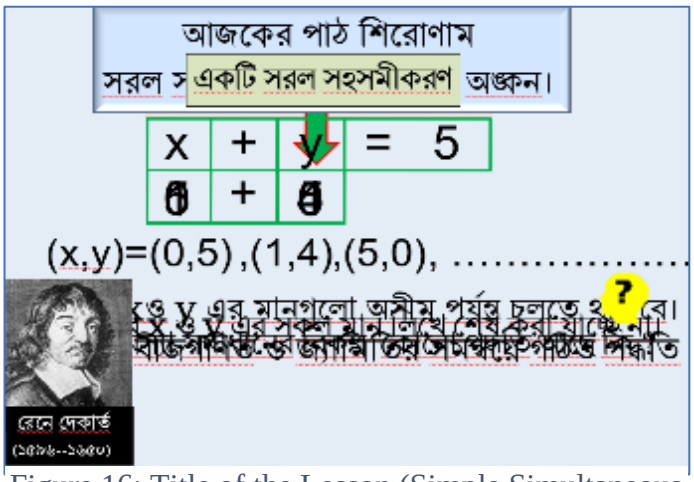


Figure 16: Title of the Lesson (Simple Simultaneous Equation)

up and replied ‘x^2’. The teacher then wrote on the board: 6+(-1) =5. He asked another student to respond. One student raised her hand and said ‘3+2’. The teacher wrote on the board: 3+2=5. Finally, he asked the class if they could all tell him the values of x and y. They responded with a chorus of ‘Ji sir’. He explained that there were no ending values of x and y in the equation x + y = 5. Instead, there were an infinite number of values. He also pointed out that these values would be plotted as a straight line on a graph. The teacher was explaining the concept of simple simultaneous equations, where two or more equations are combined to solve for unknown values. Two students were whispering to each other, and the majority of the class looked tired. Their body language suggested that they were not fully engaged in the lesson.

The teacher moved on to the next slide, which displayed an image of a scale and graph paper (Figure 17). The screen showed a series of texts appearing one by one, and the teacher explained the value of y and x, as well as the points associated with the given equation. The teacher emphasized that they should not use any fractions when plotting the points. The students were silent, their eyes fixed on the screen. The teacher then asked, “How many values of x and how many values of y”? He replied in his own way, stating that there were 3 pairs of values. The students remained silent, their faces expressionless. One student, however, stood up and walked to the back of the classroom, her bag slung over her shoulder. The teacher continued to explain, saying that they would now put the points into the graph paper. The teacher continued to click on the screen, and one point, A(2,0), appeared. Then, another point, B(1,3), and a third point, C(3,-3), appeared. As he showed the points, he asked the students what the value of x was, and he did not wait for their reply. Next, he clicked on the screen again, and a scale and a pencil appeared. The pencil drew a line through the scale, and the scale disappeared. The teacher asked, “What is this”? The students remained silent. He repeated the question but did not wait for an answer. Instead, he replied that it

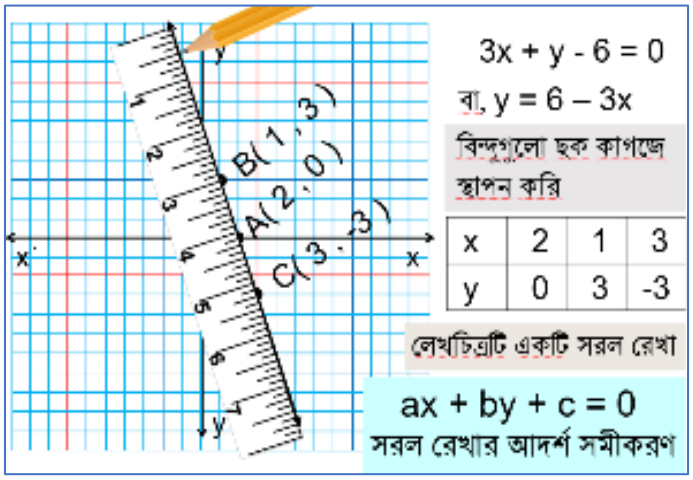


Figure 17: Drawing the Graph of the Equation

was a straight line. He pointed to the line on the screen and asked what would happen if they took any more points on the straight line. The students remained silent. The teacher then asked two more questions: “What is called a straight line?” and “How many points are on a straight line”? Again, the students remained silent. The teacher then explained himself, saying that they could make a straight line with just two points, but there were an infinite number of points on a straight line. He concluded that they could take three points to draw a straight line.

Observation Three – Grade Ten

T2_Lesson 1: Draw the Parabola

Meaningful Learning and Discovery Learning

The teacher moved on to the next slide, which displayed some images of parabolic shapes (Figure 18). He said, “I am bringing up some examples of parabolic shapes. Let us take a look at each one”. As he showed the images, the students looked curious and replied loudly all together. The teacher then added, “You know, engineers know more than general students. They know what equations they use in this monument”. Finally, he asked the students what they would be learning about that day. The students responded by saying all together ‘Parabola’.

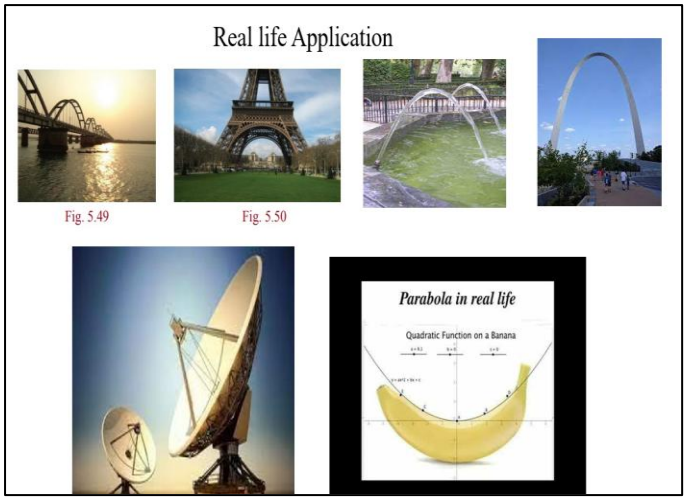


Figure 18: Pictures of parabolic-shapes

Then the teacher moved to the other slide and asked the students indicating the screen (Figure 19), “Do you know this? Tell me, what is this equation”? The students all together responded that it was a quadratic equation. The teacher continued explaining about the quadratic equations, the graph of quadratic equations, and the graph of a circle that would be a curve. He asked the students pointing to the screen what these graphs were about. The students all together replied ‘parabola’. The teacher nodded, pleased with their response. He again started explaining the types of parabolic graphs indicating the screen. He explained that these graphs were actually the equations of parabolas and that they were the graphs of those equations.

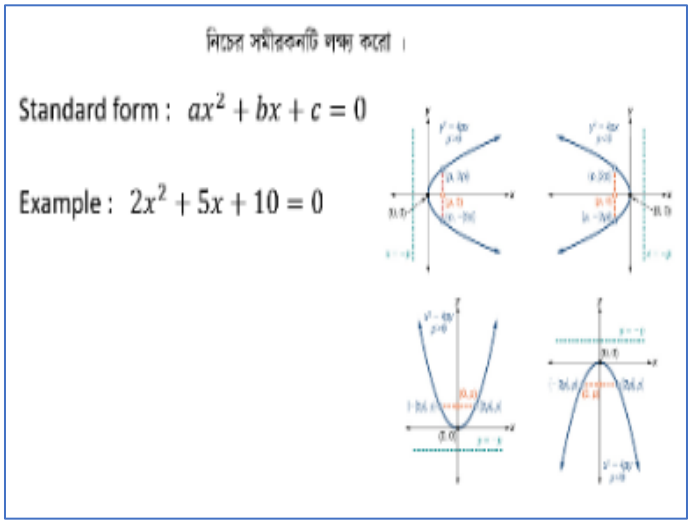


Figure 19: Graphs of Quadratic Equations

He went to the other slide and asked the students pointed to the screen (Figure 20), “What is the vertex point here”. Some students replied altogether. He began explaining that if the vertex point were changed then the position of the curve would be changed but the shape would be the same.

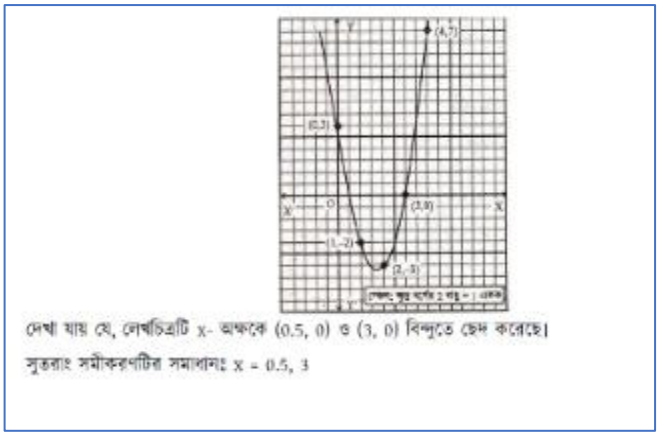


Figure 20: Graph of the Parabola

Observation Four – Grade Nine

T2_Lesson 2: Draw a Triangle (Construction-1)

Meaningful Learning and Discovery Learning

He proceeded to the next slide of the digital content and asked, “Here are some pictures, you look”. Then he started to explain some triangle shapes shown on the screen (Figures 21 to 23). He said, “This is a village picture, here is some paddy that makes a shape”. He asked a front desk boy, “What shape is it”? The boy stood up and replied, “A triangle”. He pointed to the 2nd picture and said there were some snacks. He asked a front desk girl, “What does it look like”? She stood up and replied, “Triangle-shaped”. The teacher echoed her answer and thanked her and told her to ‘sit down’.

Figure 21: Pictures of triangle-shapes

He went to the next slide and there were 3 triangle-shaped pictures. He again asked what those all looked like but did not wait for the answer and he again started to explain the pictures one by one. He explained, “What is the use of a triangle in real life? Actually there are many uses, one of them is the construction of a building; the engineers design the big constructions using triangles”.

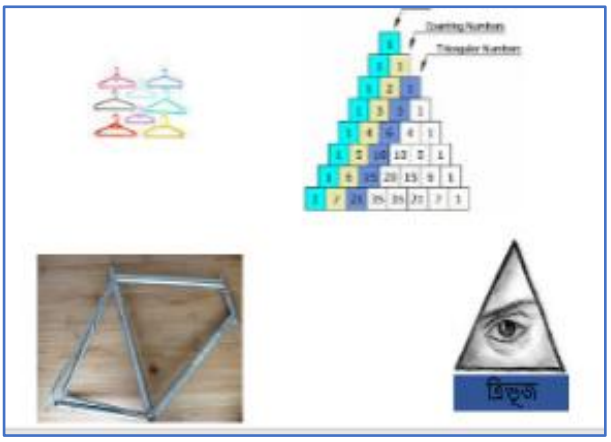


Figure 22: Pictures of triangle-shapes

The teacher turned over to the next slide and continued explaining pointing to the pictures, “Look here, you can see a tree, there is an eye, here makes a triangle shape, isn’t it, now look here is a tiger, jumping from a boat, here makes a triangle shape, if we imagine there are many triangle shapes, here is a ship, here makes a triangle-shape”.

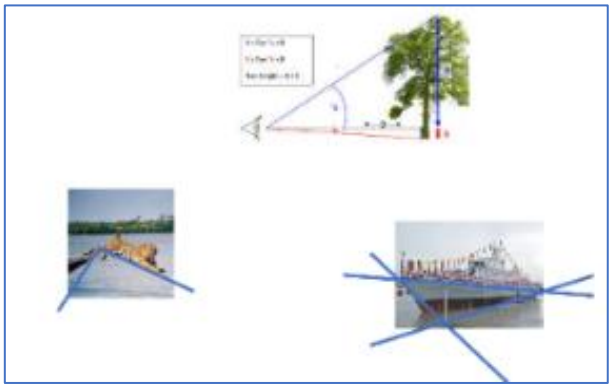


Figure 23: Pictures of triangle-shapes

The teacher asked the students to open their textbooks and to look there and underline the important lines in the book. The students opened their textbooks marked the lines and underlined them. There were six cases to construct the different six triangles described in the textbook and were in the slides also (Figure 24). The teacher asked the students to mark the six cases in their textbooks with a pen. He showed the six cases in the slides one by one and talked about when to construct the different six triangles or what were the conditions to draw a triangle.

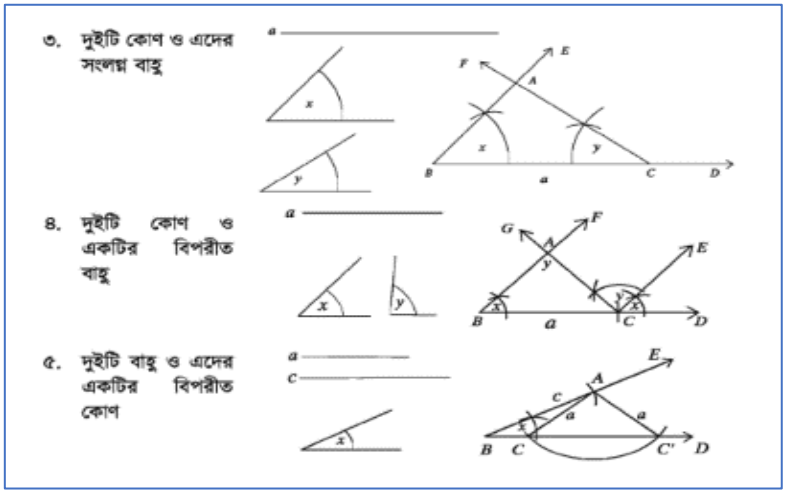


Figure 24: Construction of different Triangles

He went through the next three slides of the digital content and asked about the constructions of different triangles and replied himself indicating the slides. The teacher asked the same question twice but did not wait for their reply, “How many triangles could you construct if there are three different angles”? He then stated that it was provided in the textbook and gave the answer pointed to the text on the screen - it was written that there would be an infinite number of triangles with different shapes (Figure 25). The teacher asked the students to mark and underline the text as it was important for the examination. Some students were marking the lines in their textbooks.

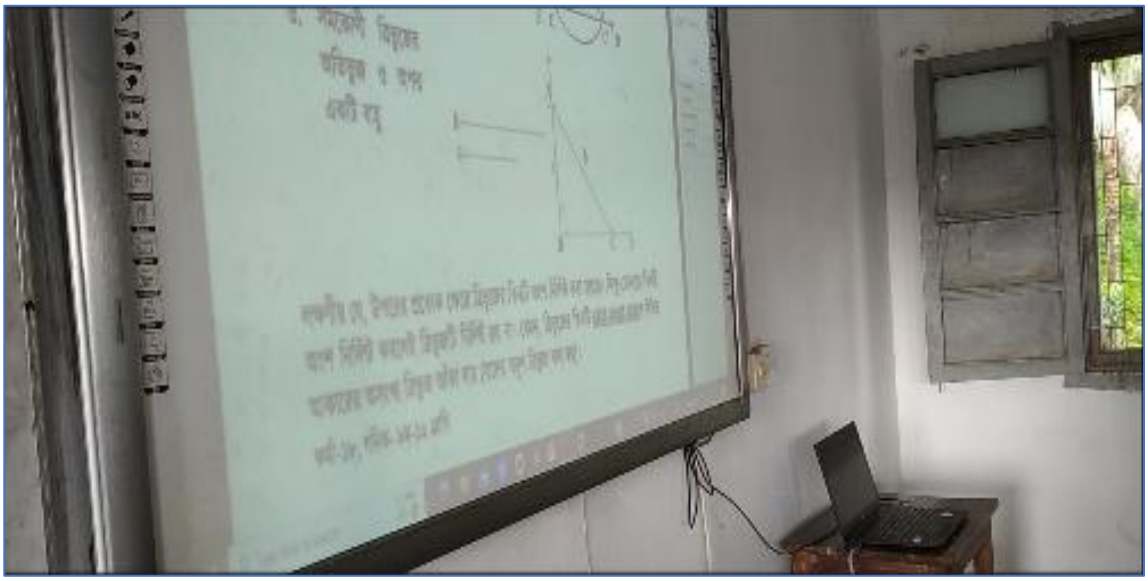


Figure 25: The text about Infinite Triangles

Observation Five – Grade Eight

T3_Lesson 1: Cone

Meaningful Learning and Discovery Learning

The teacher introduced herself to the students showing the introduction slide on the screen using the digital content and then moved on to the next slide. There were six congested cone-shaped pictures on the screen (Figure 26). She pointed to one of the pictures on the screen saying that it was a cap. He asked about another picture and pointed to it. Some students eagerly replied 'Cone ice cream'. The teacher smiled and nodded, saying, "Okay, so next". She replied to herself and then uttered the word 'next'. In this way, the teacher explained all the pictures one by one. The

Figure 26: Pictures of cone-shapes

students were watching curiously at the screen. The teacher asked, “All pictures have the similarities, what is that”? Some students all together responded, “cone”! She announced that the lesson topic was “Cone”. The students listened and watched silently.

The teacher proceeded to the next slide, which displayed two shapes of Cones and the definition (Figure 27). She began to explain herself, pointing to the screen as she spoke. Most students watched and listened to the teacher but looked like they were not actually listening. A few students were fiddling with their hair, hands, and teeth. The teacher continued to explain the definition of a cone, highlighting its key features such as a flat circular base, a curved surface, height, slant height, and radius. Her explanation lasted for almost three minutes and twenty seconds. Most students’ movements looked like they were not attentive during the lecture, and some looked sleepy.

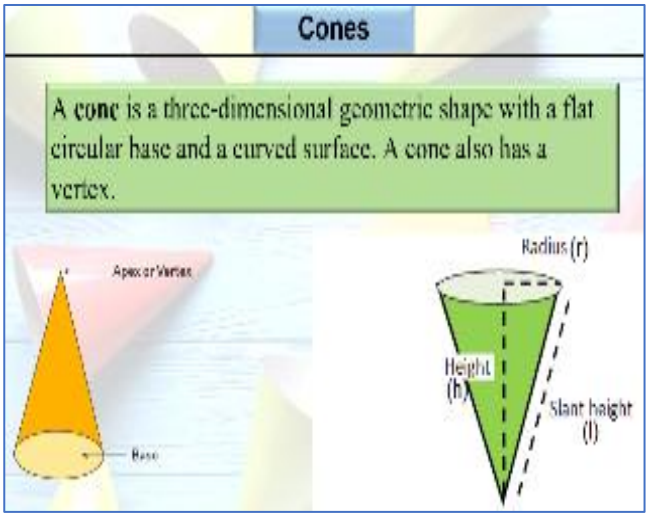


Figure 27: Definition of Cone

The teacher went to the next slide with two animated shapes of the Cone (Figure 28). She continued to explain the definition of a cone, pointing to the screen as she spoke. After almost four minutes of her explanation, she paused and asked the students, “Is this clear”? Most students were fiddling with their fingers, hands, and hair. Some students looked around the room, some made a yawn and some seemed sleepy, while only a few students seemed to be actively watching and listening to the teacher, with their eyes fixed on the screen.

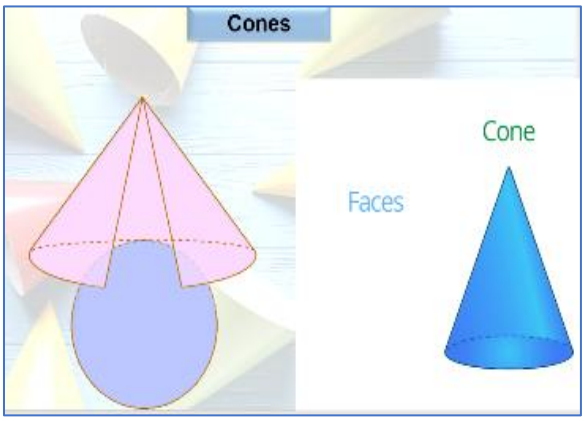


Figure 28: Surface of Cone

Observation Six – Grade Eight

T3_Lesson 2: Arithmetic Progression

Meaningful Learning and Discovery Learning

The teacher opened the PowerPoint presentation and told, welcomed everybody and introduced herself by showing it on the screen. She switched to the next slide which featured eight congested pictures (Figure 29). She asked, "What about the first picture"? The students responded all together that it was a sunflower. She continued to explain pointing to the pictures one by one as she spoke. She spoke about sequences and said that there were sequences in those pictures. Most students on the back benches were talking, laughing, and making noise, and one front-desk student was writing in his notebook.

Figure 29: Pattern in the Pictures

The teacher moved on to the next slide, filled with text (Figure 30). She read out the definitions and types of progression from the screen. Meanwhile, most of the back-bench students were chatting with each other, while a few students at the front desk nodded their heads in agreement with the teacher's explanations.

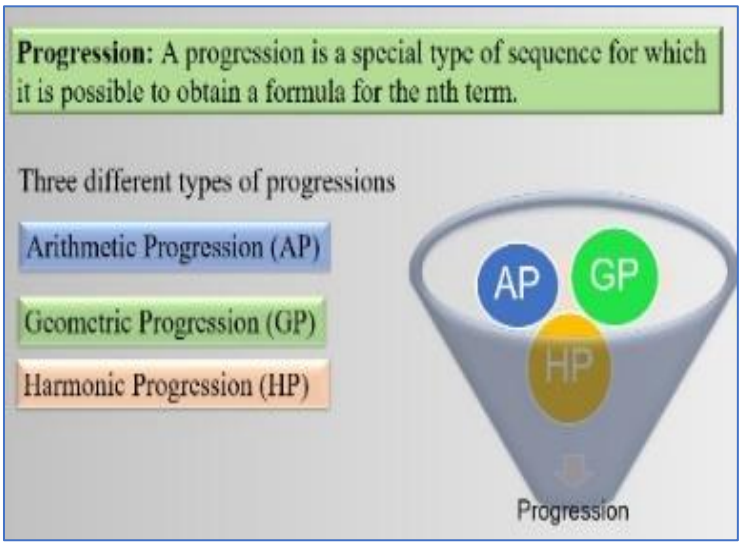


Figure 30: Definition of Progression

She asked an oral question, using the next slide to illustrate the concept of progression (Figure 31), "If a sequence is 1, 3, 5, ...; if we go from 1 to 3, what's the difference? If we go from 3 to 5, what's the difference"? Some students at the front desk responded correctly, saying that the difference was 2. The teacher continued explaining Arithmetic Progression, the common differences, and the sequences, and pointing them out to the screen as she read the words. However, more students were not engaged, some students were gossiping or looking bored, while others were yawning or fiddling with their belongings. A few students at the front desk were paying attention to the teacher's explanations and watching the digital content. Meanwhile, three students were actively taking notes in their notebooks.

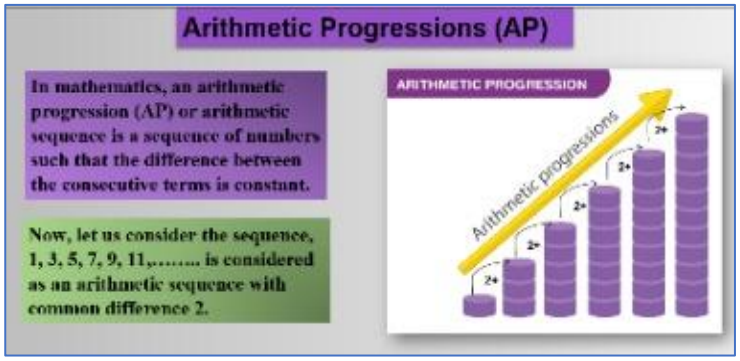


Figure 31: Concepts of Arithmetic Progression

Observation Seven – Grade Eight

T4_Lesson 1: Set Theory

Meaningful Learning and Discovery Learning

The teacher began the class by opening the digital content of the PowerPoint presentation. Students had their notebooks and textbooks out on their desks. The teacher started by showing the welcome slide and her introduction, before moving on to the next slide featuring two images of a glass set and a tea set (Figure 32). She asked, “Can you guess what would be today’s topic based on these two pictures”? Without waiting for a response, she continued talking, “We have one glass set and one cup set here”.

Figure 32: Pictures of Sets

The teacher asked the students again to guess what today's topic would be and then proceeded to the next slide. On this slide, there were five apples scattered across the screen, along with the title text (Figure 33). She announced, “Today we're going to learn about Sets”.

Figure 33: Picture of Sets

The teacher moved on to the next slide, which displayed two images and the definition of ‘Set’ (Figure 34). She asked the students what the first learning outcome was, and she provided her own answer, explaining the definition of a set in her own words. The students were not actively involved in the teacher’s discussion, instead, some were nodding their heads in agreement with the teacher, while others were fiddling with their hands or hair, one had her head down on her desk, and a few looked bored. The teacher continued to explain the concepts of Set and pointed to the images on the screen.

Figure 34: Definition of Set

The teacher went to the next slide (Figure 35) and said, “We are seeing a picture here, you can easily count how many players are here”. The students were watching the screen, one student herself was counting with her fingers. The teacher asked, “You have counted the number of players, so tell me what type of set it is”. She continued explaining, “There are many types of the set - if the elements of a set can be determined by counting, it is called a finite set”. The teacher continued to explain the concepts of finite and infinite sets. Some students were also uttering the words along with her, a few students were writing in their notebooks, most students seemed disinterested and some were yawning or looking tired.

Figure 35: Concepts of Finite Set

The teacher went to the next slide (Figure 36) and asked, “Look at the picture and count, how many stars are in the pictures”. She did not wait for their response, instead continued to explain herself about the infinite set, using the stars as the example as they could not be counted. She added, “If the elements of a set cannot be determined by counting, it is called an infinite set”.

Figure 36: Concepts of Infinite Set

She proceeded to the next slide and there was a Vann diagram, which was a visual representation of sets and their relationships (Figure 37). She was writing on the board and explaining the diagram herself, likely to clarify the concepts of A/B, AUB, and B/A, which were related to the Venn diagram. Some students were uttering words with the teacher, some were pretending to pay attention, looking at the teacher but not focusing on the lecture, one was writing on the palm of her hand and another one was writing something on her desk, which was the way of expressing their boredom or disinterest.

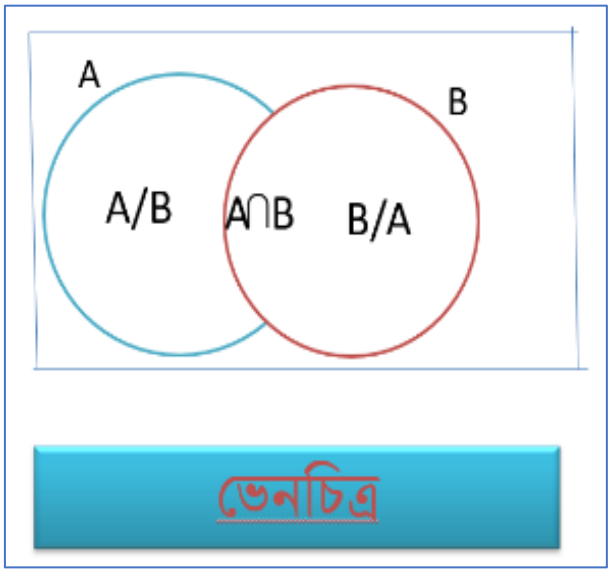


Figure 37: Concepts of Venn Diagram

Observation Eight – Grade Nine

T4_Lesson 2: Function & Relation

Meaningful Learning and Discovery Learning

The teacher opened the PowerPoint presentation of digital content and welcomed the students showing on the screen. She went to the next slide, which displayed shapes and texts to make the connection between the things called Relation (Figure 38). She began to explain pointing to the screen, “Look at the screen, here are some names of children and their mothers, here are some names of students and their teachers”. She continued to explain uttering the words and some students also uttered with her to make the

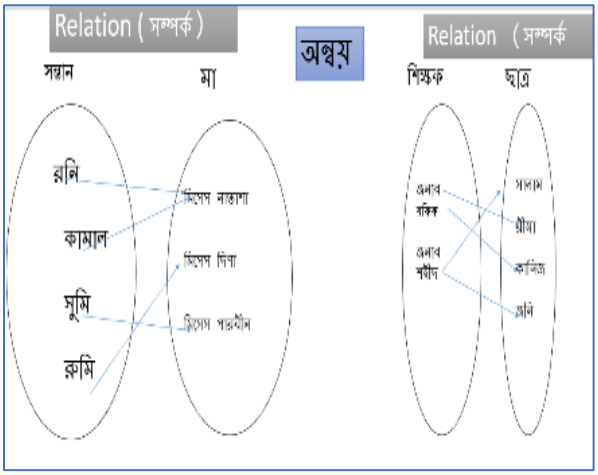


Figure 38: Concepts of Relation

connection between mother and children and also the teachers and students and made ‘Relation’. The students were watching, listening, and shaking their heads with the teacher and some were silent. Then the teacher asked, “Have you understood what will be today’s topic”? She did not wait for their response, instead replied herself and clicked on the text and the word ‘Relation’ appeared on the screen.

Then the teacher moved to the next slide (Figure 39) and said, “Look at the picture, here is the relation between mothers and children”. She continued to explain that there were two types of relations between the mothers and the children on the screen. She began explaining to the students about the first relation from the screen and pointed to the mothers and the children. After that, she pointed to the second relation and explained herself. Some students were listening to her, some uttering the words with her, the words including ‘relation’, ‘mother’s name’, ‘children’s name’ etc. Two students were looking at their textbooks, one was yawning, some were pretending to pay attention and some were silent. She repeated the explanation about the Relations and Function. She went to the laptop and clicked on it, and then the text ‘function’ and ‘not function’ appeared on the screen. Some students looked tired, one was fiddling with her hair and one was yawning.

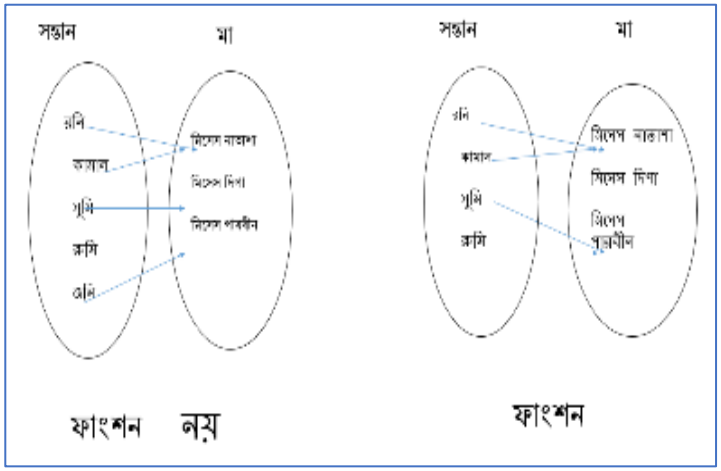


Figure 39: Concepts of Function

The teacher went to the next slide, it was similar to the previous one (Figure 40). She began explaining about the ‘function’ and ‘not function’. She explained the conditions of the connection for being the Function and not Function. Some students were listening to her, others were pretending to pay attention, looking at the teacher but not really focusing on the lecture, and uttering the words with the teacher and some looked aloof. She asked pointing to the screen, “Which is domain”? Some students answered all together, “Children”. She asked again, “Which is co-domain”? They answered the same way, “Mother”. She told them, “Now, you can easily identify the domain and co-domain in a Function”.

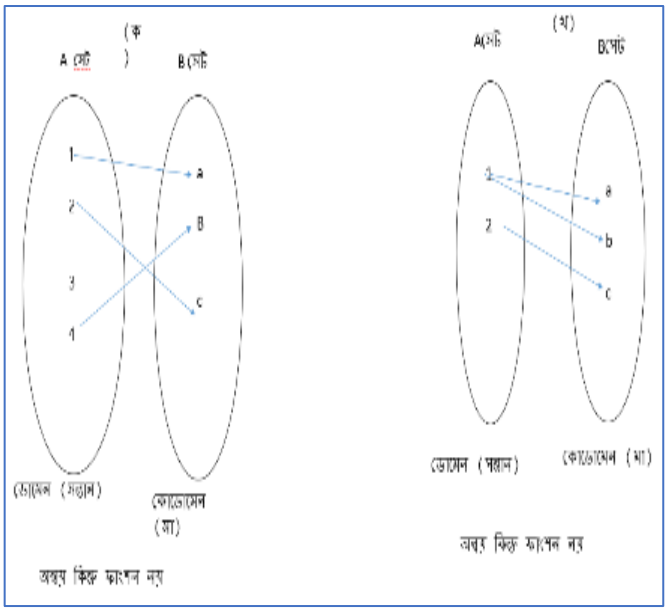


Figure 40: Concepts of Function and Relation

Observation Nine – Grade Nine

T5_Lesson1: Trigonometric Ratios

Meaningful Learning and Discovery Learning

The teacher skipped the introduction slide and went to the next slide of the digital content and opened a video about trigonometric ratios (Figure 41). During the video presentation, the teacher started explaining the content of the video. The students were watching the video and listening to him. Suddenly, he went outside for a while, and then the students started talking with each other and did not watch the video. The teacher entered

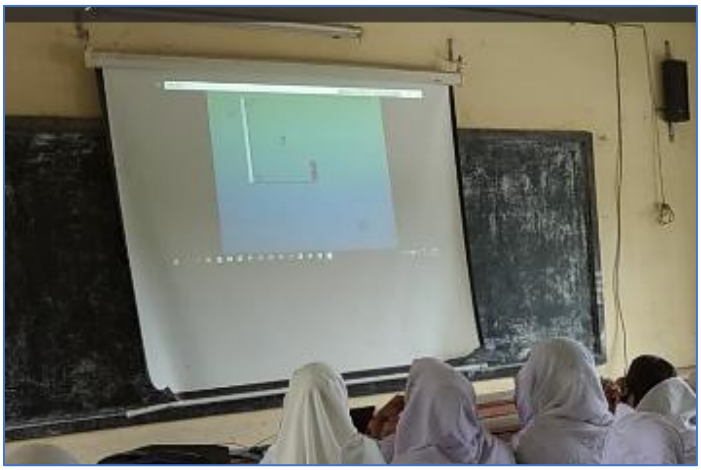


Figure 41: Video on Trigonometric Ratios

the classroom and explained indicating the screen, “We got a triangle, a base, a height, and a hypotenuse”. And he asked, “So which topic would be there in the lesson”? The students answered in chorus ‘Triangle’. The teacher opened the next slide and said, “We will discuss today Trigonometric Ratios”. He asked, “What will we discuss today”? The students answered in chorus ‘Trigonometric Ratios’.

The teacher proceeded to the next slide, displaying a right-angled triangle on the screen along with accompanying animated text (Figure 42). The teacher asked a series of questions, pointing to the screen and asking the students to respond. The teacher asked, “What type of triangle is ABC”? The students responded together, saying ‘Right-angled Triangle’ a collective chorus sound as they looked at the screen. The teacher also uttered the answer along with the students. The teacher then asked, “What is called the opposite side of the right angle”? The students responded again, saying ‘Hypotenuse’ and the teacher repeated the answer. Next, the teacher asked, “What about the angle C”? The students responded once more, saying ‘Acute angle’ and the teacher repeated the answer. Finally, the teacher asked, “What are the names of the three sides of the right-angled triangle”? The students responded again, and the teacher repeated the answer along with them.

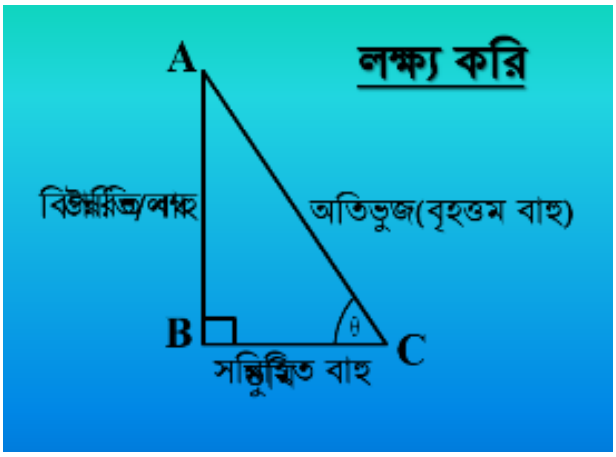


Figure 42: Concepts of Right-angled Triangle

Observation Ten – Grade Ten

T5_Lesson2: Rectangular Solid

Meaningful Learning and Discovery Learning

The teacher started the lesson by opening the digital content of the PowerPoint presentation. The teacher asked the students, “What is called a rectangle”? Some front desk students raised their hands. He asked a boy, he stood up and answered the definition. The teacher asked again, “How many surfaces are in a rectangle”? The students were silent and he explained in his own way that there was one surface in a rectangle. He added if it would be rectangular solid it would have 6 surfaces. Some front desk students were uttering with him. The teacher said that they would discuss how to determine the length, width, height, and diagonal of a rectangular solid.

The teacher then clicked on the keyboard and a picture of a brick appeared on the screen (Figure 43). He asked the students pointing to the screen, “What type of solid is this”. The students responded in unison, saying that it was a rectangular solid. The teacher then asked, “How many surfaces does it have”? The students replied that it had 6 surfaces. The teacher asked, “If a solid has 6 surfaces, what is it called”? The students responded together, saying that it was a rectangular solid. He added that the brick had length, width, and height, and the students spoke with him in agreement. Next, a picture of three tiffin boxes appeared on the screen. The teacher asked a series of questions, “Here you see some boxes, how many surfaces do the boxes have? What type of solid are these bricks, tiffin boxes”? The students responded in unison, answering all of the teacher's questions at once. After that, another solid resembling a brick appeared on the screen.

Figure 43: Pictures of Rectangular Solid shapes

The teacher went to the next slide, where a picture of a brick appeared on the screen (Figure 44). He asked, “What type of solid is this”? The students responded in unison, answering ‘Rectangular solid’. After that, the shape of a rectangle appeared on the same screen. He asked a question, and the students responded together, saying ‘Rectangle’. As the teacher continued, the definition of a rectangular solid appeared on the same screen. The teacher uttered the words on the screen about the definition of rectangular solid, and the students joined in, repeating the words with him.

Figure 44: Definition of Rectangular Solid

The teacher moved to the next slide, there were shapes and texts about the whole surface area of a rectangular solid (Figure 45). He counted the surfaces himself pointing to the screen and some students were also repeating with him. The teacher asked a series of questions one by one, “What is the length, what is the width, what is the height”? The students responded all together, saying ‘a’, ‘b’, and ‘c’. Then he asked by pointing to the screen, “What will be the whole surface area of the rectangular solid”? Most students read out the words from the screen. They were watching the screen, silently listening to the teacher, and some were chatting with each other.

Figure 45: Total surface area of a Rectangular Solid

4B.1.1.3 A detailed summary analysis of integrating ten Observed lessons

The scores are defined as **H** for high, **M** for medium, **L** for low, and **N** for not done in the lesson.

1.1 Pedagogy (Learning Objectives: Meaningful learning and Discovery learning)												
	Aspects of Observation	Scores of Ten Lessons										Descriptions
		T1		T2		T3		T4		T5		
1.1.1	Build meaningful connections between student's experiences and knowledge	N	N	N	N	N	N	N	N	N	N	The students were not required to extend their knowledge by connecting with their prior knowledge.
1.1.2	Extend knowledge connecting with students' prior knowledge	L	L	L	L	L	L	L	L	L	L	The teachers made a little connection using real-life-based digital images to go to the lesson.
1.1.3	Apply mathematical concepts and analyze critically.	N	N	N	N	N	N	N	N	N	N	The students were not required to apply and analyze the mathematical concepts critically.
1.1.4	Struggle with mathematical ideas in real-world examples.	N	N	N	N	N	N	N	N	N	N	Students were not required to struggle in real-life situations.
1.1.5	Explore mathematical information and innovate ideas.	N	N	N	N	N	N	N	N	N	N	The students did not get opportunities to explore information and innovate new ideas.

Table 6- Classroom Observation Guidelines (Pedagogy: Learning Objectives)

Dimension- Pedagogy (Learning Objective: Meaningful Learning and Discovery Learning)

4B.1.1.4 Linkage between teachers' pre-lesson interviews and their lessons

From the teachers' pre-lesson interviews, it can be said that four teachers usually started their mathematics lessons by showing real-life images or pictures on the screen. T2 confessed that he usually asked 2 or 3 questions to the students from the previous lessons showing the questions on the screen of the digital content. However, he does not relate the mathematical concepts to real life. He usually explained the mathematical concept to the students showing the image or text on the screen. T2 and T4 confessed that there was no need to check the student's prior knowledge at the beginning lesson of a new chapter, however, it needed to be checked at the 2nd and other lessons of that chapter.

From the lesson observation, it is evident that all the teachers used relevant images and texts in their digital content slides at the beginning of the lessons as they told in their pre-lesson interviews. T5 showed videos at the beginning of his two lessons to connect the mathematical concepts to real-life things and he described the facts to the students. All the teachers connected the lesson to real-life things showing the images, texts and videos and explaining it to the students using the teacher-centered approach while announcing the title of the lesson. Sometimes the teachers asked a few questions pointing at the images on the screen and the students replied by saying one or two words. However, the students did not make any relation between their experience and not extent of their knowledge in the lessons, and environments for them to engage deeply with the learning concepts were not created. The students were mostly silently watching the screen and listening to the teacher's explanations.

T1 stated in his pre-lesson interview that he usually visualized the mathematical concepts by showing images and animation and used questioning techniques where the students could think critically and explore the mathematical tasks with the images and animation by using digital content. T1 visualized the mathematical concepts in his lessons through animated images about 'Pi' and the 'area of the circle'. However, there were no effective questioning techniques, and an environment for the students to analyze things critically and innovate ideas was not created.

T2 informed in his pre-lesson interviews that he usually showed the text of mathematical definitions on the multimedia screen and recited it to help the students for their better understanding, and sometimes asked the students to underline the definition in their textbook as the important line. T2 did the same in his lessons, he visualized the procedural graphs of quadratic equations and the rules of construction of triangles in his lessons which were copied from the textbooks. He explained the quadratic equations and the rules of constructing the triangles and sometimes asked the students to underline the important lines in their textbooks that he told in his pre-lesson interviews.

T3 claimed in her pre-lesson interviews that she took the students outside to apply mathematical concepts in real-life situations. However, she did not do it in her lessons. T3 asserted that it was not possible to make the critical thinking environment in the lessons and not easy to take the classes in the way they learned at the training because of the class load. T1, T2, and T5 also confessed that they usually did not create opportunities for the students to apply mathematics in real-life situations. In their lessons, the teachers did not create such an environment for the students to apply mathematical concepts in real-world examples or create new things. T2 and T3 blame the short duration of the class for not doing so, as they are obliged to finish the syllabus on time.

All these five teachers asserted in their pre-lesson interviews that they usually explained the mathematical concepts by showing images or animation using digital content to help the students for their better understanding, and they all did it in their lessons. All the teachers reported similar reasons for not providing opportunities for students to explore and explain mathematical ideas: they noted that students often do not articulate their thoughts. The teachers argued that students primarily wanted to receive information directly from them.

In the lessons, teachers T3, T4, and T5 used images to visualize the mathematical concepts in one of their lessons of ‘Arithmetic Progression’, ‘Relation and Function’ and ‘Rectangular Solid’ respectively but they mostly explained the concepts as they told in their pre-lesson interviews. They did not provide opportunities for the students where they could analyze or apply their creative thoughts on those visual mathematical concepts. The teachers also could not create an environment for the students to explore and explain their own ideas and understanding of the facts. In some

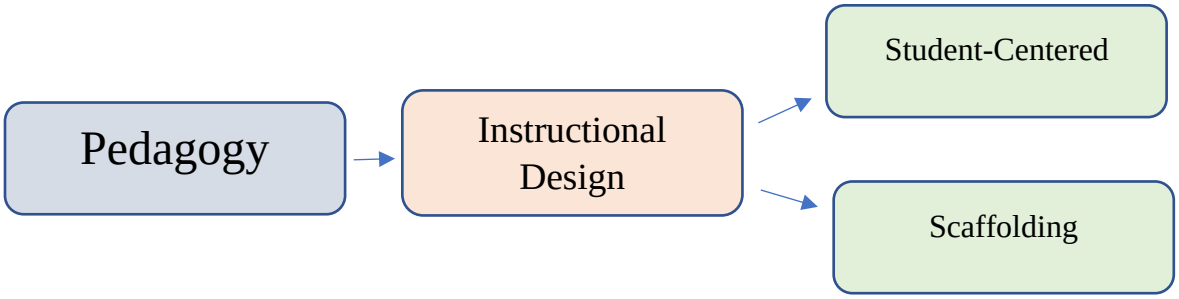
lessons, there were images, animated images, and shapes that the students could analyze critically and innovate ideas. However, the teachers could not make it creative and innovative for their students. In these five cases, the teachers used the digital content in their lessons by just following the stages of the slides showing one after another. In the lessons, they put up the slides one by one, read the words, and gave sorts of explanations of the animated images, texts, and pictures. All these five teachers explained the images to the students and the students were silently watching and listening. The students could explore new knowledge and create new rules on their own. However, the teachers were unable to create an interactive and innovative learning environment for the students in their lessons.

Dimension- Pedagogy (Learning Objective: Meaningful and Discovery Learning)

4B.1.1.5 Summary

The trained mathematics teachers have become capable of inserting text, relevant shapes, pictures, and videos in their presentation slides of the digital content. They showed the things in their lessons and explained them to the students. However, they could not create an environment where the students could extend their knowledge by connecting with their prior knowledge by using digital content. The teachers could not provide opportunities with diversified tasks using digital content where the students could analyze critically, apply creative thoughts, struggle in real-life situations, and innovate mathematical ideas. As a result, it is evident in the classroom observation guideline that the codes of meaningful learning and discovery learning of the Pedagogy Dimension have not been fully implemented in most lessons, with minimal focus on meaningful learning and no instances of discovery learning observed in the lessons. There were five segments in the observation guideline under the codes of meaningful learning and discovery learning. The total scores for the ten lessons were **10L** and **40N** out of **50**. No scores were there for **M** and **H**. It should be mentioned that all the teachers got the same scores in the code of meaningful learning and discovery learning.

4B.1.2 Pedagogy: Instructional Design (Student-Centered and Scaffolding)



This section investigates the concepts of student-centered learning and scaffolding, highlighting their significance in educational settings. The researcher begins by examining how the teacher facilitates student learning and fosters an environment that encourages learners to have a choice in the learning process, allowing them to express their understanding of mathematical concepts. Students are allowed to struggle with important mathematical tasks using their own strategies. The teachers support students in becoming decision-makers in their learning in a technologically-enhanced environment. Furthermore, teachers systematically build on student's experience and knowledge as they acquire new skills. They create a climate where making mistakes is accepted, offering guidance and support while students learn and develop new concepts or skills. To achieve this, the researcher compares the teacher's statements about their instructional methods with evidence gathered from observed classroom lessons. Through this analysis, the researcher aims to uncover the effectiveness of the teacher's pedagogical approaches. The findings from this evaluation will contribute to understanding the interaction between teaching strategies and student learning in the context of student-centered and scaffolding.

4B.1.2.1 Teacher's Pre-lesson Interviews

The teacher (Case 1) said that the students usually wanted to solve the mathematical tasks in procedural method, they loved watching the image or video on the screen but most students were not struggling with their own strategies with the tasks. He remarked that the students were not capable of grappling with the difficult mathematical tasks. He usually went through easy questioning with the difficult concept and explained it to them, showing the image and text on the presentation slides for their better understanding. He confesses that he generally did not provide the students with different mathematical tasks in the light of students' responses. The teacher T1 disclosed, "I usually provide the same tasks to all students, and the able students solve the task in procedural method and help the others". He remarked that he sometimes created an environment where the students could make mistakes in solving the tasks. If the students made more mistakes in solving the mathematical tasks, he did not discourage them. He added, "Sometimes something wonderful happens when the students make mistakes, such as when the number of people becomes a fraction. Then, I help them think about their mistakes". The teacher confessed that most students did not want to engage deeply in tasks as problem solvers or creators, they wanted procedural tasks to solve using the rules. The teacher added that he usually explained the mathematical using digital content to build their mathematical ideas but the students were not capable enough to transfer their knowledge to the new context.

The teacher (Case 2) noticed that some students were very talented, they sometimes solved the mathematical tasks with their own strategies. Sometimes the students wanted to explain mathematical facts by watching the images and text in the digital content. However, the students might have made mistakes; and that is why, the teacher usually solved the tasks to help the students and explained it to them not to make mistakes by showing them on the presentation slide. He professed, "Sometimes the students can understand the difficult mathematical concepts, but sometimes not; if not I explain it to them for their understanding. If that mathematical issue is important for their test or examination, then I explain it to the students, otherwise I give them some ideas only". He confessed that he explained the mathematical concepts to the students by showing images or text in the digital content for their deeper understanding. He pointed out, "A comparatively difficult topic I repeat explaining to help the students understand it. Sometimes I

repeatedly show them the image and texts on the screen as per revision of the lesson and repeat explaining to them". He asserted, "Sometimes I ask questions showing the text and image using the digital content if they are not able to answer, I explain it to them". When a student made a mistake in solving a task, the teacher provided necessary corrections to help the student. He commented, "I provide challenging tasks as homework to the students, not in the classroom environment". He professed that he usually explained the mathematical concepts by showing images and text in the digital content slides to build students' mathematical ideas. He explained that while he described the concepts in the lesson, if it shifts to a new context, it requires more time to explain the concepts to the students. However, the students are unable to transfer their knowledge to a new context.

The teacher (Case 3) stated, "Most students generally do not want to struggle with important mathematical ideas and practice with their own strategies, but digital content helps them to watch and think about the mathematical task in a different way". She remarked, "I usually explained the difficult concepts to the students for their deepen understanding". She shared, "Sometimes the students make mistakes when solving the tasks, and sometimes I make fun with their mistakes and then they become confused about the concepts". She added that she usually did not create an environment where students struggled with making mistakes and forming arguments about learning. She agreed, "I provide the same tasks to all students". She added, "Sometimes I provide different tasks for the different groups by using digital content". She discloses that she generally explained the difficult mathematical concepts by showing them images on the digital content slides to build students' mathematical ideas. The teacher added that the students were not capable of transferring their knowledge to the new context without receiving the teacher's explanations.

The teacher (Case 4) said that the students usually solved the mathematical task using the procedural method by watching the digital content. She confessed, "I normally explain the difficult mathematical concepts to the students showing them images and text in the digital content for their better understanding". She shared that sometimes the students made mistakes in solving the task and she helped them to correct it and explained it to them for their understanding, but she did not create an environment to make mistakes and form arguments on the task. She confessed that she usually did not do anything different for the low achievers. She stated that she usually provided

the same mathematical tasks to all the students displayed on the screen. She usually explained the mathematical concepts to the students by using digital content slides to build their mathematical ideas.

The teacher (Case 5) claimed that the students generally did not want to solve the mathematical task with their own strategies rather than using the rules or formulas. He stated, "I explain the difficult concept to the students by showing the images or video on the slide of the digital content, and I repeat explaining to them for their better understanding". He confessed, "I normally explain the difficult things very clearly to the students using digital content". He disclosed, "Actually I provide the same tasks for all, do not provide different mathematical challenges for different achiever students". He added that it became convenient for the students to solve the task differently by watching the digital content on the screen, but they generally wanted to do the task in procedural methods. He added that he usually explained the mathematical concepts using digital content, to make it easy and to build the student's ideas.

4B.1.2.2 Classroom Observations

In these five cases, there were opportunities to enhance the lessons through a Student-Centered and Scaffolding Instructional Design approach. Field notes have been compiled from a review of the data collected from the ten videos provided.

Observation One – Grade Eight
T1_Lesson 1: Area and Circumference of a Circle
Student-Centered and Scaffolding

The teacher began to explain the concept of circumference, pointing to the picture of 'pi' on the slide as he spoke (Figure 46). He asked a series of questions by pointing to the screen, "I said it's the circumference- what is circumference? The circumference, the range, the square, the rectangle, which one's sides are parallel and which side will be curved; what are the differences there? So, this is

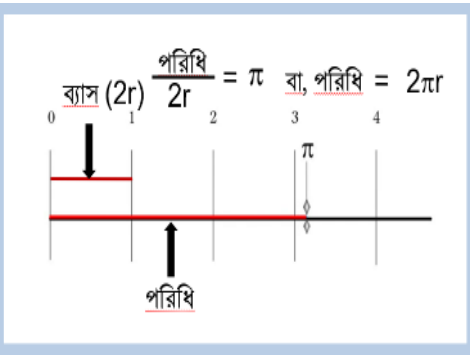


Figure 46: Concepts of Pi

the circumference." He then moved on to the next slide, showing pictures of circumference, diameter, and radius on the screen. As he explained, "The radius is double the diameter, and circumference, if the circumference is divided by diameter, it will be Pi, have you clearly understood"? He then walked over to the blackboard and wrote down the information that was on the screen. The students watched and listened to him, but their expressions seemed bored and uninterested.

The teacher moved on to the next slide, which featured an animated picture that appeared one by one with a click (Figure 47). He asked the students, pointing to the screen, "Take a good look, how many divided parts are there? Four parts? Will it be more parts? Yes, it will be more parts if you make these small". He stopped the animation and went to the blackboard to draw and explain the same concept as what was on the screen. Some students seemed confused and shook their heads when he asked the question. The teacher then returned to the screen and began counting the parts, using his pen to indicate the divisions. He asked, "Is it looking like a rectangle? Here are so many parts. Is it looking like a rectangle"? Some students replied with half-hearted answers, such as 'rectangle' or 'kind of', while shaking their heads.

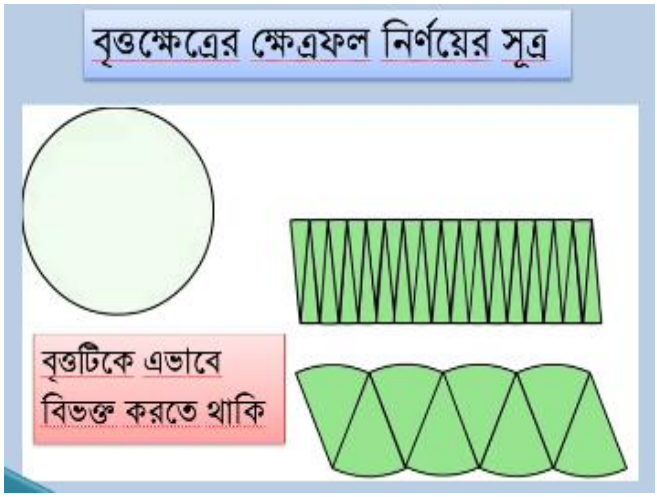


Figure 47: Concepts of Area of Circle

The teacher continued to the next two slides, which featured similar animated pictures to the previous one (Figure 48). He explained himself, pointing to the screen with his pen, “If it is divided by infinite parts, then it will be a rectangle, it is a rectangle, and it has an area. What is that? Length multiplied by width. Which one is the length? Is it? Which is tall, that is length, which is short, that is width”? The students were watching and listening, but their reactions were varied. Some replied with half-hearted answers, shaking their heads in confusion. Meanwhile, some students were distracted, fiddling with their fingers or looking around the room. Two students were leaning on their desks, and two were staring at their own desks.

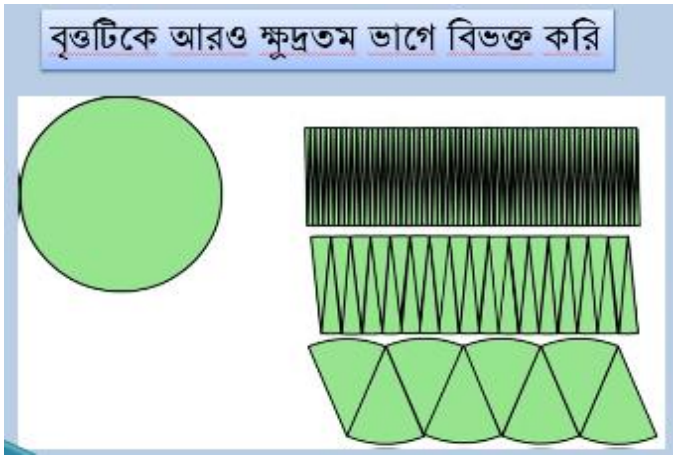


Figure 48: Area of Circle

Observation Two – Grade Eight

T1_Lesson 2: Graph of a Simple Simultaneous Equation

Student-Centered and Scaffolding

The teacher went to the next slide and the slide was about introducing the four quadrants and the corresponding points (Figure 49). He explained that the graph was a number line. The texts and shapes appeared by clicking one by one on the screen and he was explaining the number line, origin, horizontal line, two perpendicular lines, and axes. The teacher suddenly asked the students, “If I say, my house is in Dhanmondi - how do you find it, need the house number and road number”. He also explained how they would go to the house. He added that they needed two things, the

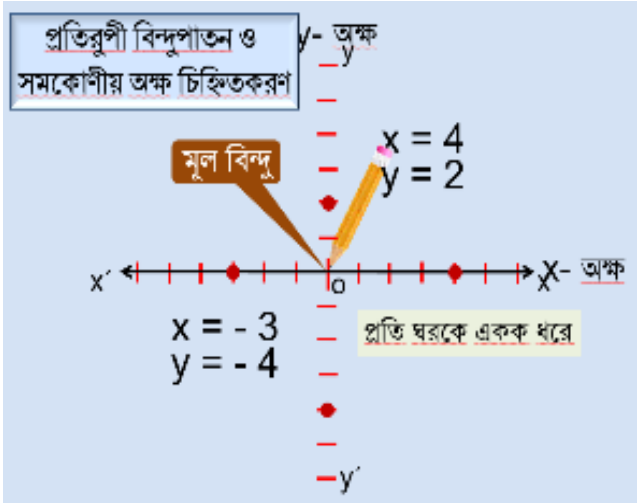


Figure 49: Four Quadrants and the corresponding points

horizontal and the vertical line as like as the road number and the house number. The students were watching and listening but some were fiddling with their hands and fingers, and some were chatting quietly with each other. He was also explaining the four quadrants drawing on the board, and what was on the screen too. Then the teacher continued explaining order-pair, four quadrants, and axes.

The teacher went to the next slide and continued explaining the four quadrants, positive values and negative values in the quadrants, coordinates, and putting the points shown at the screen (Figure 50). He explained how to put point A(4, 2) on the graph paper and asked how many points were in A(4, 2), and he replied it was one point. The teacher did not wait for the student's response, instead he was telling them to remember that it was one point. The teacher then went on to explain how to plot another point, B(-3, -4), on the screen. The students were watching and listening, but some of them looked tired and disinterested. Some students sat with their hands on their heads, indicating that they were struggling to keep up with the lecture.

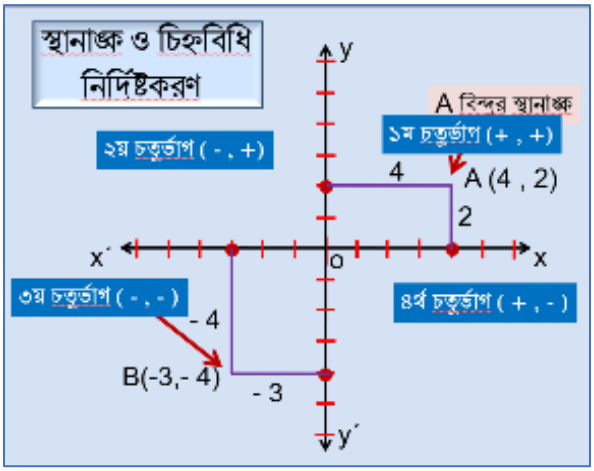


Figure 50: Four Quadrants and the Coordinates

The teacher moved on to the next slide, which showed how to draw the graph of a given equation (Figure 51). He explained the steps to the students, pointing to the screen as he went along. He asked a question to the students, “If the value of x is 3, what will be the value of y”? But he did not wait for their response, instead, he explained that there was no y variable in the equation. The students looked confused, but the teacher explained that the value of y would be zero. Then the teacher clicked on the screen and a graph appeared. He then asked the same question again and said, “That's right, the value of y would be zero”. The students were silent, but looked tired and struggling to keep engaged in the lecture. The teacher then pointed to the screen and explained how to use positive and negative coordinates. He clicked on the screen and a pencil appeared, moving 3 units to the right along the x-axis. He explained that this was what they had so far. The teacher then asked if they had any more values. When there was no response, he repeated the question and told them to refer to their textbook. He explained that there would be two graphs: one with only values of x, and one with only values of y. As he spoke, the pencil disappeared from the screen and another pencil appeared. The teacher began drawing the graph again on the screen using the animated pencil, explaining as he went along. He emphasized that when they only had values of x, the graph would be parallel to the y-axis. The students watched and listened intently, but some of them looked tired and were sitting with their hands on their heads. They seemed to be struggling to keep up with the lesson.

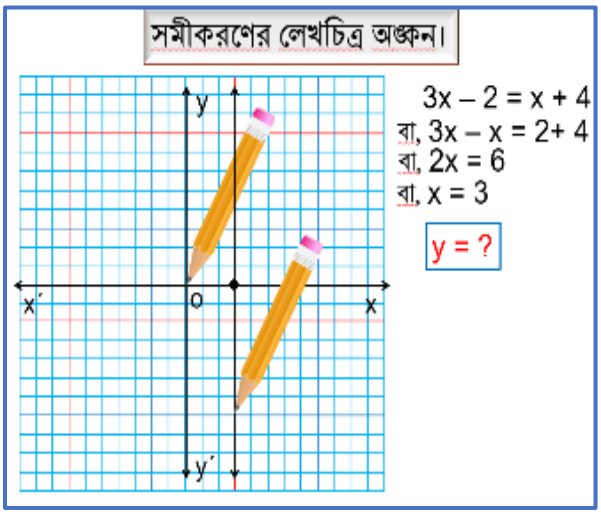


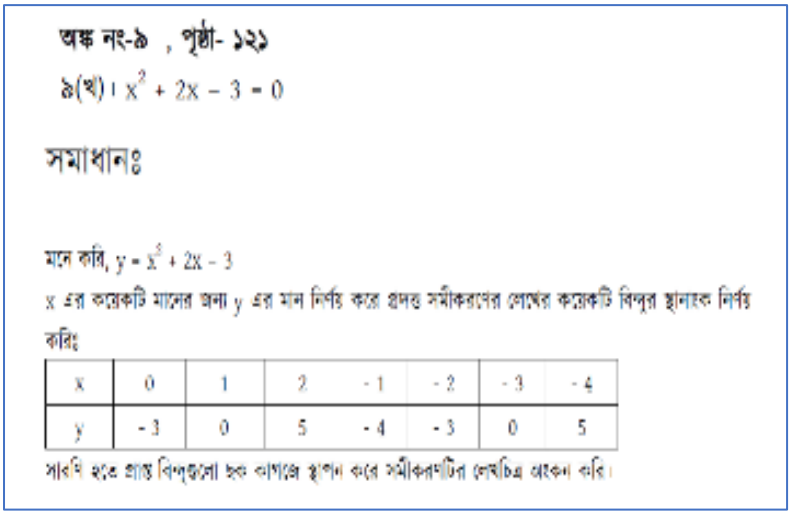
Figure 51: Graph of the Equation

Observation Three – Grade Ten

T2_Lesson 1: Draw the Parabola

Student-Centered and Scaffolding

The teacher went to the laptop opened another slide and announced, “We will now draw a parabola from the textbook chapter”. He pointed to the screen (Figure 52) and said, “This equation is from the textbook, open your book, everybody”. The students obediently opened their textbooks and began to scan the pages. As they looked at their books, the teacher walked along the row, repeating himself, “We can even solve this equation using a calculator. We can also get the coordinate points using a calculator”. He emphasized that solving the equation manually would take more time, but using a calculator would make it quicker. Some students took their calculators out of their bags, eager to start working. The teacher then went back to the laptop and clicked on the next slide. He pointed to the previous screen and said, “Look, I will show you now”. He began explaining the coordinate points, x and y, and how many points were needed to make a complete graph. Sometimes, he asked questions to the entire class and replied himself. Some students responded altogether saying 1/2 words while shaking their heads. Some students seemed to be doing something with their calculators, one student was fiddling with his hair, one was looking down at his desk, and most of them looked tired.



অঙ্ক নং-৯ , পৃষ্ঠা- ১২১

৯(খ)। $x^2 + 2x - 3 = 0$

সমাধানঃ

মনে করি, $y = x^2 + 2x - 3$

x এর কয়েকটি মানের জন্য y এর মান নির্ণয় করে প্রদত্ত সমীকরণের লেখের কয়েকটি বিন্দুর স্থানাংক নির্ণয় করিঃ

x	0	1	2	- 1	- 2	- 3	- 4
y	- 3	0	5	- 4	- 3	0	5

সারণি হতে প্রাপ্ত বিন্দুগুলো ছক কাগজে স্থাপন করে সমীকরণটির লেখচিত্র অংকন করি।

Figure 52: The Equation of parabola

The teacher went to the laptop, opened the GeoGebra, and asked the students to draw the axis x. He told the students, “Look, how I draw the axis x and the axis y, I am drawing the axes using the software”. He was asking the first point and one student replying the point was (0, -3). The teacher put the point in the software and showed the graph (Figure 53). He asked for the next point and went on the steps of the graph. One or two students replied saying one or two words like ‘ji sir’, 2, or 3. Some students were looking at the screen of the teacher’s work with GeoGebra and some doing their tasks in their notebooks. Then he said if they would add the coordinate points with a sharp pencil, they would get the graph like that. He put the equation in the GeoGebra saying that if he would write the equation there the coordinate points would be added. He asked whether the points had been touched, but did not wait for the reply. He explained again walking along with the students, “If you added the points you would get a graph like that”. The students were working in their notebooks as per the previous instruction. He said, “When we do sign your practical notebook, we see that you make angles at adding points, it will be a curve,”. He asked, “Could you draw the graph adding the points”? The students all together replied, “Ji sir”. H then repeated the explanation of putting the equation in the software GeoGebra. Two students in the back bench were talking in a very low voice, one boy was using a calculator, and most students were watching the GeoGebra work silently.

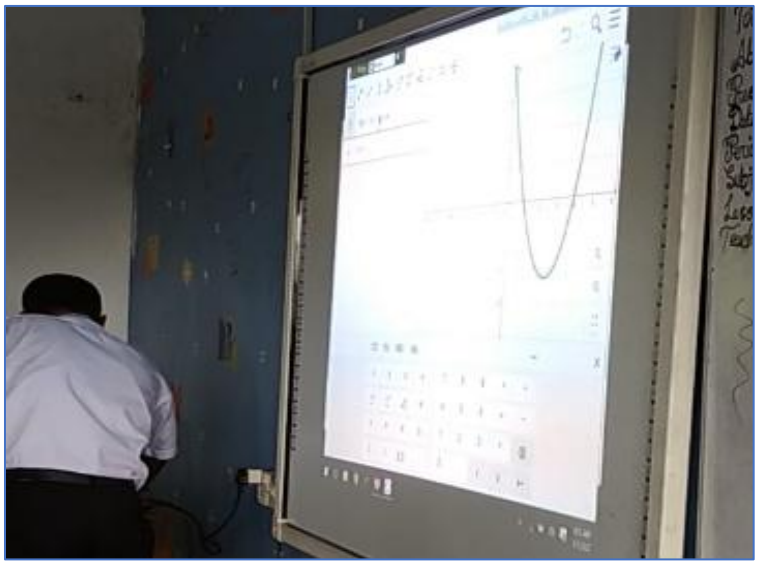


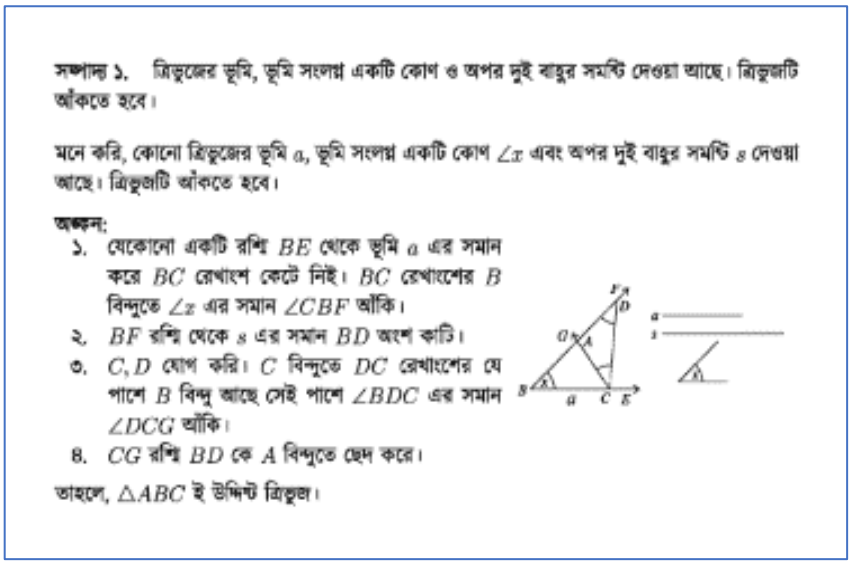
Figure 53: Teacher’s work with GeoGebra

Observation Four – Grade Nine

T2_Lesson2: Draw a Triangle (Construction-1)

Student-Centered and Scaffolding

The teacher went to the next slide, which displayed the construction-1 of the triangle and it was filled with text (Figure 54). The teacher asked the students pointing to the screen, “Look, this is construction-1”. He said, “First we have learned about what is construction and who invented it, have you understood all”? He explained that some information was provided in the ‘construction-1’. He looked at the screen and described, “The base, base adjacent angle, and the sum of the other two sides of a triangle are given, it is required to construct it”. Some students were looking at him and some looked at their test books. The teacher repeated saying that the measurements were not given. He talked about the measurement of base, and angles and how he would make question papers for the test. Then he instructed, “Now you all draw a base of 5cm in length, one 60-degree angle, and the sum of the other two sides will be 8cm”. The students opened their notebooks and tried to do the task with the geometrical instruments. He repeated about the Smartboard, “Here is the software and we are going to draw the triangle using this software Smartboard”. He also said that he did it earlier in the slide to show them but they could not understand what he did. That was why, he would go step by step for their better understanding.



সম্পাদ্য ১. ত্রিভুজের ভূমি, ভূমি সংলগ্ন একটি কোণ ও অপর দুই বাহুর সমষ্টি দেওয়া আছে। ত্রিভুজটি আঁকতে হবে।

মনে করি, কোনো ত্রিভুজের ভূমি a, ভূমি সংলগ্ন একটি কোণ $\angle x$ এবং অপর দুই বাহুর সমষ্টি s দেওয়া আছে। ত্রিভুজটি আঁকতে হবে।

অঙ্কন:

১. যেকোনো একটি রশ্মি BE থেকে ভূমি a এর সমান করে BC রেখাংশ কেটে নিই। BC রেখাংশের B বিন্দুতে $\angle x$ এর সমান $\angle CBF$ আঁকি।
২. BF রশ্মি থেকে s এর সমান BD অংশ কাটি।
৩. C, D যোগ করি। C বিন্দুতে DC রেখাংশের যে পাশে B বিন্দু আছে সেই পাশে $\angle BDC$ এর সমান $\angle DCG$ আঁকি।
৪. CG রশ্মি BD কে A বিন্দুতে ছেদ করে।

তাহলে, $\triangle ABC$ ই উদ্দিষ্ট ত্রিভুজ।

Figure 54: Construction 1 (Triangle)

The teacher started using the software Smartboard and told the students, “Take a scale, what will be the length of the base, draw a line of 5 cm”. He drew a line of 5cm with the scale and asked what was the name of the side, which was ‘a’. He said that they had to denote those with small letters. Then he asked what was the angle, which was ’60 degrees’, and asked them to draw. He drew himself on the board and described the way of drawing. Most of the students were doing the tasks in their notebooks and students were watching the teacher’s board work. He said that they expressed the angle with ‘x’. Then he asked for the given length of the sum of the other two sides, which was 8cm. He drew a line of 8 cm on the Smartboard (Figure 55) and asked them, “Have you understood, these three pieces of information were given, you all draw these, I will check all the notebooks, and now we will construct the triangle. He said, “You read one line from the book and I will draw”. Then he asked one student to read out from the book loudly, and the student was reading from the textbook. Then the teacher asked, “Here is said about ray, do you understand the difference between ray, line and line segment”? He was describing and said, “There was cut line segment from the ray in the textbook as it was drawn ray in the book but we have taken line segment, so we will write line segment in the notebook”. The students were silently listening, watching, and working in their notebooks. One student was fiddling with her fingers. The teacher drew line segments on the board described the way of drawing and asked them continuously, “What is named the line segment in the book, we will follow the book, read one line and do it, so then you will practice properly at home”. Then he put the name of the line segment ‘BE’ as in the textbook and asked them if they would understand. He asked the same student to read another line, and the student read out, “Cut the line segment BC is equal to a”. And the teacher pronounced with him and worked on the board and described. He asked all the students to look at his work and told them he would allow them to draw it later. Some were looking at his work but they looked tired,

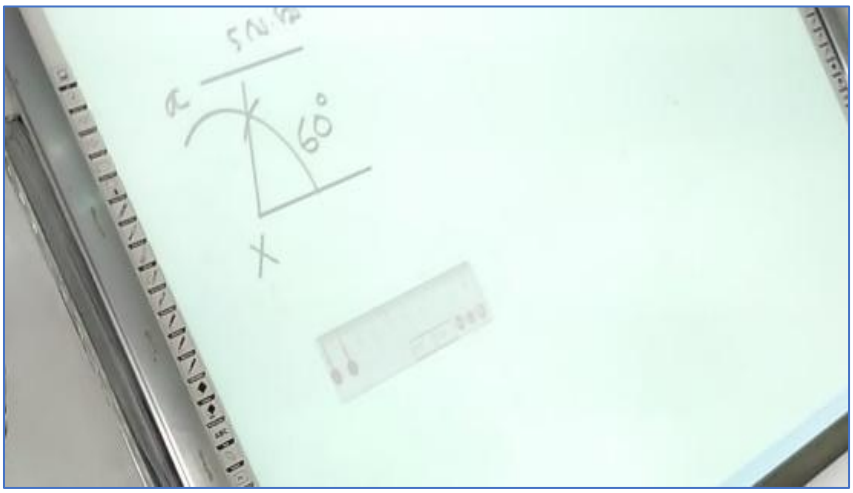


Figure 55: Teacher’s work on the SmartBoard

some were working themselves. Then he asked, “Draw you all, have you drawn”. Then the student again read out the next line from the textbook, “Draw an $\angle x$ at the point B of the line segment BC”. The teacher explained how to draw the angle and worked on the board following the text. He also asked the students to follow him drawing themselves. Most students were looking at the teacher’s work on Smartboard and some doing the task individually in their notebooks.

Observation Five – Grade Eight

T3_Lesson1: Cone

Student-Centered and Scaffolding

The teacher turned to the next slide, which displayed the formula of the curved surface area of the cone and contained text (Figure 56). She said, “This is a tough topic for you about the curved surface area of a cone”. She started to describe the curved area, surface area, circle, proportion, and the words indicated at the screen. Some students were watching and listening to her, and some looked tired. The teacher gave the lecture three more minutes and asked the technician for help. The technician came and helped her open the Smartboard. Then she drew a circle on the Smartboard and described πr^2. Most students were fiddling with their pens, and body parts, some were yawning. After another 2.40 minutes of lecture, she asked them to write the curved surface area πrl. Some students were writing in their notebooks, and some were chatting amongst themselves. Most student’s movements indicated that they were not attentive to the lecture.

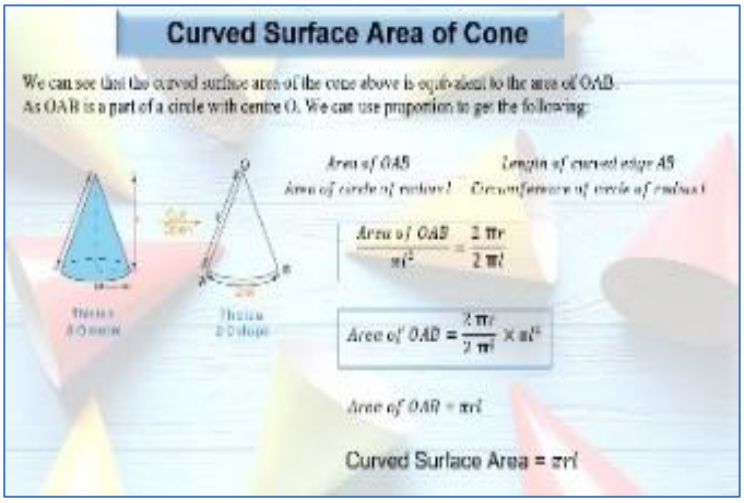


Figure 56: Surface Area of Cone

She proceeded to the next slide and continued to explain pointing to the screen- it was about the shapes of the Cone, the base area and curved surface area, and also the total surface area of the cone (Figure 57). She also read out the words from the screen,

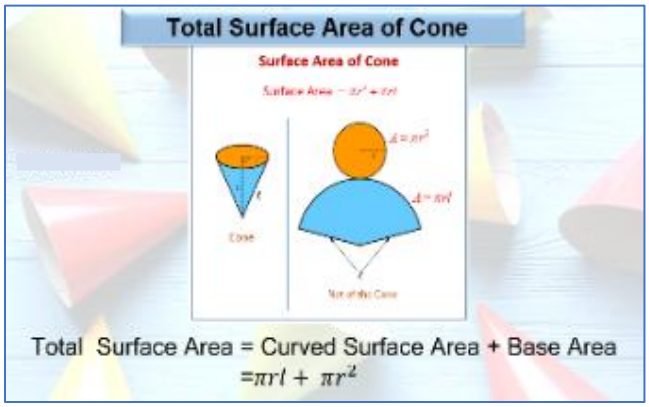


Figure 57: Surface Area of Cone

She turned to the next slide about the surface area of the cone and continued to explain the same things and formulas of the surface area of the cone and total surface area pointed to the screen (Figure 58).

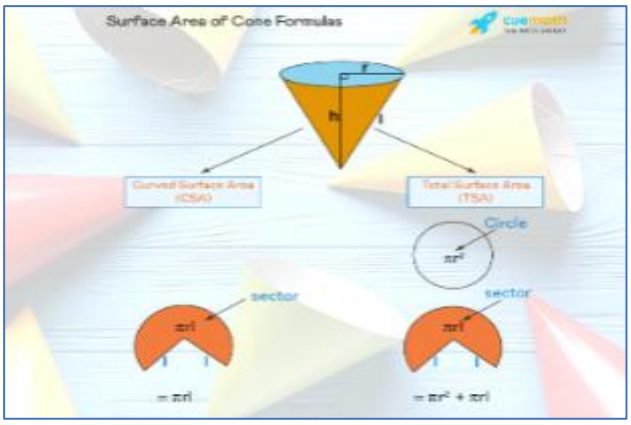


Figure 58: Surface Area of Cone

Observation Six – Grade Eight

T3_Lesson2: Arithmetic Progression

Student-Centered and Scaffolding

The teacher proceeded to the next slide, which displayed an image and filled it with text about the common difference and the sequence of the arithmetic progression (Figure 59). She continued to explain the sequences, common differences, the first term, and the arithmetic progressions pointing to the screen. She asked pointing to the screen, "Here is 6 and 13, what will be the common difference? - it's 7, if it is 13 and 20, what will it be - it's 7". Some students were uttering with her. She was saying the words and explaining the formula pointing to the screen. The students were watching and listening to the teacher, but their expressions seemed bored and uninterested. Most student's movements indicated that they were not attentive in the lecture.

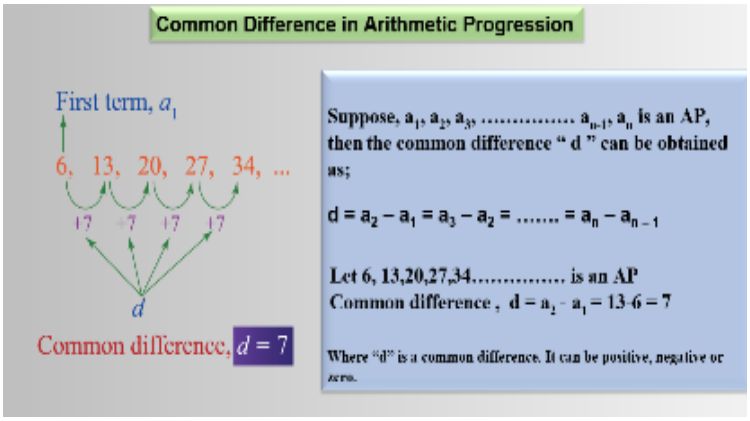


Figure 59: Common Difference in Arithmetic Progression

She continued to the next slide, which was filled with text about the sequences, common differences, the terms, and the formula of the nth-term (Figure 60). She read out the words and continued to explain the text, line by line pointing at the screen with her finger. The students seemed to be having difficulty staying focused and attentive during the lesson.

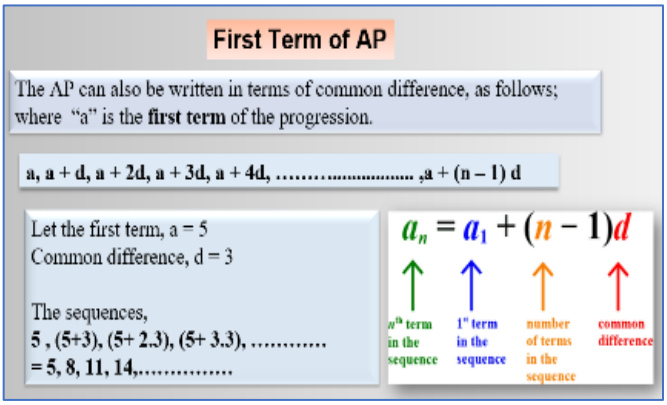
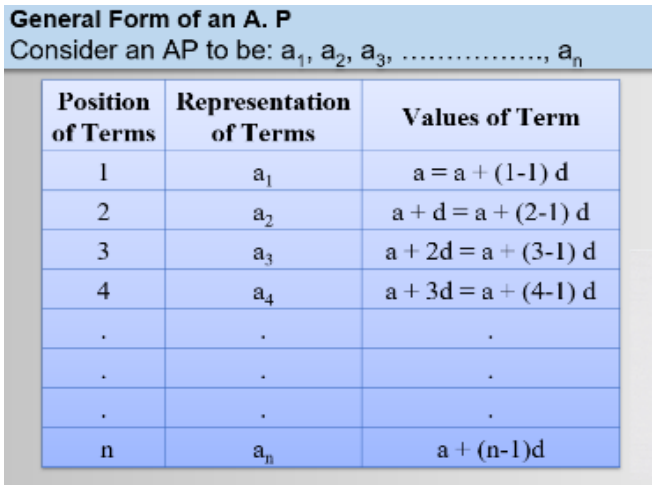


Figure 60: First Term of Arithmetic Progression

She went to the next slide which contained text about the Position of Terms, Representation of Terms, and the Value of Terms (Figure 61). She read out the words and continued to explain the text, line by line pointing at the screen with her finger. The students were as it was before. Some students were gossiping, some seemed to be bored, some were yawning, 3 students were writing in their notebooks and some front desk students were watching and listening to the teacher, but it seemed that they were struggling to stay engaged.



Position of Terms	Representation of Terms	Values of Term
1	a_1	$a = a + (1-1)\,d$
2	a_2	$a + d = a + (2-1)\,d$
3	a_3	$a + 2d = a + (3-1)\,d$
4	a_4	$a + 3d = a + (4-1)\,d$
.	.	.
.	.	.
.	.	.
n	a_n	$a + (n-1)d$

Figure 61: General Form of Arithmetic Progression

Observation Seven – Grade Eight

T4_Lesson1: Set Theory

Student-Centered and Scaffolding

The teacher moved on to the next slide and began to explain the concept of the 'union set', pointing to the screen as she spoke (Figure 62). She asked the students, "What set it would be if we used to join the orange and apple together"? And then she answered herself that it was a 'union set'. She continued to explain, pointing to the screen, about the concepts of 'set of intersection' and 'disjoint set', using the same format as before. Most students were listening quietly or watching the screen, their faces expressionless. Some students were fiddling with their body parts, unable to

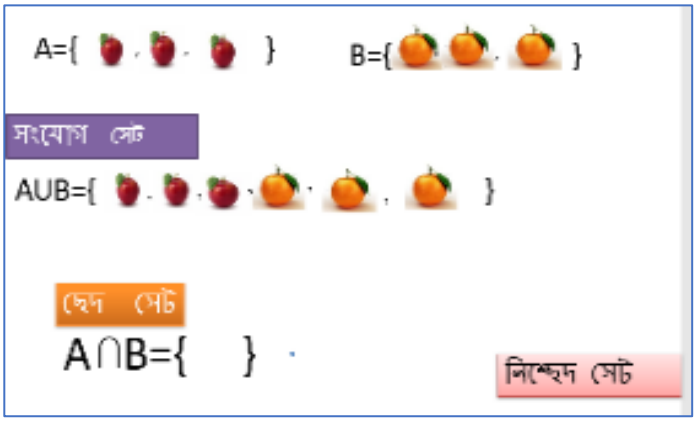


Figure 62: Concepts of the union of sets and intersection of sets

focus on the lesson. Two students had their heads down on their desks, indicating that they were disinterested or struggling to keep up. Only a few students participated uttering a few words in response to the teacher's questions.

Then she went to the next slide (Figure 63) and said, "Look, here is a picture of the Veen diagram". She began to explain the universal set and said, "You can write the set by looking at the Venn diagram". She added that they could write the set A. She asked the students, "What are the elements of set A"? She did not wait for their response, instead, she answered herself. Then the teacher went to the whiteboard and wrote the same words, which were on the screen. Some students looked attentive and listening to the teacher. Other student's expressions seemed bored and uninterested in engaging in the lecture.

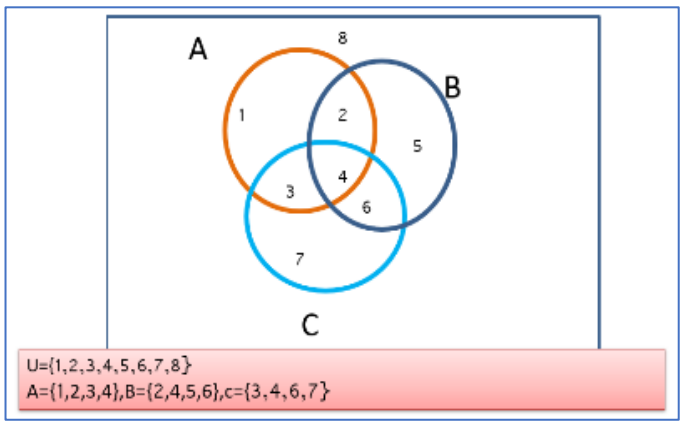


Figure 63: Task on Venn Diagram

Observation Eight – Grade Nine

T4_Lesson2: Relation & Function

Student-Centered and Scaffolding

The teacher moved on to the next slide and began to explain the concept of 'Relation and Function', pointing to the screen as she spoke (Figure 64). Some students listened silently, quietly nodding, or uttering a few words in agreement with the teacher.

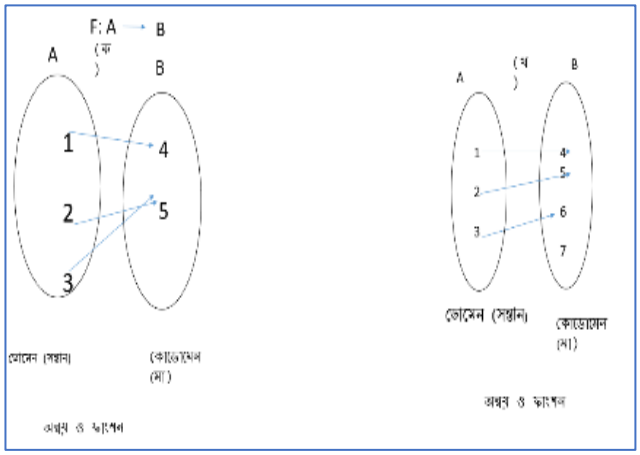


Figure 64: Concepts of Domain and Codomain of a Function

The teacher went to the next slide read out the words and continued to explain by pointing the screen (Figure 65). Some front desk students were uttering the words in agreement with the teacher, two were yawning, and most were watching and listening to the teacher, but their expressions seemed bored and not interested to engage in the lecture. She has continuously explained the concepts of 'domain', 'co-domain', 'image', and 'range'.

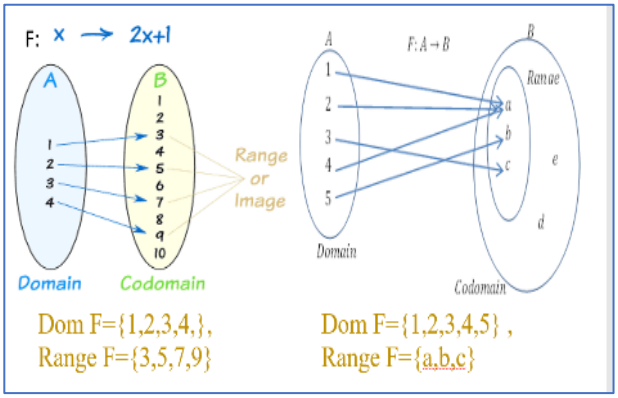


Figure 65: Domain and Range of the Function

The teacher proceeded to the next slide and continuously explained the concepts of ‘domain’ and ‘co-domain’ (Figure 66). Some students were watching and listening, some were writing in their notebooks, some front desk students were uttering with the teacher, two were fiddling with their pens and some were aloof. She explained the concepts of ‘one-one function’, ‘not one-one function’, and ‘universal function’ and pointed to the screen. She also explained how they could identify the ‘function’. Sometimes she was asking questions and did not wait for their response, instead answered herself. The students sometimes responded by saying one or two words altogether. A few students watched and listened intently to the teacher’s explanations and their eyes fixed on the screen. Other students also watched and listened, but their body language suggested that they were not attentive to the lecture.

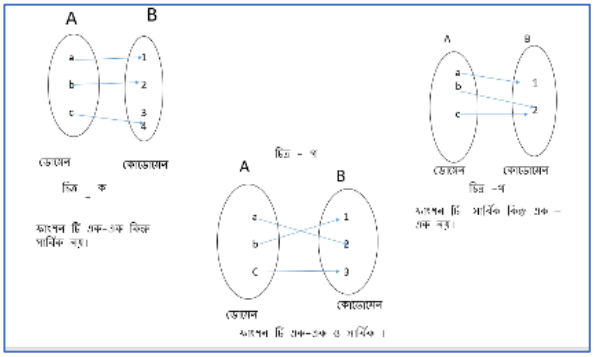


Figure 66: One-One Function and Universal Function

Observation Nine – Grade Nine

T5_Lesson1: Trigonometric Ratios

Student-Centered and Scaffolding

The teacher opened the next slide- there was one right-angled triangle and the trigonometric ratios with animations (Figure 67). He asked a series of questions one by one about the right-angled triangle and the trigonometric ratios clicking on the mouse and pointing to the screen. The answers appeared one by one on the screen on a mouse click. Most students were watching, listening, and responding in chorus saying one or two words by

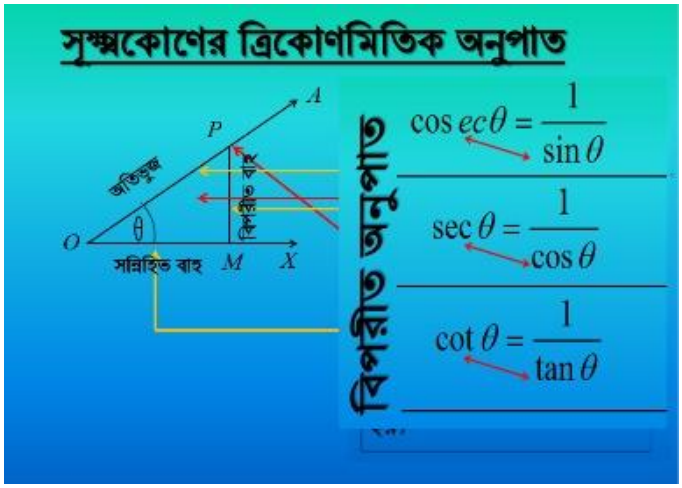


Figure 67: Concepts of Trigonometric Ratios

looking at the screen. Two students were fiddling with their hair and pen, one yawning, and some were silent and looked bored. The teacher read out the words from the screen and explained the concepts of trigonometric ratios. One student was writing in his notebook, one was turning the pages of his textbook, two students were fiddling with their hair and some were uttering the words with the teacher, their body language indicated that they were struggling to keep up with the lecture. He asked the students to write the trigonometric ratios from the screen. The students were opening their notebooks and writing the text from the screen. The teacher went to the back side to see the screen clearly and read the words from the screen. A few students did not open their notebooks and did not do as told. The teacher was walking along with the students.

The teacher continued to the next slide, which was about the relations between trigonometric angles and filled with texts (Figure 68). He was reading the text himself pointing to the screen. He asked questions about the trigonometric ratios and their relations and answered himself by clicking on the mouse and pointing to the screen. The answers were on the screen. The students were silent, some were writing, and some were watching and responding saying one or two words altogether.

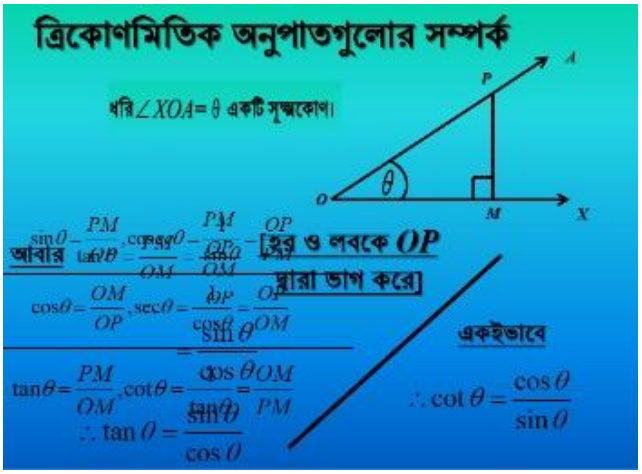


Figure 68: Relation among Trigonometric Ratios

Observation Ten – Grade Ten

T4_Lesson2: Rectangular solid

Student-Centered and Scaffolding

The teacher opened the next slide and opened a video on the screen (Figure 69). The students were looked very curious to watch it. The video was about the concepts of the volume and surface area of a rectangular solid. All the students were watching the video attentively; however, it was in English language. They were trying to understand the animation and the conversation in English language; the length of the video was about 40 sec. The teacher began to explain, "We have watched the length, width, and height of a rectangular solid". The students were watching the video.

Figure 69: Video on Rectangular Solid

After finishing the video the teacher moved on to the next slide, there was a rectangular shape and the formula of the area and volume of it (Figure 70). He asked a series of questions one by one looking at the screen, "Here is a rectangular solid, which side is the length of it, which side is the width, which side is the height". The students responded by making a chorus saying one or two words looking at the screen. The teacher clicked on the mouse, and the text with the formula of area and volume appeared on the screen. Then the teacher asked the students to repeat the formulas. The

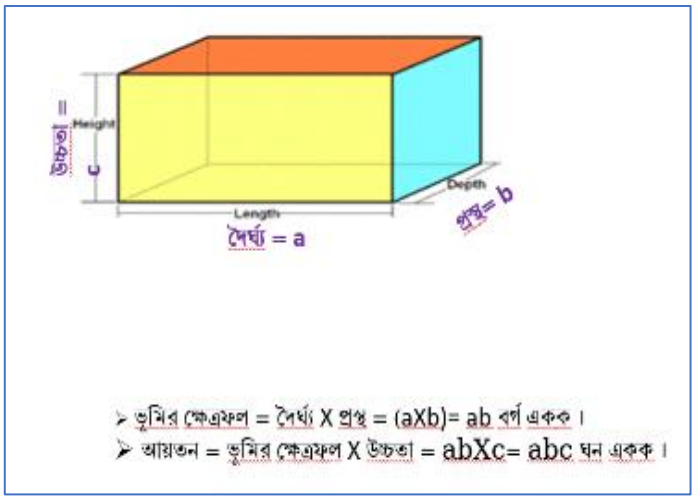


Figure 70: Area and Volume of Rectangular Solid

students responded in chorus and read out the words from the screen. He said, “Have you all understood”? He asked again who could tell the formula of the surface area. Some students raised their hands. He asked one student. The student stood up and repeated the words from the screen that ‘length multiply width’. Then the teacher asked what would be the volume. Most students raised their hands and answered the formula of the volume, reading out the words from the screen. The teacher also pronounces the words with them. The students were watching the screen and listening to the teacher, some students were chatting with each other, and some were looking at their books.

The teacher went to the next slide and said, “Now we will determine the diagonal of a rectangular solid”. There was a solid shape on the screen (Figure 71). He asked the students, “Can anybody tell the formula of the diagonal of a rectangular solid”? Some students raised their hands and one student read out the formula from the screen. He explained the concepts and the formula of diagonal indicating to the solid shape on the screen. He was uttering the text from the screen. The students were listening looking at the screen, and repeating the words told by the teacher.

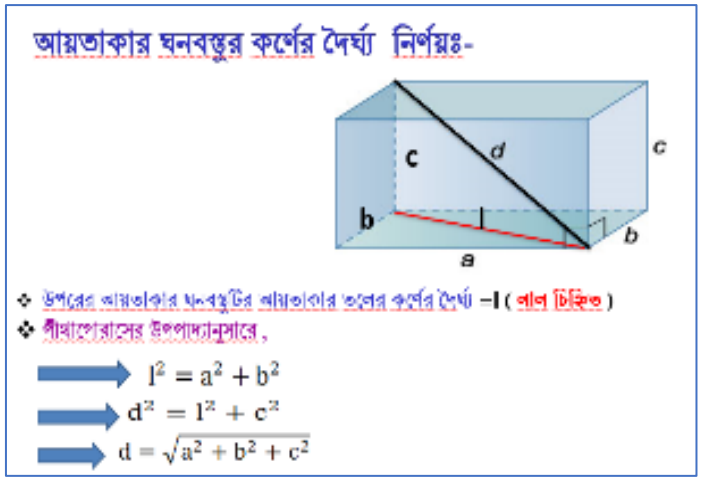


Figure 71: Diagonal of the Rectangular Solid

4B.1.2.3 A detailed summary analysis of integrating ten Observed lessons

The scores are defined as **H** for high, **M** for medium, **L** for low, and **N** for not done in the lesson.

1.2 Pedagogy (Instructional Design: Student-Centered and Scaffolding)												
	Aspects of Observation	Scores of Ten Lessons										Descriptions
		T1		T2		T3		T4		T5		
1.2.1	The students struggle with important mathematical ideas and practice with their own strategies/approaches	N	N	N	N	N	N	N	N	N	N	The students were not required to struggle with important math tasks with their own strategies.
1.2.2	Struggle with difficult concepts and challenging problems individually/collectively to deepen understanding	N	N	N	N	N	N	N	N	N	N	The students were not required to encounter any difficult concepts and challenges.
1.2.3	Different challenges for different achiever students	N	N	N	N	N	N	N	N	N	N	There were no different challenges for the students.
1.2.4	Value to students' struggles and mistakes	N	N	N	N	N	N	N	N	N	N	There were no situations to value the student's mistake and not form arguments.
1.2.5	Deeply engaged as problem solvers or creators of mathematical ideas	N	N	N	N	N	N	N	N	N	N	The students were not required to engage deeply as problem solvers or creators.
1.2.6	Support to build on student's mathematical ideas where students transfer knowledge and skills to a new context	N	N	N	N	N	N	N	N	N	N	There was no support for the students to transfer their knowledge and skills to a new context.

Table 7- Classroom Observation Guidelines (Pedagogy: Instructional Design)

Dimension- Pedagogy (Instructional Design: Student-Centered and Scaffolding):

4B.1.2.4 Linkage between Teacher's pre-lesson interviews and their lessons

From the teacher's pre-lesson interviews, four teachers claimed that most students wanted to solve the mathematical tasks in procedural method because the students could not think of their own strategies for the task. However, T2 noticed that some students were very talented, as they sometimes solved mathematical problems with their own strategies. He added that if they solved the problem with their own strategies, they could make mistakes. That was why T2 explained the tasks and the proper solutions showing the image and text to the students to avoid making any mistakes. All these five teachers acknowledged that if the students made mistakes in solving the problem, then they helped them to correct those. However, they usually did not create an environment where the students could make mistakes and form arguments on the task. They confessed that they usually explained the difficult concepts to the students displayed on the screen and did not provide diversified challenges to engage them as problem solvers or creators. They stated that they usually provided the procedural mathematical tasks from the textbook shown on the screen to the students, the abled students solved the problems individually and sometimes helped others using the rules or formulas. T1 claimed that he usually went through easy questioning with difficult concepts for their deeper understanding. All the teachers confessed that they repeatedly explained the difficult mathematical topic to the students showing the image, texts, and video on the screen using digital content to help the students understand and build their own ideas. They all noticed that the students were not able to transfer their knowledge to the new context without receiving the teacher's explanations.

In the lessons, teachers T1, T3, and T5 provided interactive images in their lesson using digital content, but they described it to the students and could not make it student-centered. T1 used an interactive animated slide about the concept of the area of the circle, but the instructional design was teacher-directed and lacked scaffolding elements. In another lesson, there was some unnecessary animation and text and T1 explained it to the students. Teachers T2 and T4 used excess text and scattered and unnecessary images in their digital content and they explained it to the students. Teacher T2 used texts with unnecessary color, graphs, and pictures of scientists in his digital content slides and he explained those. T2 used the software GeoGebra to make the graph

and explained it to the students. In another lesson, there were only texts and triangles in the digital content slides as in the textbook; the teacher constructed the triangle using a Smartboard which was the teacher-directed instructional design and lacked scaffolding elements. Teacher T5 also used only texts and the right-angled triangles in the digital content slides in his lesson on 'Trigonometric Ratios' as in the textbook. There were mostly procedural mathematical tasks used in digital content.

All the teachers explained the procedural mathematical tasks showing the images and text using the digital content in their lessons, they sometimes asked questions to the students indicating the screen but did not wait for their reply, and continued explaining the slides one after another. They sometimes repeatedly explained difficult concepts by pointing to the screen. The teachers did not create an environment where the students were offered support to enhance their learning. They did not provide the opportunity for the students to deal with difficult concepts and diverse challenges to engage deeply, make mistakes, and form arguments. Most students were silently watching or listening and seemed less engaged and rather fatigued. Some students were copying the text from the screen of the digital content.

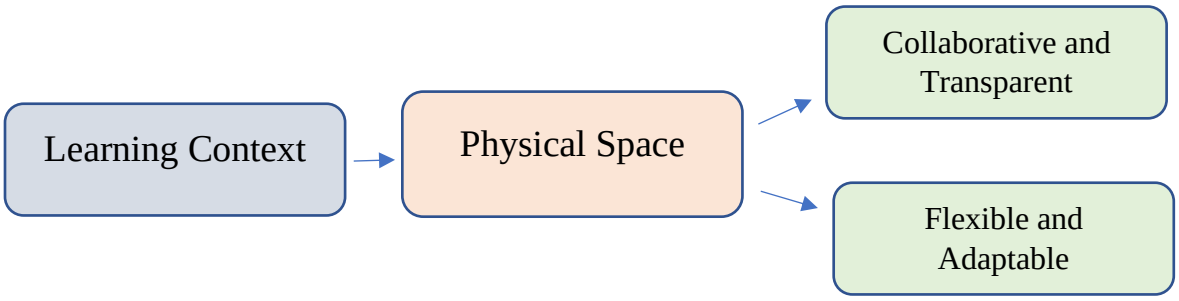
Dimension- Pedagogy (Instructional Design: Student-Centered and Scaffolding)

4B.1.2.5 Summary

The trained mathematics teachers have developed the ability with text, relevant shapes, pictures, and videos to enrich their digital content presentations, however, their slides also included unnecessary text and animations. The teachers explain the things displayed on the screen to the students. The teachers could not create an environment where students could struggle with difficult concepts with their own strategies, and they could engage in tasks as problem solvers or creators. The teachers have not provided opportunities for the students to make mistakes and form arguments. The teachers could not support them in building their mathematical ideas and understanding. They could not create a supportive environment, where the students transfer knowledge and skills to a new context. As a result, it is evident in the classroom observation guideline that the codes of pedagogy dimension, student-centered learning, and scaffolding have not been implemented in all the lessons. There were six segments in the observation guideline,

with a score of N for each segment, resulting in a total of 6N for all six segments in each lesson. Therefore, the overall total score was 60N out of a possible 60. No scores were recorded for L, M, or H. It should be mentioned that all the teachers got the same scores in the code of student-centered and scaffolding.

4B.1.3 Learning Context (**Physical Space**: Collaborative and Transparent, Flexible and Adaptable)



This section investigates the concepts of collaborative, transparent, flexible, and adaptable physical spaces, highlighting their significance in educational settings. The researcher begins by examining the design of multimedia classrooms (MMCs), where the teacher facilitates student learning and fosters an environment that encourages learners to work independently through problem-solving. Students can engage deeply with essential mathematical tasks in a supportive atmosphere that promotes collaborative and observational learning. The furniture and spatial arrangements are designed to be flexible and adaptable to accommodate different learning styles and activities. To achieve this goal, the researcher compares the teacher's statements about their instructional methods with evidence gathered from observed classroom lessons. The findings will contribute to a deeper understanding of physical space design within the context of learning.

4B.1.3.1 Teacher's Pre-lesson Interviews

T1 (Case 1) reported that the space designs did not fit between pedagogy and the physical setting. He added that the learning space was flexible to move for the students, but the classroom space was not designed for collaborative and observation learning. However, the students could observe the screen easily in the lesson. T2**,** T3, T4, and T5 also reported the same things. They said the physical settings were congested and unsuitable for collaborative and observation learning. The students could move, but the chairs, and desks were not movable and adjustable.

4.2.3.2 Classroom Observations

In these five cases, the learning spaces were not designed to be flexible and adaptable for collaborative and observational learning. One school had just one multimedia classroom (MMC) with a projector and a whiteboard, while another had three MMCs and another had four. One institution had one MMC in its college section that included a multimedia projector, a whiteboard, and a Smartboard. In the fifth institution, all classrooms had a multimedia projector, a Smartboard, and a whiteboard, and teachers were required to use digital content in every lesson. Overall, these classrooms were not set up to promote collaboration and observational learning, and the furniture and lighting were not easily adjustable to support various learning activities.

4B.1.3.3 A detailed summary analysis of integrating ten Observed lessons

The scores are defined as **H** for high, **M** for medium, **L** for low, and **N** for not done in the lesson.

2.1 **Learning Context** (**Physical Space: Collaborative and Transparent & Flexible and Adaptable)**												
	Aspects of Observation	Scores of Ten Lessons										Descriptions
		T1		T2		T3		T4		T5		
2.1.1	The learning space and furniture	N	N	N	N	N	N	N	N	N	N	The learning space was not flexible and adaptable.
2.1.2	Classroom space design supports collaboration and observation learning	N	N	N	N	N	N	N	N	N	N	The classroom space was not designed for collaboration and observation learning.

Table 8- Classroom Observation Guidelines (Learning Context: Physical Space)

Dimension- Learning Context (**Physical Space**)

4B.1.3.4 Linkage between Teacher's pre-lesson interviews and their lessons

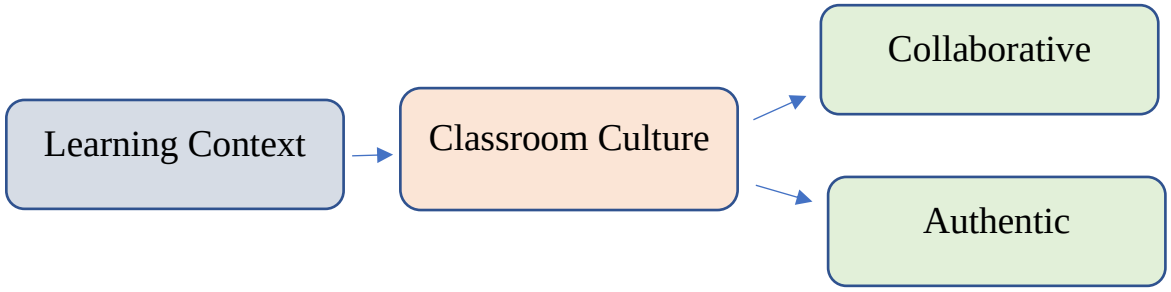
From the teacher's pre-lesson Interviews and the lessons observed, it can be said that the classroom space designs were not flexible for the students and the teachers. The furniture including chairs, desks, and lights were not movable and adjustable for activity-based learning. The physical settings were not fit for collaborative and observation learning. The physical space design did not allow the students to get the opportunity to move and discuss in a collaborative learning environment.

Dimension- Learning Context (Physical Space)

4B.1.3.5 Summary

The classroom space designs did not support the student's collaboration and observation learning. The learning spaces were not flexible and adaptable in all five cases. The chairs and desks were not movable and adjustable for the pedagogy and physical settings. The physical design of the classroom did not allow students to take advantage of opportunities to move and engage in collaborative learning, which was a significant limitation in promoting a dynamic and interactive learning environment. As a result, it has appeared in the classroom observation guideline that the codes of the dimensions of Learning Context and physical Space are not Flexible and Adaptable in almost all the lessons. There were two segments in the Observation Guideline, and the scores were 2N in every lesson. So, the total scores were 20**N** out of 20 segments in all 10 lessons. No scores were recorded for L, M, or H.

4B.1.4 Learning Context (Classroom Culture: Collaborative and Authentic)



This section delves into the concepts of collaborative and authentic classroom culture, highlighting their significance in educational settings. The researcher begins by examining how the teacher facilitates students to form groups of students that learn together, solve problems, build strategies and ideas and create tasks. The teacher fosters an environment that requires joint intellectual effort by the students among themselves and also with the teacher's help. An authentic classroom culture fosters an environment rich in peer interaction, teacher-student engagement, and collaborative

learning through various activities. This includes pair work, group projects, and interactive inquiry-based learning, all enhanced by the effective use of educational technology. Such an environment encourages meaningful interactions and promotes deeper understanding among students. There is an opportunity to capture other students' thoughts and characterize them. To accomplish this, the researcher compares teacher's statements about their instructional methods with evidence gathered from observed classroom lessons. In particular, the researcher looks at how the teacher encourages the students to interact in the learning activities. Through this analysis, the researcher aims to uncover the effectiveness of the learning context. The findings from this evaluation will contribute to understanding the interplay between teaching strategies and student learning outcomes in the context of collaborative and authentic classroom culture.

4B.1.4.1 Teacher's Pre-lesson Interviews

The teacher (Case 1) claimed, "I usually provide the mathematical tasks to the students with individual works and sometimes with group works to facilitate peer interaction and collaboration". The teacher acknowledged that he mainly relied on procedural tasks from the textbook, but there were not any challenging tasks using ICT. He added that he occasionally devised similar problems and included them in the presentation slides for his students using images. The teacher claimed that there were not many challenging tasks in the textbook. He explained, "I generally ask questions, make eye contact to interact, and encourage them to speak. I use relevant images, animations and videos in my digital content to interact with them". He added, "When I use video in my digital content lessons, the students love watching and listening to it, the videos attract them and they become active watching it and interact amongst themselves". He remarked that the students could not always understand his explanation, and then he tried to help the students by solving the mathematical tasks. He noticed that the students could easily explain the mathematical concepts by watching the images or videos displayed on the digital content. However, very few students wanted to explain their own ideas and understanding.

The teacher (Case 2) confessed, "I usually provide the students individual works, we do not have enough space to make groups in the lessons". He added, "The environment of group work activities happens only in the practical math lessons where the students learn deeply, but group works make

the class undisciplined". He remarked, "I show the text from the textbook in the slide of my digital content and explain it to the students by using the whiteboard". He explained that he made the lesson interactive by showing the image and text in his digital content and describing it to the students. The teacher acknowledged that he usually used the tasks from the textbook, but no tasks were in the textbook using ICT. He claimed that a few students wanted to explain their own ideas and understanding by watching the images and text, while most wanted to listen to the teacher's explanations. He reminded that he asked questions to interact with the students and asked more questions to the backbencher students to engage them too. He added that he generally showed the students the text of some questions displayed on the screen using digital content and explained the questions to them to make the lesson interactive.

The Teacher (Case 3) admitted that she usually used the procedural tasks from the textbook and showed them on the presentation slide. The teacher claimed there were no challenging tasks in the textbook using ICT. The teacher claimed, "The students usually do the task individually, sometimes they share with their friends". She noticed, "Using the images and videos attracts the students, they enjoy watching the mathematical tasks in the digital content instead of their textbook". She remarked that the students became active in group work, but group work made the class undisciplined, and good students wanted to do the task individually. The teacher added that the abled students help others to solve the task, but some students do not want to learn from other students. She confessed that she asked the students questions showing the pictures by using digital content to make the lesson interactive. She claimed that very few students wanted to explain their own ideas, while most of them wanted to listen to her explanations.

The Teacher (Case 4) claimed, "I usually provide the students pair work and group work showing them mathematical tasks by using the digital contents". The teacher admitted, "I generally use the procedural tasks from the textbook, sometimes I use tasks from the internet and show them in the presentation slide using download images". She added that there were no diversified tasks in the textbook using ICT. The teacher explained that the good students became active in doing the task individually and did not want to share with other students. She confessed that she usually asked questions to the students showing images and text by using her digital content to make it interactive. She remarked that most students did not want to explain deeply their own ideas and

understanding. She pointed out that it would be better if she could create an environment for the students to explain their own understanding of the mathematical task, but the class time did not support that as they had to finish the lesson on time and as well as the syllabus.

The Teacher (Case 5) claimed that he provided the students with individual and group work showing the mathematical task on the screen, but sometimes they liked doing it individually. He acknowledged that he usually used the procedural tasks from the textbook. He explained, "I ask questions to interact with the students showing the texts or pictures by using the digital content and sometimes I walk around to check their notebooks". He claimed that he provided the students with mathematical problems to solve, shown on the digital content slide to engage them as problem solvers. The teacher claimed there were no diverse mathematical tasks using ICT in the textbook. He pointed out that the students usually did not want to explain their own ideas and understanding.

4B.1.4.2 Classroom Observations

In these five cases, there were opportunities to enhance the lessons through a Collaborative and Authentic culture approach. Field notes have been compiled from a review of the data collected from the ten videos provided.

Observation One – Grade Eight
T1_Lesson 1: Area and Circumference of a Circle
Collaborative and Authentic Culture

The teacher opened the next slide named 'group work', the slide displayed a task to find the area of a garden (Figure 72). He explained a little about how to find the area and asked the students to do the task quickly. The students were opening their bags to take their notebooks. He instructed them to do that individually, no need to make groups but they could consult each other. The teacher was walking among them and telling about the formula. Some students were writing in their notebooks, some were doing nothing, and two students were very busy with their calculators and notebooks. The teacher asked a serious girl to explain her solution and instructed others to listen to that student. The student stood up and went to the front and said, 'Given the diameter'. The teacher also repeated and asked the other students to ask her questions, but the students were silent. The teacher explained the diameter indicating the screen and asked the others, "Have you understood the diameter"? The students looked uninterested. The teacher asked the serious girl what she did then. The girl said that she determined the radius first. The teacher asked why radius first. The student said that she needed the value of 'r' to put in the formula. The teacher uttered the formula πr^2 and explained it, looking at the students. The teacher asked the girl, "Is it possible to solve the problem with diameter"? The student was silent and the teacher explained it himself, the student's expressions looked bored and

Figure 72: Group-Work on Circle

uninterested. The teacher asked the students to applaud her. The students gave applause for the girl and the teacher thanked her. Most students seemed unconcerned. The teacher explained that they needed to know the values to put in the formula, so they could solve the problems.

Then the teacher moved on to the next slide of ‘evaluation’ (Figure 73), and asked the students by pointing to the screen, “What is Pi”? The students were silent. He repeated the question three times and asked a girl directly. The girl stood up and said something in a low voice. The teacher explained the definition of ‘Pi’ and it was the ratio of the circumference and the diameter. He added that any fraction would be a ratio and then wrote the formula of ‘Pi’ on the board. After that, the teacher went to the next question on the screen, which was the value of π. The serious student replied by saying the value of Pi. The teacher asked why the other students were not responding. Then the teacher went to the last question about the formula of the area of the circle. The students were again silent. He asked a girl directly and the girl stood up and looked at her notebook and told the answer.

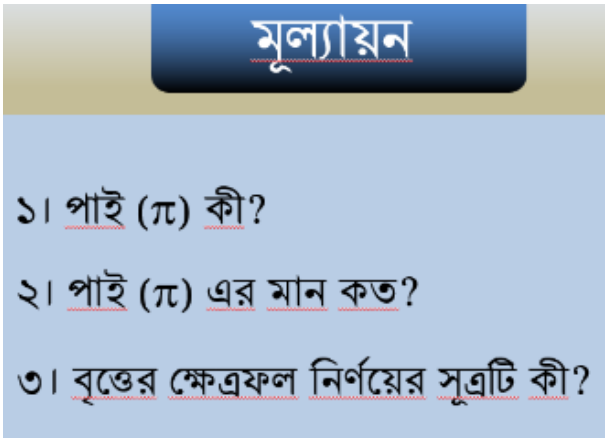


Figure 73: Evaluation Slide on Circle

Observation Two – Grade Eight

T1_Lesson 2: Graph of a Simple Simultaneous Equation

Authentic and Collaborative Culture

The teacher opened the next slide named ‘group work’ (Figure 74). He asked, “If I give you this task to do, could you do it”? They said, “Ji sir”. Then the teacher read out the words from the screen and then skipped the slide. He was checking for the next slide but found nothing. And then he said that they would finish the class. The teacher also said that the task ‘group work’ would be their ‘homework’ and thanked the students. The students were prepared to finish the class.

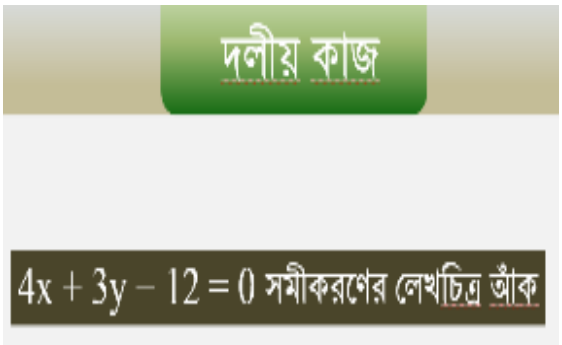


Figure 74: Group-Work on Simultaneous Equation

Observation Three – Grade Ten

T2_Lesson 1: Draw the Parabola

Collaborative and Authentic Culture

The teacher turned to the slides of ‘individual work’ (Figure 75) and ‘evaluation’ (Figure 76), and told the students that they had no time to go there, so he would give them ‘homework’. He opened the homework slide (Figure 77) and said, “You will divide the graph paper into two parts and draw the graph as you do in the examination paper”. The teacher asked the students to write down the homework from the screen. The students did not do it, as there was no task on the screen to write, there was only the exercise number and the question number.

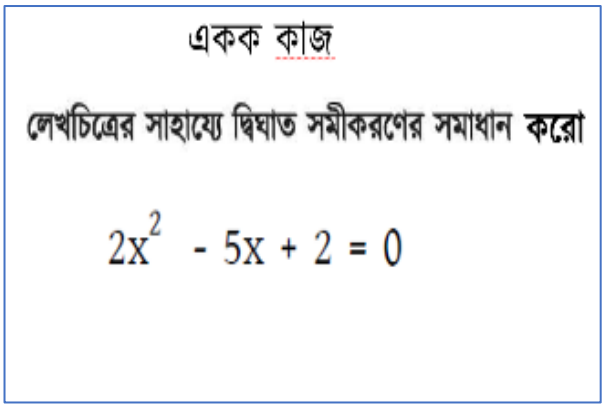


Figure 75: Individual Work on Graph of Quadratic Equation

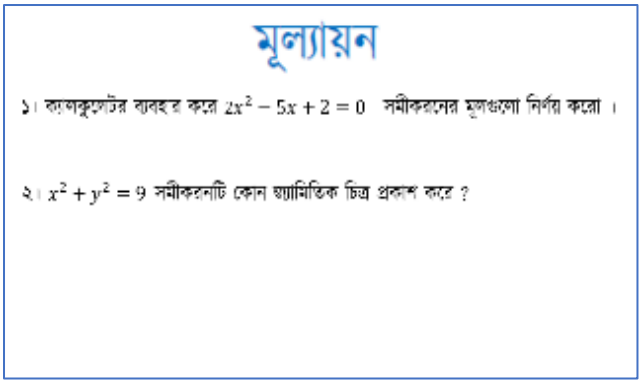


Figure 76: Evaluation on Quadratic Equations

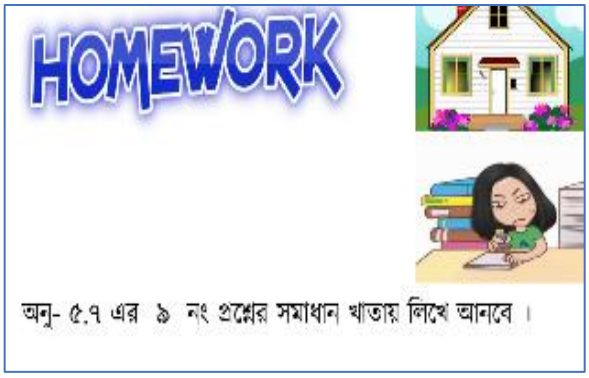


Figure 77: Home-work from Textbook

Observation Four – Grade Nine

T2_Lesson 2: Draw a Triangle (Construction-1)

Collaborative and Authentic Culture

The teacher opened the next slide of 'evaluation' (Figure 78) and told the students, "I will ask you some questions about what was discussed before". He looked at the screen and asked a boy, "Tell me, how many parts are in a triangle"? The boy stood up and answered, "Three parts". Then he asked the same question to several students one by one and they all answered wrong that was three. Then the teacher explained that there were six parts in a triangle. He loudly asked again how many parts there were, and the students all replied, "Six". Then the teacher explained that there were three sides and three angles in a triangle. He elaborated to explain that it was as like they had hands, legs, and eyes as their parts. Then he went to the next question from the screen, "What is the sum of the angles of a triangle"? The students responded all together, saying 180 degrees.

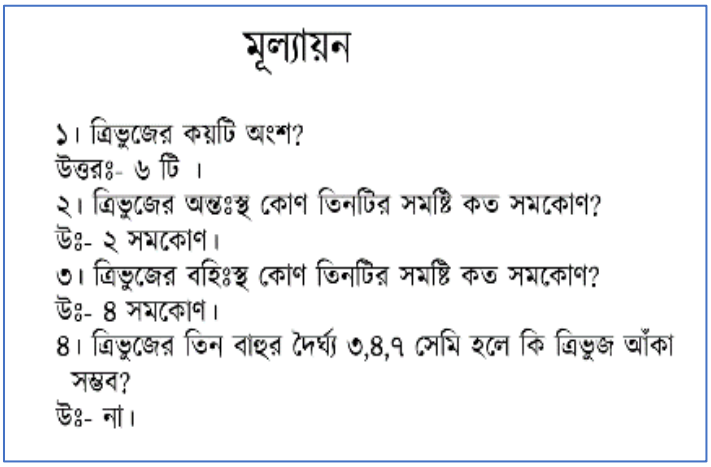


Figure 78: Evaluation slide on Triangle

Observation Five – Grade Eight

T3_Lesson 1: Cone

Collaborative and Authentic Culture

The teacher turned to the next slide of problem-solving (Figure 79). She read out the words from the screen and explained the problem. She asked the students to solve the problem, and she continued to explain the measurements given in the problem. She went along the row of the students and continued her explanations. Some students were writing in their notebooks but most students were doing nothing. She asked the technician and returned to the screen. The technician opened the Smartboard and the teacher solved the problem on the board by explaining herself. Some students were copying the teacher's board work, but most students were not doing it.

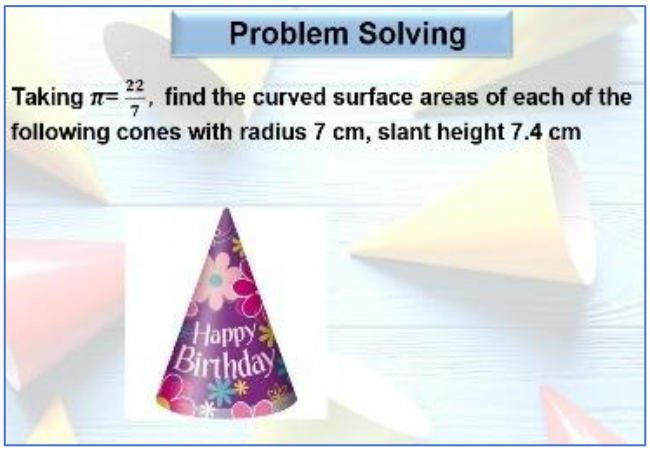


Figure 79: Problem on Surface Area of Cone

The teacher continued to the next slide with a similar problem and she read out the words from the screen (Figure 80). The slide displayed that the task was group work. The teacher stated that there would be 3 groups; i.e. row 1 is Group 1, row 2 is Group 2 and row 3 is Group 3. She declared that the task was for Group 1. She asked them, "Please write down the question". Some students of Group 1 wrote the question in their notebooks and other students were not doing anything. The technician was providing blank papers and pencils to the students. The teacher went to the next slide with a similar problem and she said, "This problem is for Group 2". Some students of Group 2 were copying the problem from the screen. One student raised his hand, but the teacher

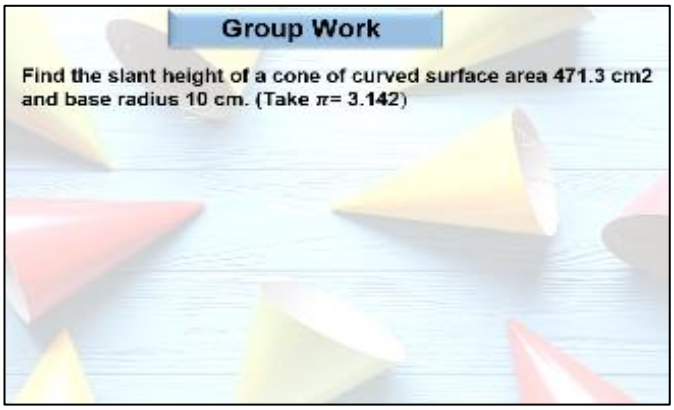


Figure 80: Group-Work on Cone

ignored him. She asked the students of Group 3 to write down a similar problems from the screen. The students made a little noise and the technician asked them to keep silent. The teacher was on the dais and suddenly, the students were making noise. The teacher got down from the dais and went along the rows to the students. Some students were working in their notebooks individually, some were gossiping with each other, and some were copying from another student's sheet.

Then the teacher went to the dais and moved on to the next slide (Figure 81) and asked, "Here is the homework for you". She uttered the words from the screen and thanked the students.

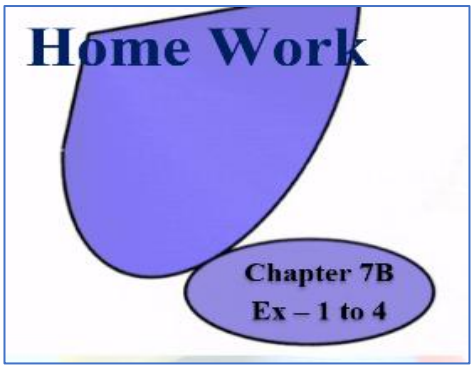


Figure 81: Home-work

Observation Six – Grade Eight

T3_Lesson 2: Arithmetic Progression

Collaborative and Authentic Culture

The teacher went to the next slide, which displayed formulas of 'Arithmetic Progressions' and text (Figure 82). She was uttering and explaining the texts of formulas line by line indicating the screen with her finger. Then the teacher opened a music video related to progressions. Some students were looking at the video, some were laughing and gossiping with each other. The teacher came to the dais again and she was talking about something with the technician. These activities took almost 3.30 minutes. One student put his head down on his table. Some students were holding their ears with their hands due to the sound of the music in the video. After closing the video the teacher said, "We can learn formulas through the music video like this". Most students were gossiping loudly, some students looked around the room, while others were yawning or appeared to be sleepy. A few students

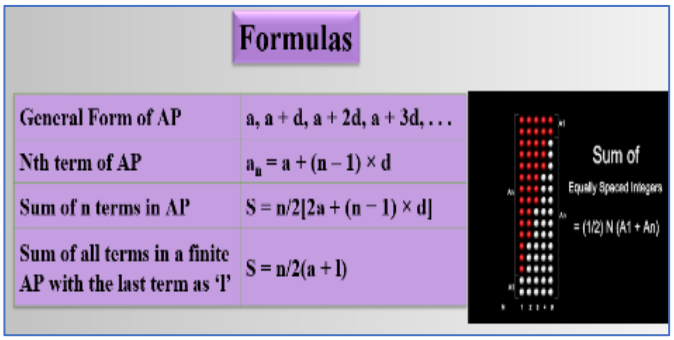


Figure 82: Formulas of Arithmetic Progression

seemed to be watching and listening to the teacher, with their eyes fixed on the screen, but their body language suggested that they were not attentive to the lesson.

After almost 1.30 minutes of describing the formulas of arithmetic progressions, the teacher turned to the next slides with some similar exercises (Figures 83, 84 and 85). She got down from the dais and told the students, “Now, it is time to exercise”. She was walking among the students and uttering the words shown on the screen and explained them. Some students were writing in their notebooks individually. The teacher clicked on the mouse and the solution appeared on the screen; some students also responded, saying their result was 81. She went to the next slide with another exercise same as the previous one. She asked Group 1 to do that exercise. A few students from row 1 were doing the task individually. So, the students of the other two rows had nothing to do. Then the teacher went to the next slide with the same task as exercise for Group 2. She was uttering the words from the screen. The members of group 2 started to do the exercise in their notebooks. The teacher came down from the dais and was walking among the students. Some students were discussing between themselves. Two students were doing very seriously and discussing, some were trying individually on their own, most students were gossiping and some were doing nothing, indicating that they were not fully engaged in the lesson.

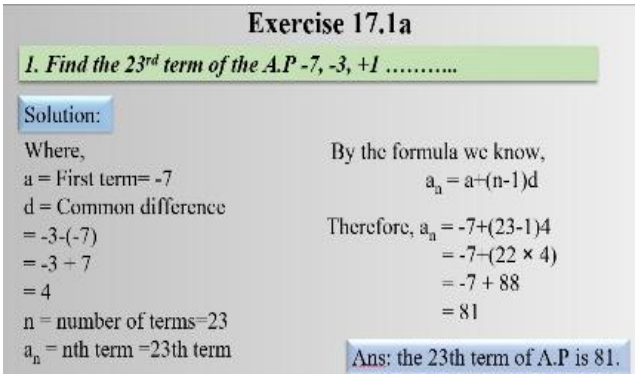


Figure 83: Problem and the Solution on Arithmetic Progression

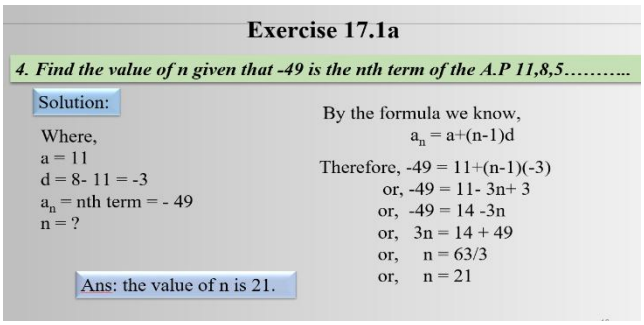


Figure 84: Problem and the Solution on Arithmetic Progression

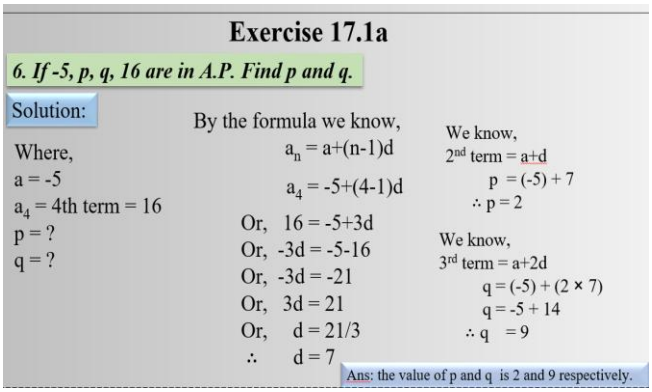


Figure 85: Problem and the Solution on Arithmetic Progression

Observation Seven – Grade Eight

T4_Lesson 1: Set Theory

Collaborative and Authentic Culture

The teacher opened the next slide and there were two tasks on the screen, it was for individual work (Figure 86). The teacher began to explain the 'universal set'. After explanation, she asked the students to do the tasks. The students were opening their notebooks very idly. Some students were writing in their notebooks, some were looking at the screen, and one was turning over the pages one by one for a while. The teacher walked among the students and asked, "Have you finished"? She did not wait for their response, instead, she went to the next slide which contained the answers. The teacher read out the answer and pointed to the screen.

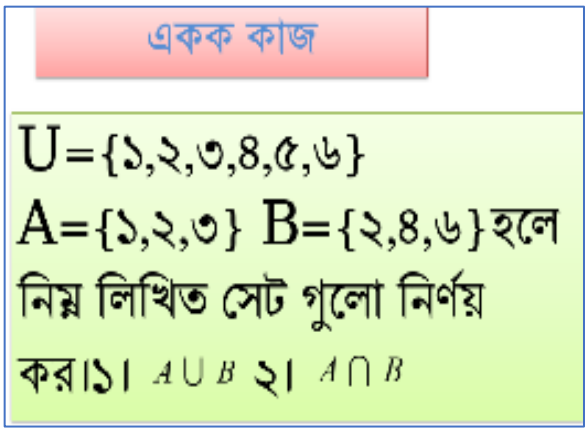


Figure 86: Individual-Work on Set

The teacher proceeded to the next slide with two tasks for pair work (Figure 87). She asked the students to do the task in pairs and she walked among them. Some students were working independently, some were doing in pairs, some were fiddling with something, and some were doing nothing, which indicated that they were not interested in doing the tasks.

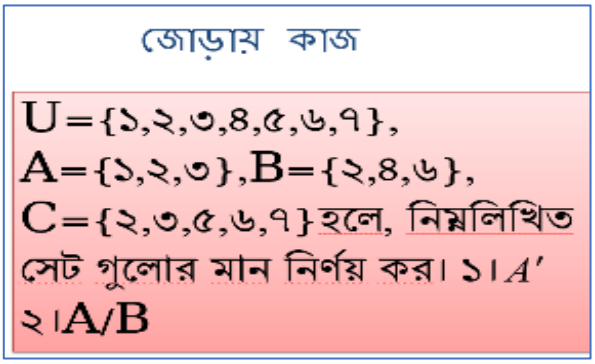


Figure 87: Pair-Work on Set

The teacher went to the next slide with tasks for group work (Figure 88). The teacher asked the students to do that in pairs and she was walking along them. Some students were doing the task individually, some were doing in pairs, some were pretending, some were copying the words looked at the screen, some were fiddling with something, and some doing nothing, and seemed less interested.

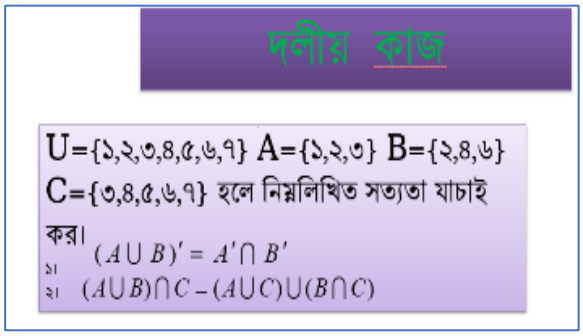


Figure 88: Group-Work on Set

The teacher went to the next slide of 'evaluation' (Figure 89) and she told to the students, "Now, I will ask some questions to evaluate you". The teacher looked at the screen for some time, it seemed that she was confused about the texts. Two multiple-choice questions were on the slide. She read out the words from the screen and asked the students to do the tasks. Some students were copying the texts from the screen, some were fiddling with their hair and headscarf, some were talking to each other, some looked at the screen, and some were pretending to do the tasks while actually doing nothing. The teacher walked among the students and checked two students' notebooks and then concluded, "So, you all have done it".

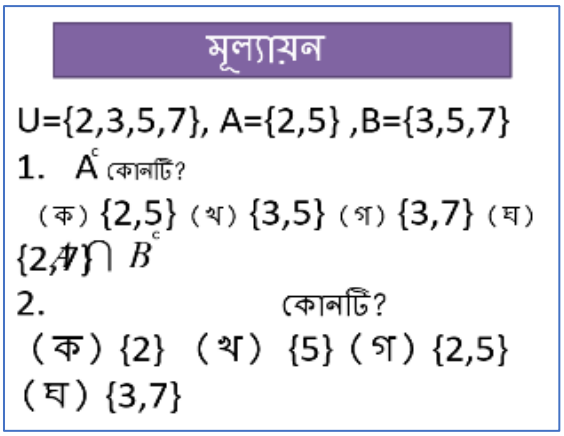


Figure 89: Evaluation slide on Set

Observation Eight – Grade Nine

T4_Lesson 2: Relation and Function

Collaborative and Authentic Culture

The teacher opened the next slide, which displayed five images together, the slide was with an individual task (Figure 90). The task was to find out the domain and range of the relationship. She began explaining the images of the concepts of 'domain' and 'range'. She told the students, "We talked about learning outcomes-1 in the previous slide, this slide is for learning outcomes-2". She asked them to do the task individually. Some students were doing it individually, other students seemed less interested in doing the task.

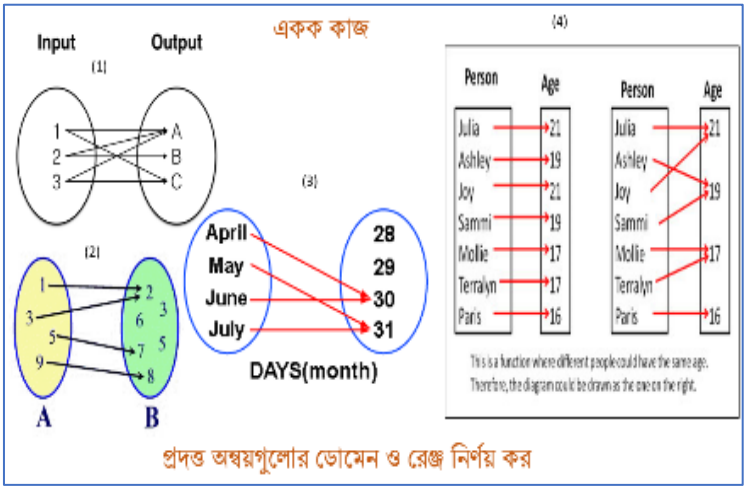


Figure 90: Individual-Work on Function

The teacher proceeded to the next slide, which contained some hazy images on the screen (Figure 91). The task was to present the relationship in tabular format and identify the function. She uttered the words from the screen and asked the students to do the task in pairs. Some students were doing it individually, a few were doing it in pairs, some were copying from the screen, some were gossiping silently and seemed uninterested in doing the task. The teacher was walking among the students.

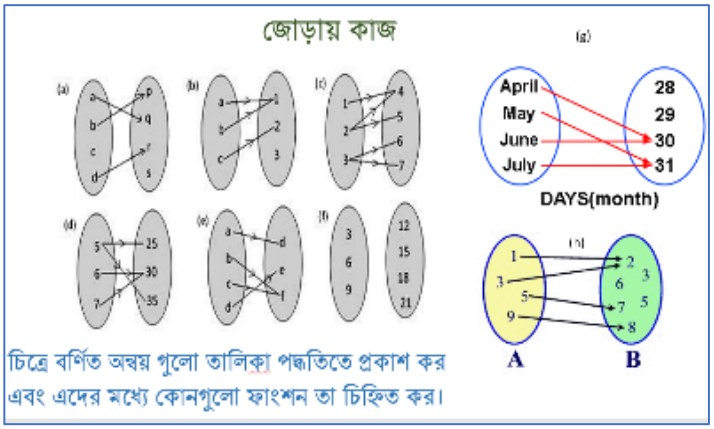


Figure 91: Pair-Work on Function

The teacher moved to the next slide, containing a procedural task to find the ‘one-one function’ (Figure 92). She read out the words from the screen and explained it in her own way. She was solving the problem on the board and explaining herself. A few students were solving themselves or copying from the board, some front desk students were uttering with the teacher, and most backbench students were not doing anything, they seemed to be struggling to stay engaged in the task. The teacher clicked on the mouse and the image of a visual representation of the ‘function’ appeared on the screen. Then the teacher began to explain pointing to the image why the result was one-one function but not universal.

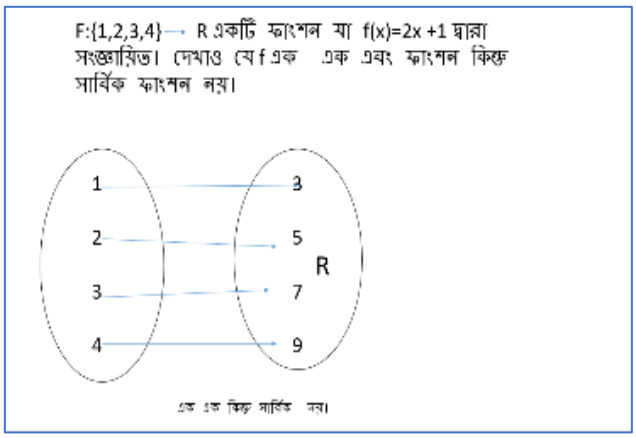


Figure 92: Problem on Function

The teacher went to the next slide, containing some scattered images with a task, to be done in groups (Figure 93). She explained the images pointed to the screen and asked the students to do the tasks in pairs. A few students were discussing with each other, some were doing individually and most student’s faces were expressionless, indicating that they were not interested or struggling to keep up with the task.

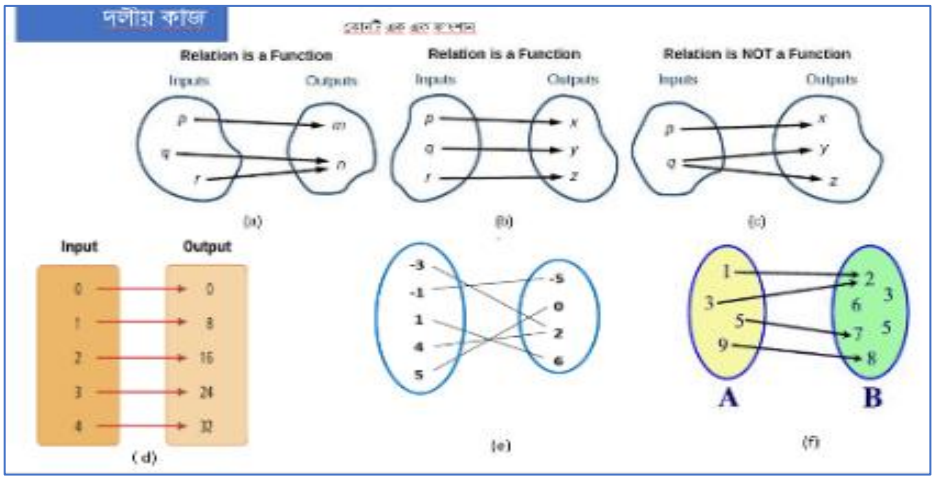


Figure 93: Group-Work on Function

The teacher turned over to the next slide, which contained text and the answer to the previous task (Figure 94). She asked the students to match their results to the screen. She read out the words from the screen.

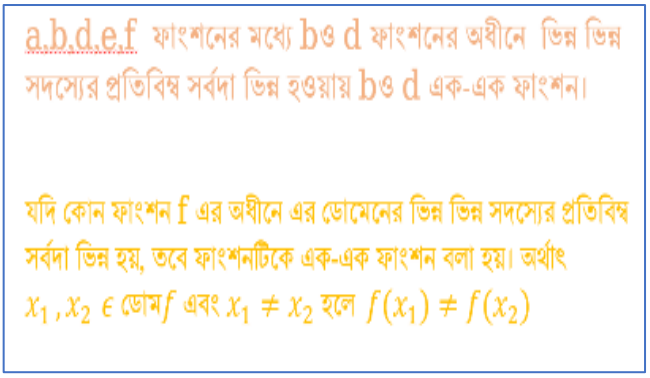


Figure 94: Solution of the Group-Work

Then the teacher went to the next slide, which was filled with text, and a couple of questions to evaluate the students (Figure 95). She asked the students to look at the screen and to write down the answer in their notebooks, and she would check it. However, the teacher began explaining the questions by pointing to the screen. The students were not listening to her- some were copying from the screen, some were pretending to do the tasks but some were doing nothing and seemed not interested in engaging with the tasks.

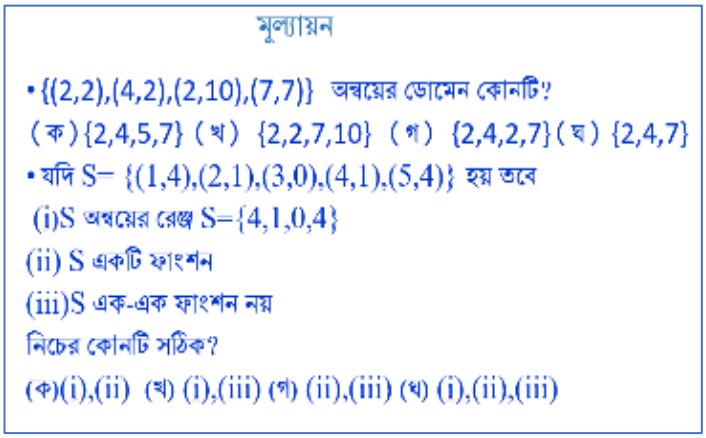


Figure 95: Evaluation slide on Function

Observation Nine – Grade Nine

T5_Lesson1: Trigonometric Ratios

Collaborative and Authentic Culture

The teacher went to the next slide, the slide displayed some text (Figure 96). He pointed to the screen and asked the students, what were the names of the sides of the right-angled triangle. Some students were answering all together, but most students were copying from the screen, they were not listening to the teacher and not answering to his questions. The teacher asked the students to do the task individually. He was walking among them while the students were copying the task from the screen.

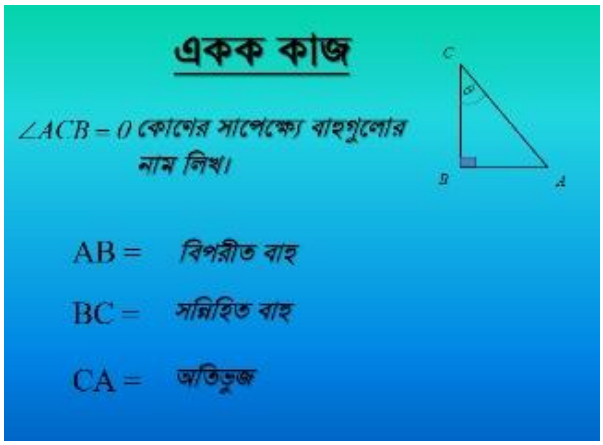


Figure 96: Individual-Work on Trigonometric Ratios

The teacher went to the next slide, there was a task to do in groups - to draw the given triangles by looking at the screen (Figure 97). He asked the students to draw the picture in groups. The students copied the triangles individually from the screen. Some students did not open their notebooks and did not do the tasks. The teacher walked among the students, checked their tasks and appreciated them.

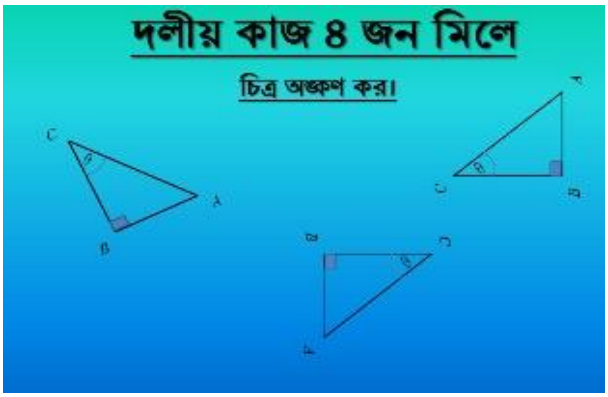


Figure 97: Group-Work on Trigonometric Ratios

The teacher proceeded to the next slide, which contained one multiple-choice question to evaluate the students (Figure 98). He asked the students about the previous slide, “Have you all drawn the pictures? Which ratio would it be if the opposite side is divided by the adjacent side”? Some students responded all together in a low voice. The teacher clicked and the answer appeared on the screen, upon which all students answered loudly looking at the screen.

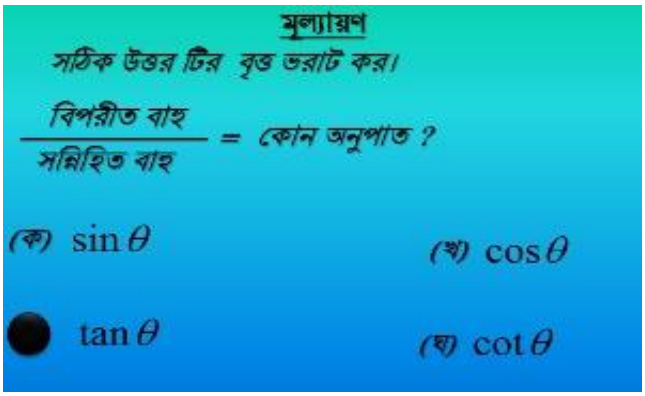


Figure 98: Evaluation slide on Trigonometric Ratios

Observation Ten – Grade Ten

T5_Lesson2: Rectangular Solid

Collaborative and Authentic Culture

The teacher went to the next slide, where there was an individual task about the volume of a rectangular solid (Figure 99). He asked the students to solve the problem. The students opened their notebooks from their bags and started to work individually. The teacher uttered the given values of length, width and height of the rectangular solid looking at the screen and walked among the students. He was checking the student’s tasks in their notebooks. Most students were curious to show their tasks to the teacher. The teacher was checking one by one and some students were standing up to show their tasks to the teacher.

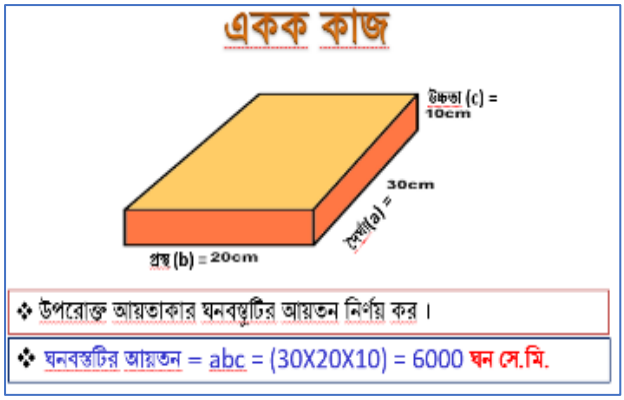


Figure 99: Individual-Work on Rectangular Solid

The teacher proceeded to the next slide, there was a task to do in pairs – to find out the diagonal of a rectangular solid (Figure 100). The teacher was uttering the words from the screen. The students had already started to do the task individually. Then the teacher asked the students to do the task in pairs and to help others. Some students were doing in pairs, some were using the calculator and some were ready to show their solution to the teacher. The teacher started to check their notebooks one by one.

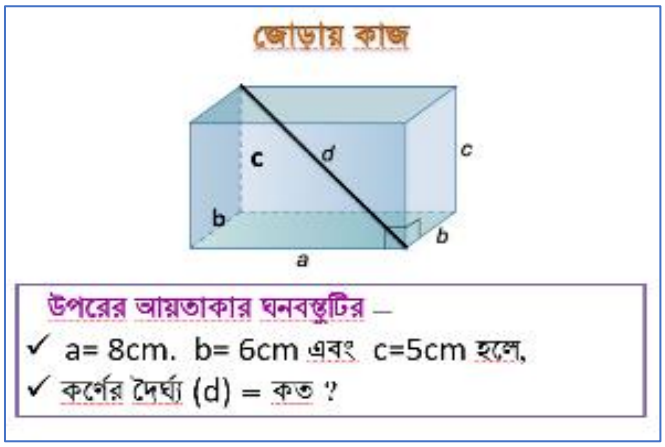


Figure 100: Pair-Work on Rectangular Solid

The teacher went to the next slide, with a task to be done in groups (Figure 101). The task was to find out the whole area of a rectangular solid. The students started to write in their notebooks individually. The teacher asked the students to make a group with two benches and he was walking among them. The students did not bother - some students were doing the task, some were watching others' notebooks, some were discussing and some were calculating with the calculator to help their friends. Some students were standing to show their solution of the given task to the teacher. The teacher was checking their notebooks one by one. The students were talking to each other and laughing. The teacher clicked on the slide and the solution of the task appeared on the screen.

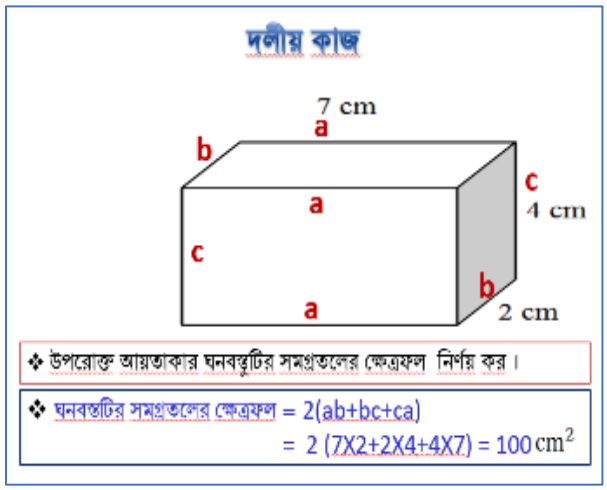


Figure 101: Group-Work on Rectangular Solid

The teacher moved on to the next slide and there were some questions for evaluation (Figure 102). He said, “Now we will see what we have learned today”. The students were making noise, they were talking to each other. He was asking questions one by one and looked at the screen about the definitions and formulas of the rectangular solid. Most students raised their hands and one was asked to answer.

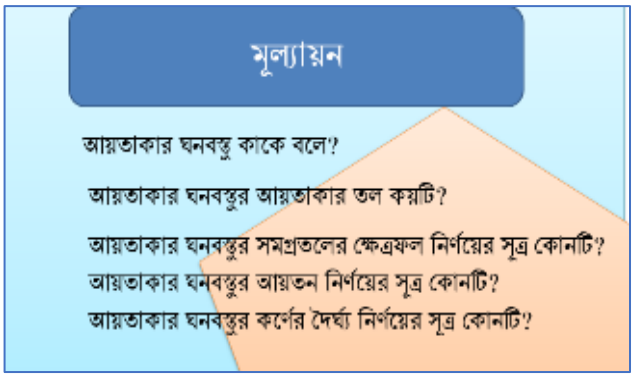


Figure 102: Evaluation slide on Rectangular Solid

4B.1.4.3 A detailed summary analysis of integrating ten Observed lessons

The scores are defined as **H** for high, **M** for medium, **L** for low, and **N** for not done in the lesson.

2.2 **Learning Context** (**Classroom Culture: Collaborative and Authentic)**												
	Aspects of Observation	Scores of Ten Lessons										Descriptions
		T1		T2		T3		T4		T5		
2.2.1	The environment of individual work, peer interaction, and collaboration	N	N	L	L	N	L	L	L	N	L	In the six lessons out of ten, both individual and collaborative tasks for the students were displayed on the slides. However, there was limited peer interaction during the lessons. Additionally, the tasks did not require student's understanding, just to memorize the formulas.
2.2.2	Students become more active in math tasks that necessitate joint intellectual effort.	N	N	N	N	N	N	N	N	N	N	The students were not required to be deeply engaged in tasks.
2.2.3	Create a climate of teacher and student interaction	L	L	L	L	L	L	L	L	L	L	Student and teacher interactions were mostly procedural. The teacher asked questions to recall the definitions, rules or formulas.
2.2.4	Create opportunities to explain deeply student's own ideas and respond to other ideas in a meaningful way.	N	N	N	N	N	N	N	N	N	N	The students were not required to provide explanations, only pro forma answers to procedural questions.

Table 9- Classroom Observation Guidelines (Learning Context: Classroom Culture)

Dimension- Learning Context (Classroom Culture: Collaborative and Authentic)

4B.1.4.4 Linkage between Teacher's Pre-lesson interviews and their lessons

From the teacher's pre-lesson interviews, it can be said that all the teachers usually provided individual tasks to the students using the procedural tasks from the textbook. They all claimed that there were not many challenging tasks in the textbook. However, T1 and T4 claimed that they occasionally used their own created diverse tasks using images in the presentation slide. T1 claimed that he sometimes provided group work to the students to encourage peer interaction and collaboration. All five teachers declared that there was not enough space to make groups in the classrooms. However, T2 commented that group work activities were suitable for the practical mathematics lessons only but not for the theoretical lessons. All the teachers noticed that group work makes the class undisciplined. The good students did not want to discuss with others and wanted to do the task individually to show their ability. All the teachers claimed the same way that most students did not want to explain in details their own understanding. The teachers also claimed that they usually interact with the students by asking questions and by showing images and text using their digital content.

From the lesson observations, it can be said that the teachers provided the mathematical tasks by showing them on the digital content slides. T1, T4 and T5 used images in their presentation slides but the tasks were mostly procedural and some students solved the tasks individually just by recalling the formulas. There was no meaningful collaboration or peer interaction in the lessons. There were some teacher-student interactions, with the teachers asking students to recall the mathematical definitions and formulas. Some students were asked direct questions which had one answer. The environment was not created for the students to provide explanations using their own understanding of learning mathematics. Teachers T1 and T5 provided interactive images that had potential for collaborative and authentic learning, but they did not utilize them in a way that enabled student interaction or engagement. They explained the images and the students were watching and listening silently. T1, T3, and T4 provided mathematical tasks for group work using digital content slides which had to be solved just by recalling the formulas and procedural method. However, only a few students did the task individually and most did not do any tasks. In another lesson of T1, there was the concept of drawing the graph with some unnecessary animations which

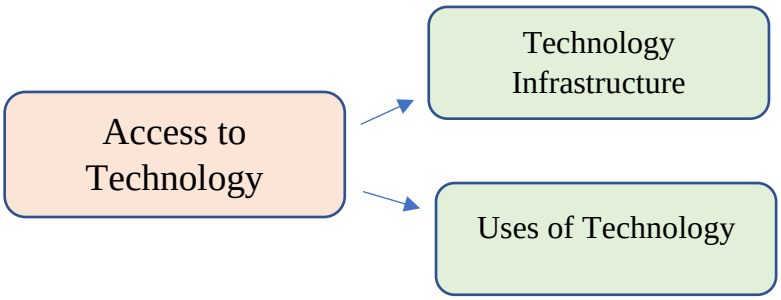
could be used in collaborative learning but he could not make it. Furthermore, he skipped the group work slide. T2 explained the mathematical task about drawing the parabola and the solution showing on the screen, the task was copied from the textbook page. He used the software GeoGebra to solve the problems by explaining the solving method. The teacher had asked the students some questions, which had one answer to be memorized. T5 provided three slides of individual work, pair work, and group work - but the tasks were mostly done individually by the students just recalling the formula and procedural method.

Dimension- Learning Context (Classroom Culture: Collaborative and Authentic)

4B.1.4.5 Summary

The trained mathematics teachers have developed their ability to make the presentation slides of individual work, pair work, and group work with text, relevant shapes, and pictures; however, the tasks were mostly procedural and copied from the textbooks. The teachers did not make any group in their lesson, the tasks were done individually by some students recalling the rules or formulas. The teachers could not provide diversified and challenging mathematical tasks to create an environment for the students to be deeply engaged and become more active in tasks that necessitate joint intellectual effort. The teacher-student interactions were not meaningful, and the students were not required to explain their own ideas deeply and respond to others. So, as a result, it is evident in the observation guideline that the codes of learning context dimension, that is collaborative, and authentic culture have not been implemented in all the lessons. There was minimal interaction between teachers and students, and many individual tasks assigned to the students focused primarily on memorizing procedural methods and formulas. There were four segments in the observation guideline, and the total scores were **16L** and **24N** out of 40 in all 10 lessons. There were no scores for **M** and **H**.

4B.1.5 Access to Technology (Technology Infrastructure and Uses of Technology)



This section investigates the concepts of technology infrastructure and the application of technology in educational settings, emphasizing their critical role in enhancing teaching and learning experiences. The researcher begins by examining the technology infrastructure of multimedia classrooms (MMCs), where teachers integrate various types of Information and Communication Technology (ICT) equipment into their lessons. In particular, the researcher looks at how students are provided with opportunities to engage with ICT tools during mathematics lessons, facilitating an interactive and dynamic learning process. To assess the effectiveness of access to technology in these technology-enhanced classrooms, the researcher compares the instructional methods described by teachers with direct evidence gathered from observations of classroom lessons. This comparative analysis will illuminate the alignment between teachers' reported practices and actual classroom implementation, revealing how effectively technology is integrated into the learning process. The findings from this investigation are expected to provide valuable insights into the role of ICT equipment in the classroom, as well as the proficiency levels of both teachers and students in using such technology.

4B.1.5.1 Teacher's Pre-lesson Interviews:

The Teacher (Case 1) said that there was a projector and a whiteboard in the multimedia classroom. There was only one multimedia classroom in the institution and he used his own laptop to use the digital content of power point presentation. They had no technologies for the students use in the classrooms. He confessed that he usually followed the steps of the digital content slides of power point presentation as per the content's need, sometimes he used the whiteboard when necessary.

The Teacher (Case 2) affirmed that they had a projector, a Smartboard, and a whiteboard in every classroom in their institution. He used his own laptop for the digital content of PowerPoint presentations, GeoGebra software, and Smartboard in his lessons. However, they had no technologies for the student's use in the classroom. He generally followed the steps of the digital content slides of PowerPoint presentations and the software as per content needs.

The Teacher (Case 3) said that they had no multimedia classroom in their school, but they had one multimedia classroom in the college section. There was a laptop, a projector, a Smartboard , two sound boxes, and one video camera in the classroom. She added that she had to get permission from the college authority to use that classroom. However, they had no technologies for the student's use in the classroom. She confessed that she followed the steps of the digital content slides of the PowerPoint presentation as per the content's need.

The Teacher (Case 4) said that there was a projector and a whiteboard in the multimedia classroom. They have four (4) multimedia classrooms in their institution and she used her own laptop for the digital content of the PowerPoint presentation in the lesson. However, they had no technologies for the student's use in the classroom. She confessed that she followed the steps of the digital content slides of PowerPoint presentation as per the content's need and sometimes used the whiteboard if needed.

The Teacher (Case 5) said that they had a projector and a whiteboard in the multimedia classroom in the institution. They had four (4) multimedia classrooms in their institution and he used his own

laptop for the digital content of PowerPoint presentations, but they had no technologies for the student's use in the classroom. He confessed that he followed the steps of the digital content of PowerPoint presentation slides as per the content's need and sometimes used the whiteboard.

4B.1.5.2 Classroom Observations

In these five cases, the multimedia classrooms were not well equipped with different technologies and no technologies were there for the students' use in the classrooms. Field notes have been compiled from a review of the data collected from the ten videos provided.

Observation One and Two – Grade Eight
T1_Lesson_1 and 2: Area and Circumference of a Circle and Graph of a Simple Simultaneous Equation
Technology Infrastructure and Uses of Technology

There was a multimedia projector, a laptop, a screen, and a whiteboard behind the projector's screen. There was no other technology equipment available in the classrooms and for the students' use. The school has only one MMC (Multimedia Classroom). The teacher's proficiency in technology access varied on the stages of the lesson as per slide but did not vary between content areas and student needs.

Observation Three and Four– Grades Ten and Nine
T2_Lesson_1 and 2: Draw the Parabola and Draw a Triangle (Construction-1)
Technology Infrastructure and Uses of Technology

There was a multimedia projector, laptop, Smartboard, and a whiteboard in every classroom in the school. No other technology equipment was in the classroom and not for the student's use. The teacher's proficiency in technology access varied on the stages of the lesson as per slides and use of the software GeoGebra and Smartboard, but did not vary between content areas and student needs.

Observation Five and Six– Grade Eight

T3_Lesson_1 and 2: Cone and Arithmetic Progression

Technology Infrastructure and Uses of Technology

There was a multimedia projector, a laptop, a screen, a Smartboard, and a whiteboard in the classrooms. Two sound boxes and one video camera were also in the classroom but no technology equipment for the students' use. It was the only MMC (Multimedia Classroom) in the college section, not in the school. The teacher's proficiency in technology access varied on the stages of the lessons as per slides, but did not vary between content areas and student needs. She was using the Smartboard with the help of a technician.

Observation Seven and Eight – Grades Eight and Nine

T4_Lesson_1 and 2: Set Theory and **Relation and Function**

Technology Infrastructure and Uses of Technology

There was a multimedia projector, a laptop, a screen, and a whiteboard in the classrooms. There was no other technology equipment available in the classroom and for the student's use. They had three MMC (Multimedia Classrooms) in the school. The teacher's proficiency in technology access varied on stages of the lesson as per slides, but did not vary between content areas and student needs.

Observation Nine and Ten– Grades Nine and Ten

T5_Lesson_1 and 2: Trigonometric Ratios and Rectangular Solid

Technology Infrastructure and Uses of Technology

There was a multimedia projector, a laptop, a screen, and a whiteboard in the classrooms. There was no other technology equipment available in the classrooms and for the student's use. There were four MMC (Multimedia Classrooms) in the school. The teacher's proficiency in technology access varied on stages of the lesson as per slides, but did not vary between content areas and student needs.

4B.1.5.3 A detailed summary analysis of integrating ten Observed lessons

The scores are defined as **H** for high, **M** for medium, **L** for low, and **N** for not done in the lesson.

3 **Access to Technology (Technology Infrastructure and Uses of Technology)**												
	Aspects of Observation	Scores										Descriptions
		T1		T2		T3		T4		T5		
3.1	Teachers use types of ICT equipment	L	L	M	M	L	L	L	L	L	L	The teachers used their laptops and projectors to show the digital content of the PowerPoint presentation. T2 used also GeoGebra and Smartboard in his lessons.
3.2	Students use technology	N	N	N	N	N	N	N	N	N	N	There was no technology for the students.
3.3	Student's proficiency in using technology	N	N	N	N	N	N	N	N	N	N	No technologies for the student's use.
3.4	Teacher's proficiency in using technology	L	L	L	L	L	L	L	L	L	L	The teacher accessed technology just showing the slides one by one. The access varied on the stages of the lesson as per slides but did not vary between content areas and student needs.

Table 10- Classroom Observation Guidelines (Access to Technology)

Dimension- Access to Technology (Technology Infrastructure and Uses of Technology)

4B.1.5.4 Linkage between Teacher's pre-lesson interviews and their lessons

From the teacher's pre-lesson interviews, teachers T1, T4, and T5 declared that there was a projector and a whiteboard in the multimedia classrooms in their institutions. They used their own laptop to use the digital content of PowerPoint presentations in their lessons. Teacher T2 claimed that there was a projector, a whiteboard, and a Smartboard in all the classrooms in his institution and he used his own laptop to use the digital contents in the lessons. T3 complained that they had no multimedia classroom in their school, but they had one in the college section with a laptop, a projector, a Smartboard, and a camera.

All the teachers confessed that they generally used PowerPoint presentations as digital content in their lessons. Teacher T2 added that he also utilized GeoGebra and Smartboard software in his lessons. They all followed the steps of the digital content slides as per the content's need and sometimes used the whiteboard. They all said that there were no technologies for the students to use in their classrooms.

Dimension- Access to Technology (Technology Infrastructure and Uses of Technology)

4B.1.5.5 Summary

All the teachers were proficient in the use of technology to show and explain the learning contents by using PowerPoint presentation slides. The teacher T2 used two more software named GeoGebra and Smartboard to describe the mathematical facts in his lessons. The students had no technologies to use in the classrooms. The teacher access to technology was a teacher-centered approach and did not vary between content areas and student needs. There were no technologies for the students to use in the lessons. As a result, it appeared in the Classroom Observation guideline that according to the code Technology Infrastructure and Uses of Technology, of the Dimension Access to Technology, the classrooms have not been well equipped with different technologies in these five cases. There were four segments in the observation guideline, and the total scores were 2M, 18L, and 20N out of 40 scores for all ten lessons.

4B.2 Chapter Summary

In summary, the exploration of digital content usage in secondary mathematics lessons revealed that the five trained mathematics teachers felt equipped to create and utilize PowerPoint presentations as part of their teaching practices. Through the digital content development training, the teachers could develop digital content of PowerPoint presentations incorporating a range of multimedia elements, including text, shapes, images, pictures, animations, and videos. Also, one teacher chose to incorporate static elements from textbooks in his presentation slides. The digital content also contained excess text, images, and animations across all five cases. Despite incorporating digital content, the teachers mostly employed a teacher-centered approach. They presented the slides sequentially, primarily reading from them and providing explanations for the images and videos displayed, thereby limiting student interaction. Students engaged in activities mainly focused on recalling mathematical facts as highlighted in the slides, but these activities did not encourage meaningful engagement; instead, students remained passive, mainly watching and listening to the teacher throughout the lessons. Moreover, the teachers struggled to visualize complex concepts and failed to create an environment that fostered student innovation and idea generation. Real discussions regarding mathematical concepts were absent from all lessons. While teachers occasionally posed procedural questions, students typically responded by recalling procedures and formulas rather than engaging in deeper conceptual understanding. Classroom conditions further hindered effective learning, as the physical space and furniture were not conducive to a technology-enhanced environment, and there were no readily available technological resources for students.

The analysis of these five cases revealed that the teachers lacked the competence to develop and utilize digital content effectively in alignment with pedagogical principles. They struggled to create digital materials that incorporated real-world examples, diverse and challenging tasks, or complex mathematical concepts, and they did not employ appropriate animations and images to enhance their presentations. The teachers lack a clear understanding of how to utilize digital content to effectively check student prior knowledge, facilitate collaborative and group learning to achieve a joint intellectual effort, deepen student understanding by incorporating real-world examples, build and refine student strategies and ideas, create tasks that promote active engagement, and capture and characterize their peers' thoughts and ideas. So, the lessons were

delivered using a traditional lecture format incorporating digital content of PowerPoint presentations and other software. As a comprehensive analysis of the ten (10) lessons of the five (5) cases, it appeared that almost 76 percent of segments have not been done in the classroom observation guideline in their mathematics lessons using digital content. There were 21 segments for every lesson under the three domains of Pedagogy, Learning Context, and Access to Technology. It should be mentioned that all the teachers got almost the same scores in their lessons. Hence, the total obtained scores were 160N, 48L, 2M, and no scores for H out of 210. The scores were designated as **N** for not done in the lesson, **L** for low, **M** for medium, and **H** for high following the **MQI** (Mathematical Quality of Instructions) rubric.

Chapter Four C

Data Analysis and Findings

4C.1 Use of digital content affects the secondary mathematics teaching-learning process

After lesson observation, post-lesson interviews with the teachers and focus group discussions (FGDs) with the students were conducted. Each teacher participated in two lessons, which were two Focus Group Discussions (FGDs), eight students were selected for each lesson in one FGD, resulting in a total of ten FGDs being conducted. The students were chosen based on their diverse responses and by gender during the lesson. The post-lesson interviews with teachers lasted approximately 45-60 minutes each, while the FGDs with students took around 20-25 minutes to complete. In total, ten (10) post-lesson interviews and ten (10) FGDs were conducted over a period of three months, during which I interacted with the five (5) selected teachers. Two (2) lessons from each teacher were analyzed through the post-lesson interviews and FGDs.

The post-lesson interviews with the teachers and focus group discussions (FGDs) with the students were analyzed through the lens of three components as the dimensions, guided by the TIP (Technology Integration Panel) framework (Figure 10, Page 44).

Those are:

- **Pedagogy** (Learning Objectives: Meaningful Learning, Discovery Learning;
  Instructional Design: Student-Centered, Scaffolding)
- **Learning Context** (Classroom Culture: Collaborative, Authentic)
- **Access to Technology** (Technology Infrastructure, Uses of Technology)

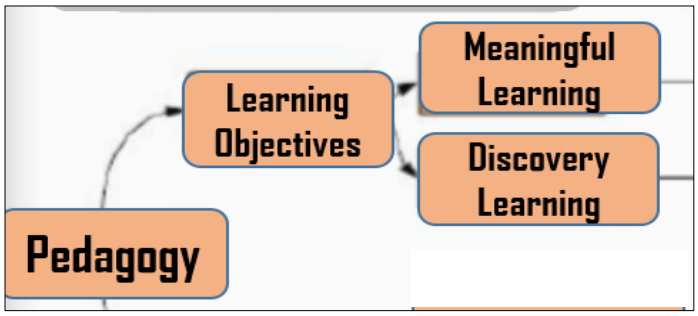
This section presents a brief description of the observed lessons that were conducted by the teachers, along with insights from the post-lesson interviews and notes from focus group discussions (FGDs) with the students. These elements are discussed under each dimension. Subsequently, data from these three areas were integrated across the five cases under the same dimension and then triangulated to compare these three areas across all five cases. Finally, data from all dimensions were synthesized into a summary note. All activities were carried out using the systematic method developed by Strom and Fagermoen (2012) (Figure 11, Page 51).

4C.1.1 Pedagogy: Learning Objectives (Meaningful Learning and Discovery Learning)

In this dimension, the researcher explores the codes related to Learning Objectives within the dimension of Pedagogy. The exploration of the Learning Objectives highlights two key areas:

1. Meaningful Learning: This code focuses on how well students can connect their prior knowledge with new ideas. It examines the extent to which they can extend their understanding by relating new information to real-world examples.

2. Discovery Learning: This area emphasizes student engagement in learning tasks that require them to apply, analyze critically, and innovate ideas. The students will be encouraged to explore information actively and create new knowledge. By engaging in inquiry-based activities, they not only participated in the learning process but also developed critical thinking skills and a sense of ownership over their learning.



In the observed lessons, it is evident that there were opportunities in all five cases within their lessons to apply the Learning Objectives codes of Meaningful Learning and Discovery Learning as part of the Pedagogy dimension. There were six segments in the Observation Guideline in the code of Learning Objectives and the total scores obtained were **19L** and **41N** out of 60 scores for the **10 lessons.** No scores were there for **M** and **H**; where H for high, M for medium, L for low, and N for not present in the lesson.

4C.1.1.1 A brief description of the observed lessons conducted by the teachers, along with insights from post-lesson interviews and FGDs with the students, is provided below:

Observation One – Grade Eight

T1_Lesson 1: Area and Circumference of the Circle

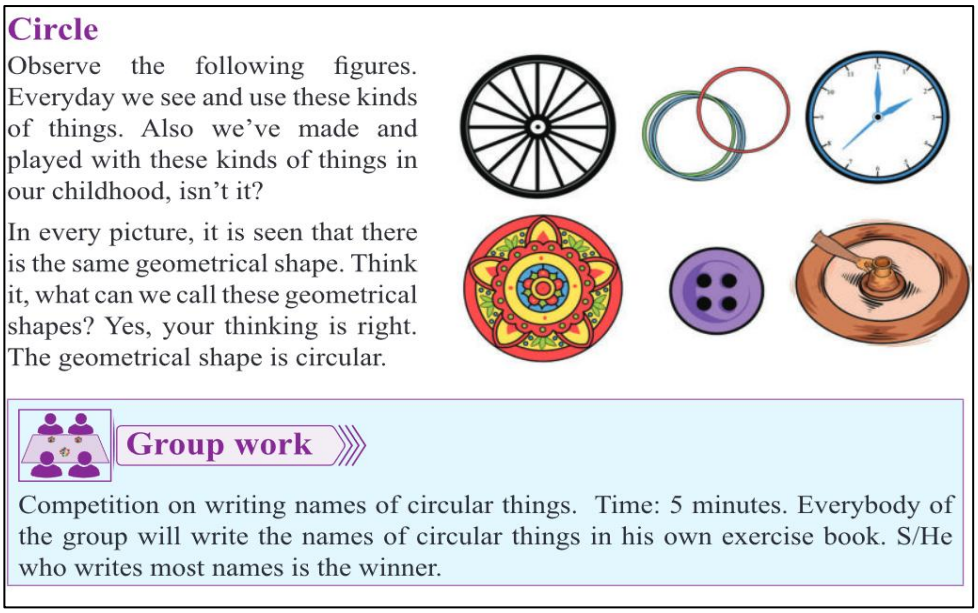
Meaningful Learning

The teacher showed a hazy picture of the Shaheed Minar monument and asked the students to respond to the image (Figure 12). A few students responded by replying with 'red circle' and 'round circle' aspects of the picture. The teacher then pointed out the rectangular shapes in the picture and described their length and width.

In the post-lesson conversation, the teacher claimed that he asked questions using the picture of Shaheed Minar with a circle-shaped flower bucket to connect with real-life situations. He argued that he checked students' prior knowledge about the circle showing the images on the screen to go to the topic 'Area of a circle'. However, the teacher agreed that the students were not required to make a meaningful connection between their knowledge. He argued that the images should be clear like in Figure 103, and the questions could be activity-based and interactive so that the students could connect their experience and knowledge.

Figure 103: Pictures of circle shapes (Collected from Google)

The teacher agreed that he could use the activity with real-life things introduced in the new textbook, which incorporates real-life examples, this would allow students to make connections between their experiences and prior knowledge (Figure 104).



Circle

Observe the following figures. Everyday we see and use these kinds of things. Also we've made and played with these kinds of things in our childhood, isn't it?

In every picture, it is seen that there is the same geometrical shape. Think it, what can we call these geometrical shapes? Yes, your thinking is right. The geometrical shape is circular.

Group work

Competition on writing names of circular things. Time: 5 minutes. Everybody of the group will write the names of circular things in his own exercise book. S/He who writes most names is the winner.

Figure 104: Circle (Collected from the new textbook)

Discovery Learning

The teacher described 'Pi' showing a moving circle on a straight line in the digital content slide (Figure 13). He repeated the description of the diameter, the circumference, and the value of Pi. Also, by showing the animated images, he explained how the circle transferred to a rectangle and how to create the formula of the area of the circle (Figure 14). But he could not make it interactive and innovative.

In the post-lesson conversation, the teacher confessed that there was scope for discovery learning in the lesson but he described most. The students could analyze the given animated images and explain their own ideas about Pi (Figure 13) and the Area of the Circle (Figure 14) and apply creative thought to form arguments, but the teacher could not facilitate that. The students could explore, analyze and create the rules of the circle by discussing themselves. However, the teacher argued that it was not possible to make a student's discussion environment, as the class time duration was not sufficient for activity-based learning.

The teacher also agreed that he could use the activity introduced in the new textbook, allowing the students to analyze the data from the table and make the formula of Pi (Figure 105).

Draw a table like below on your exercise book. Measure the areas and note down the measurements beside your names.

Name	Radius of circle	Diameter of circle	Circumference of circle	Ratio of circumference and diameter
Nilima				
Shahed				
Ranjana				
Pratik				
…….				

It seems that you are astonished watching the result of the table. Probably you have thought, each of you has taken circular area of different radius and also measurement of diameter and circumference are different but the results of all are almost the same. How is it possible? Discuss it in the group.

Figure 105: Making Pi (Collected from the new textbook)

However, the teacher remarked, "Most students do not like to analyze the diverse tasks; they want to know the solution only. So, I explained about Pi showing them animated images for their better understanding".

FGD with Students

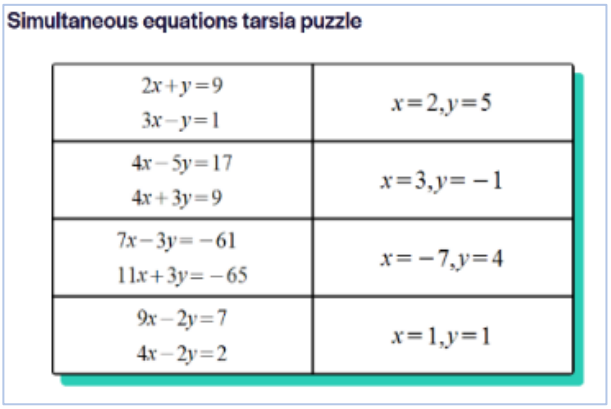
In a focus group discussion, students expressed their enjoyment of digital content in lessons but felt it often lacked engagement. S4 and S5 appreciated images of Shahid Minar and flower bouquets but felt disconnected, as S5 noted, "I did not get to connect my thoughts with the pictures". Several students, including S2 and S7, felt they passively observed animations of mathematical shapes without the chance to share their ideas or analyze them. S5 mentioned missing the opportunity to derive the area formula for a circle since the teacher explained it instead. Overall, the students felt they lacked chances for critical thinking, problem-solving, and real-life application of their lessons.

Observation Two – Grade Eight

T1_Lesson 2: Graph of a Simple Simultaneous Equation

Meaningful Learning

The teacher described the equation of two variables with texts, images, and some unnecessary animations (Figure 16). He sometimes asked questions to the students about the values of x and y in the equation but did not wait for their response.

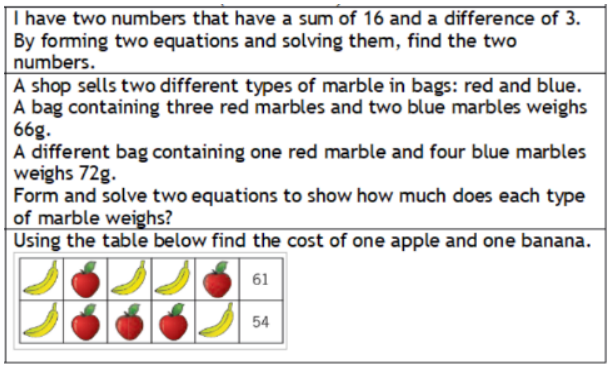


Simultaneous equations tarsia puzzle

$2x+y=9$ $3x-y=1$	$x=2, y=5$
$4x-5y=17$ $4x+3y=9$	$x=3, y=-1$
$7x-3y=-61$ $11x+3y=-65$	$x=-7, y=4$
$9x-2y=7$ $4x-2y=2$	$x=1, y=1$

Figure 106: Use of Tarsia Puzzle (Collected from Google)

In the post-lesson conversation, the teacher claimed that he tried to make a meaningful connection between knowledge by asking questions to the students. However, he agreed that he could not make it interactive and he could not build a connection between student's knowledge. If he had done that, then the students could have explored the concepts of the simultaneous equation themselves. The teacher agreed that it could be interactive through the tasks from the digital content, as with the Tarsia puzzles (Figure 106), to make a meaningful connection between their knowledge. The teacher also agreed that if he could use relevant real-world problems of simultaneous equations (Figure 107), then the students could make meaningful connections between their knowledge. The students could take the decision that, "there were no ending values of x and y in the equation 'x + y = 5', there were an infinite number of values" by discussing between themselves what the teacher described.



I have two numbers that have a sum of 16 and a difference of 3. By forming two equations and solving them, find the two numbers.

A shop sells two different types of marble in bags: red and blue. A bag containing three red marbles and two blue marbles weighs 66g. A different bag containing one red marble and four blue marbles weighs 72g. Form and solve two equations to show how much does each type of marble weighs?

Using the table below find the cost of one apple and one banana.

🍌	🍎	🍌	🍌	🍎	61
🍌	🍎	🍎	🍎	🍌	54

Figure 107: Connecting Real-life with simultaneous equation (Collected from Google)

Discovery Learning

The teacher explained showing a graph paper on the screen, saying that there was an image of a scale and graph paper. He also put the coordinate points of the given equation and drew the graph on the screen through animation (Figure 17). The texts appeared one by one on the screen through animations, and he described the value of y and x, the other points, and asked the students not to take any fraction of the points. He sometimes asked questions to the students but did not wait for their response and continued the explanation indicating at the slide about the rules of drawing a graph.

In the post-lesson conversation, the teacher agreed that he explained most but there was scope for discovery learning in his lesson that he could not facilitate. He could use a real-world problem to make an environment for discovery learning (Figure 108). The teacher should include activity-based mathematical tasks and ask questions where the students could analyze about plotting the coordinate points in the graph paper and making the graph of the simultaneous equations (Figure 109). The students would be able to explore new knowledge about simultaneous equations, identify key concepts or rules of making the graph, and create new knowledge by applying their own thoughts.

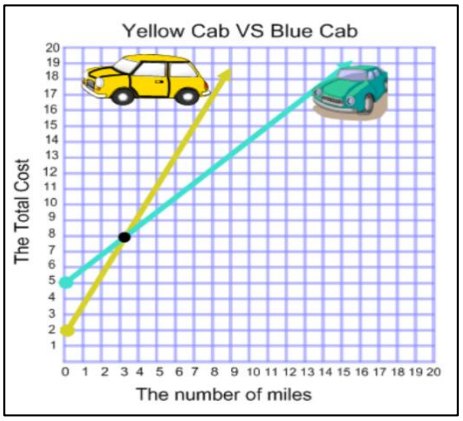


Figure 108: Real-world Problem of Simultaneous Equation (Collected from Google)

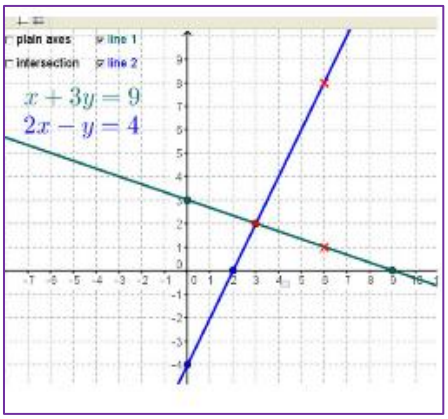


Figure 109: Graph activity of Simultaneous Equation (Collected from Google)

But the teacher claimed, “These types of images are new to the student. We should explain first some ideas directly to the students, then we could give them tasks otherwise they would not be able to solve the task”.

The teacher also agreed that he could use the activity introduced in the new textbook, where the students could struggle with the challenge and apply their creative thoughts (Figure 110, Figure 111).

Problem: Setu's friend Rafi buys 2 packets of pin and 3 pens at Tk 28 and Sonia buys 4 packets of Pin and 6 pens from the same shop at Tk 56. In this case neither Rafi nor Sonia knows the price of one packet of pin and one pen. Can't we solve Rafi and Sonia's problem like we did for Setu? Let's try it:

Solution: Suppose, the price of 1 packet of pin is Tk x and the price of 1 pen is Tk y.

$\therefore$ the equations are,

$$2x + 3y = 28 \text{ .....(i)}$$

and $$4x + 6y = 56 \text{ .....(ii)}$$

What type of equation would you call the two equations (i) and (ii)? Write in the blank space below with the reason.

Figure 110: Simultaneous Equation activity (Collected from the new textbook)

Have a look and discuss with your friends (Figure 111):

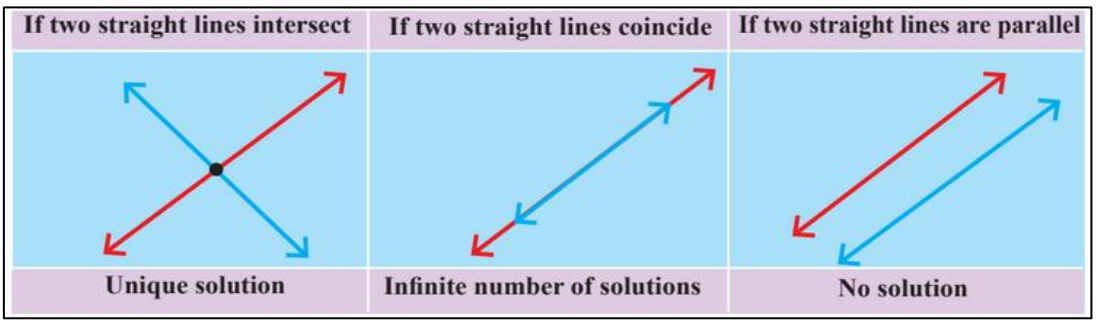


Figure 111: Simultaneous Equation activity (Collected from the new textbook)

FGD with Students

In the focus group discussion, all the students enthusiastically expressed their love for watching digital content in their lessons. S1 exposed, “I like watching the texts and animation”. S3 explained their own ideas about the animation, “I enjoy viewing the pencils and the text appearing one by one on the screen”. Student S8 mentioned, “I like watching the animated pencil drawing the graph on the screen”. Student S5 expressed her feelings, “I did not get the opportunity to build a connection between my thoughts and the pictures of the graphs”. S4 said, “I silently watched the screen and listened to the teacher without participating or sharing my own thoughts”. S6 and S7 also mentioned that they did not get the chance to struggle with the graph, and therefore did not have the opportunity to struggle with applying, analyzing and creating the graphs. The students also shared that they didn’t get the opportunity to apply in real-life situations what they learned in the lessons.

Observation Three – Grade Ten
T2_Lesson 1: Draw the Parabola

Meaningful Learning

The teacher turned to the slide with some parabolic-shaped pictures and explained those to the students (Figure 18). He was asking about every picture. The students seemed curious looking at the parabolic-shaped pictures and responded by saying one or two words altogether loudly. The teacher spent almost 30 minutes announcing the title of the lesson explaining different sentences in Mathematics and English literature, simple linear equations and graphs, the standard form of the equation, exponents, equation of the circle, and the graph, drawing the graph of the circle, quadratic equations and the graphs and parabola by using GeoGebra.

In the post-lesson conversation, the teacher claimed that he asked questions using some images of the parabolic-shaped which were the Eifel-Tower, a banana, a bridge and others, at the beginning of the lesson, and he tried to connect between students’ knowledge and real-world examples after that announcing the topic ‘Parabola’. The teacher also argued that he tried to make a meaningful

connection between student's knowledge and their experience. He said that he should explain the previous knowledge to revise the lesson so that the students could understand better. The teacher agreed that instead of the 30-minute explanations he could give the students time to think about the pictures, then they could relate the topic to their knowledge and explain their own ideas.

However, the teacher argued that their explanation would not effectively enhance the student's learning and understanding, as it would encourage them to talk to each other and result in a lack of discipline in the class.

Discovery Learning

The teacher explained a standard form of a linear equation and the variables shown on the screen. There were four graphs of quadratic equations on the screen which the teacher described to the students (Figure 19). He explained the quadratic equations, the graph of quadratic equations, and the graph of a circle that would be a curve. Showing another presentation slide, the teacher explained if the vertex point would be changed, the position of the curve would be changed but the shape would be the same. However, he could not make it interactive and innovative.

In the post-lesson conversation, the teacher confessed that there was scope for discovery learning in the lesson using Figure 19, but he mostly described it. The students could analyze the given graphs of the quadratic equations and the parabolic graphs on the screen and explain their own ideas about them. They could be able to explore new knowledge about the types of parabolas and the graphs on the screen. The students could also make the rule of the vertex point by collaboratively discussing the graphs that the teacher described to the students. The teacher acknowledged that the students could relate mathematics to real-world examples, made mistakes,

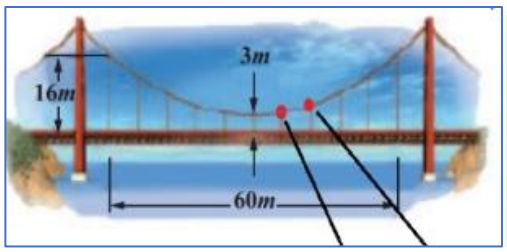


Figure 112: Real-world problem on Parabola (Collected from Google)

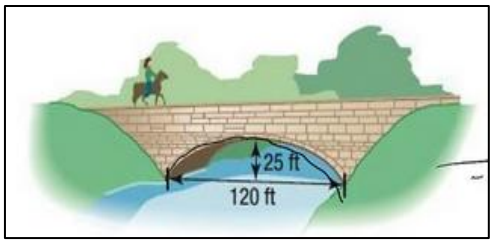


Figure 113: Real-world problem on Parabola (Collected from Google)

and applied their creative thoughts to form arguments using these types of pictures (Figures 112 and 213).

However, the teacher claimed the students were not able to make the rules, and the students' discussion was not suitable in the regular lesson, but it might be suitable in the mathematics practical classes. He also commented on the pictures (Figures 112 and 113), "This type of pictures could be used in a research work, not for the lesson work".

FGD with Students

During the focus group discussion, student S1 expressed frustration, stating, "I watched the standard form of the equation and listened to the teacher, but I did not get the chance to explain my own ideas". S2 echoed this sentiment, mentioning they were unable to connect their thoughts with the images of the circle's standard form. While S3 and S5 enjoyed seeing images of objects like the Eiffel Tower and parabola, they felt they lacked the opportunity to share their interpretations. S6 stated, "I was silently watching the pictures and listening to the teacher without any chance to participate". S8 also observed the parabola but did not get to apply or analyze the images. S4 liked watching four graphs but felt she missed the opportunity to critically analyze them or engage in discussions. S7 appreciated the quadratic equation graph but wanted more chances to explore and innovate. S6 additionally lamented not being able to share his thoughts about the vertex point.

Observation Four – Grade Nine
T2_Lesson 2: Draw a Triangle (Construction-1)

Meaningful Learning

The teacher showed the presentation slides one by one with triangle-shaped pictures and explained those to the students (Figures 21 to 23). There were triangle-shaped pictures including snacks, hangers, and human eyes in the digital content presentation slides.

In the post-lesson discussions, the teacher claimed that he asked questions using some images of snacks, and hangers that were triangle-shaped at the beginning of the lesson to connect between students' knowledge and real-world examples and then he went to the word 'Triangle'. He spent almost 32 minutes discussing triangles, the instruments of drawing the triangle, theorem and constructions, the inventors of constructions, sides of the triangle, polygon, sum of the angles of a triangle, angles of an equilateral triangle, sum of external and internal angles of the pentagon and the hexagon and then announced the topic **Draw a Triangle (Construction-1)**'.

In the consequent conversation, the teacher claimed that he tried to make a meaningful connection between knowledge by explaining and showing the relevant images. He added that he revised the previous lessons to help the students understand the mathematical concepts. However, he agreed that instead of the 30-minute explanations he could give the students time to think about the pictures, so they could relate their knowledge. Yet, he argued that if he would do so, the class would become undisciplined. Hence, he deemed that the 30-minute explanations were important for the students for their better understanding.

Discovery Learning

The teacher asked the students to open their textbooks and mark the important lines in the book. There were pictures of six cases to construct the triangles in the textbook and the pictures were on the screen also (Figure 24). He showed the cases in the presentation slides one by one and explained when to construct a triangle or what were the conditions to draw a triangle. The teacher also told the infinite number of triangles with different three angles (Figure 25).

In the post-lesson conversation, the teacher confessed that there was scope for discovery learning in the lesson but he could not facilitate it. The teacher agreed that he could create the environment and give the students challenging tasks where they could be able to explore and create new knowledge about the construction of the triangle by applying their own thoughts and forming arguments (Figure-114). The students could be able to decide that there would be an infinite number of triangles with different three angles, which the teacher described.

However, the teacher claimed that he should explain to the students first for their better understanding, the students could do better listening to the teacher's explanations.

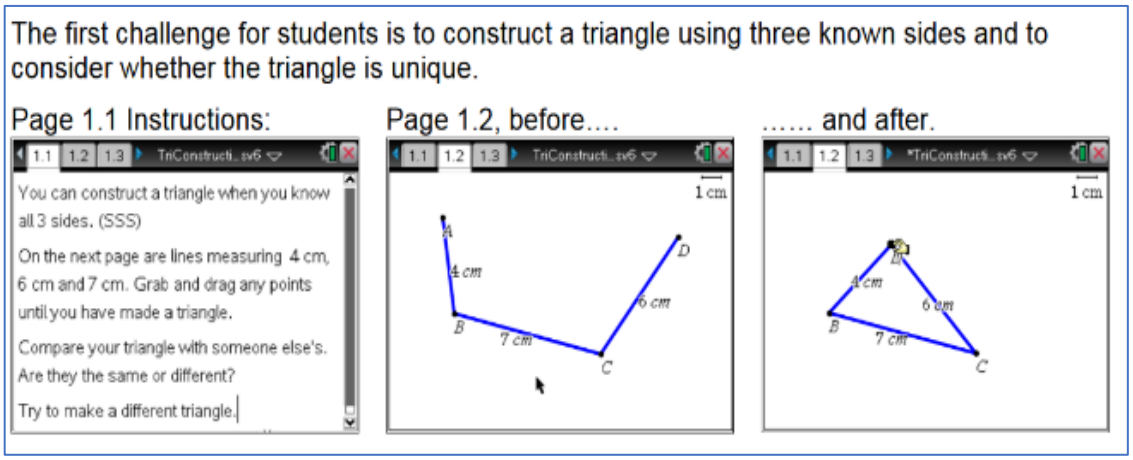


Figure 114: Construction of Triangles (Collected from Google)

FGD with Students

In the focus group discussion, students conveyed a deep appreciation for the digital content used in their lessons, yet they shared a significant concern regarding their lack of active engagement with the material. S3 expressed, "I liked watching the triangle-shaped pictures on the screen, but did not have any opportunity to build a connection between my thoughts and the pictures". Similarly, S8 mentioned, "I responded to the teacher saying the word 'triangle', without elaborating on my own thoughts". Student S5 indicated that he followed the teacher's guidance by marking and underlining key lines in his textbook, a sentiment echoed by others in the group. S7 shared, "I watched the diagrams of the triangle constructed by the teacher and listened to his explanations, but did not have the opportunity to share my own ideas about constructing the triangle". S6 added, "I did not get the chance to explore my own ideas about constructing the triangle". Furthermore, S4 voiced her frustrations, stating, "I did not get the opportunity to struggle with the construction of the triangle or form any arguments with others about it". Many students shared similar feelings of not being able to engage deeply with the content. S1 noted, "The teacher always gave us important tips to solve the mathematical problems in the examination, but did not give us a chance to think critically about the problems". The group also expressed their

disappointment regarding the lack of opportunities to apply what they learned to real-life situations. S6 and S8 mentioned they remained silent during lessons, merely watching the screen and listening to the teacher, without the chance to participate or share their thoughts. Overall, while the students loved the digital content, they clearly desired more opportunities for active engagement and critical thinking.

Observation Five – Grade Eight

T3_Lesson 1: Cone

Meaningful Learning

The teacher showed the cone-shaped pictures one by one using the digital slide (Figure 26). She described the shapes to the students but was not able to engage the students.

In the post-lesson discussions, the teacher claimed that she asked questions using some images of cone-ice-cream, cone-shaped cape, and flower at the beginning of the lesson to connect between student's knowledge and real-world example and then she announced the topic 'Cone'.

In the consequent conversation, the teacher agreed that she tried to make a meaningful connection between knowledge but it was less interactive. She could give the students time to think about the pictures, so they could relate their knowledge and explain their own thoughts.

However, the teacher argued that it was not possible due to the short class time duration, and she could not finish the lesson on time.

Discovery Learning

The teacher described the shapes of the Cone, the parts of the Cone, and the definition of the Cone by using digital content in her lesson (Figures 27 and 28). There were animated cone-shaped images on the screen and the teacher described the surface of the cone to the students.

In the post-lesson conversation, the teacher agreed that there was scope for discovery learning in her lesson but she explained most. The teacher also agreed that the students could analyze the given animated cone-shaped images on the screen and discussed the flat circular base, curved surface, height, slant height, and radius of the Cone. The students would be able to make the definition of the Cone by applying their own ideas, what the teacher described by showing on the screen. The teacher confessed that the students would be able to make the definition of the Cone with collaborative learning.

However, the teacher claimed that if she did not explain the concepts to them, the students could make mistakes. So, the teacher emphasized her explanation for the student's better understanding. Furthermore, the teacher added that collaborative learning made the class undisciplined.

FGD with Students

During the focus group discussion, student S1 expressed appreciation for the visual aids, stating, “I liked watching the pictures of cone-shaped objects, but I did not get the chance to build a connection between my thoughts and the pictures”. S8 shared a brief response to the teacher’s question about cones, saying simply “cone ice cream” without elaborating on their own ideas. Student S3 echoed the sentiment by noting, “I liked watching the cone-shaped objects and listening to the teacher’s explanation, but I didn’t have the opportunity to analyze the material”. S6 also voiced his frustration, mentioning that while he watched the curved surface of the cone-shaped object, he lacked the opportunity to engage critically with the concept. S2 and S7 expressed enjoyment in viewing the pictures of cones, including their curved surfaces, height, and radius, yet both felt they did not have the chance to apply their own thoughts or generate new ideas. Furthermore, S4 highlighted her desire for more engagement, stating she did not get the chance to create a definition of a cone, a concern that resonated with her peers. The students collectively expressed that they did not have opportunities to apply what they learned about cones to real-life situations. Although they watched the definition of a cone on the screen, they desired the chance to form their own arguments and engage in deeper discussions about the concept. Overall, the group clearly valued the visual content but felt restricted in their ability to connect, analyze, and critically engage with the material presented.

Observation Six – Grade Eight

T3_Lesson 2: Arithmetic Progression

Meaningful Learning

The teacher opened the presentation slide with congested pictures of monuments, pineapples, and flowers (Figure 29). She pointed to the pictures and asked the students what the picture was about, but did not wait for their responses. Instead, the teacher explained the pictures one by one indicating the presentation slide. She explained that there were sequences in those pictures.

In the post-lesson conversation, the teacher claimed that she asked questions by showing the relevant pictures of sequences at the beginning of the lesson to connect between student's knowledge and real-world examples and then she announced the topic 'Arithmetic Progression'.

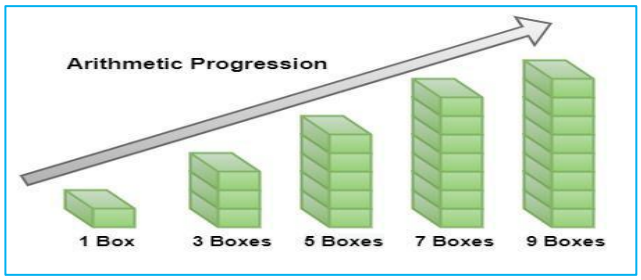


Figure 115: Concepts of Arithmetic Progression (Collected from Google)

The teacher agreed that she tried to make a meaningful connection between knowledge and real-life things, but could not make it interactive and effective. She could give the students time to think about the pictures, so they could relate between their knowledge and explain their own ideas about sequences. The teacher could use daily-life-based images related to Arithmetic progression where the students extended their knowledge by connecting with their prior knowledge (Figures 115 and 116).

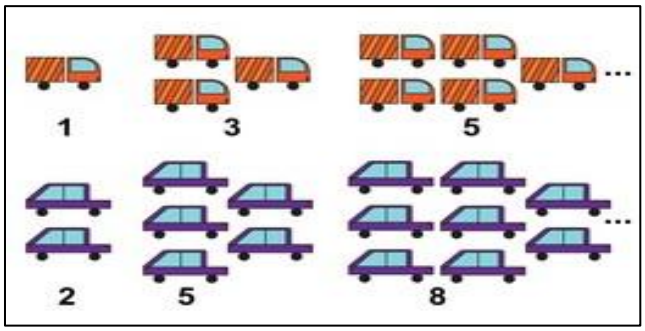


Figure 116: Concepts of Arithmetic Progression (Collected from Google)

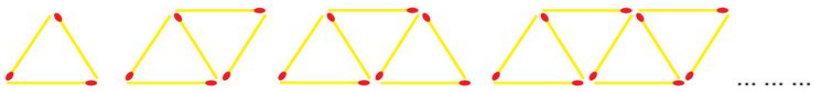
However, the teacher argued that it took more time, and she could not finish the lesson on time. She also added that she needed more training to make the lesson more interactive.

Discovery Learning

The teacher was explaining the progressions showing the text on the screen of digital content. There were definitions of Arithmetic Progression and types of progressions and she was uttering the words from the presentation slides and describing them (Figures 30 and 31).

In the post-lesson conversation, the teacher agreed that there was scope for discovery learning in her lesson but she explained most and could not create the interactive environment for the students. The teacher should incorporate the interactive and challenging mathematical activities featured introduced in the new curriculum textbook, creating a learning environment that enables students to analyze tasks, explore and create new knowledge about progressions and construct arguments. They would be able to make the definition of progression and arithmetic progressions and identify the rules by applying their own thoughts (Figure 117).

Attach the matchstick to the exercise book and create a pattern like the one below



... ...

Now try to find the answers to the following questions:

i) How many sticks are needed for each of the pictures? Write the numbers in the adjacent boxes in order:	_____ , _____, _____, ...
ii) Determine the difference between two consecutive numbers and write it in the adjacent box.	
iii) Have you found any common characteristics among the numbers? Write your comments in the box.	

Figure 117: Activity on Arithmetic Progression (Collected from the new textbook)

However, the teacher argued that the students would be able to make the definition of the progression and arithmetic progression. However, she claimed that if she would not explain to the students, they would be making mistakes. She added that they did not have enough time to make such opportunities for the students, because they had to finish the syllabus on time.

FGD with Students

In a focus group discussion, the students enthusiastically expressed their love for watching digital content in their lessons. However, they also shared a common concern: they did not have the opportunity to express their own thoughts and ideas and did not build a connection between their thoughts and the pictures. S3 mentioned that he liked viewing the pictures of patterns, but did not have the opportunity to express his own thoughts about them. Student S5 confessed, “I responded to the teacher saying the word ‘sunflower’, without being able to share my own thoughts”. S1 stated, “I watched the pictures of pattern and progressions, but did not have the scope to analyze and create new ideas about it”. Other students shared similar experiences, feeling that they did not have the chance to think critically about the material. Student S5 explained, “I did not have the opportunity to struggle with creating the definition of arithmetic progressions”. S3 and S7 mentioned that they were simply copying text from the screen into their notebooks, without engaging with the material on a deeper level. S4 pointed out, “I watched the sequences and formula of common differences of the progressions on the screen, but I did not have the opportunity to apply and analyze critically”. Other students also agreed, feeling that they did not have the chance to think critically or make connections between concepts. S7 and other students mentioned that they did not have the opportunity to struggle with making the definition of progressions with common differences, nor did they get to make arguments about it and they did not apply the things in real-life situations that they learned in the lessons.

Observation Seven – Grade Eight

T4_Lesson 1: Set Theory

Meaningful Learning

The teacher explained the 'Set' showing the pictures including the glass set, tea set, and apple set (Figure 32 and 33). However, she could not make it interactive by engaging the students.

In the consequent discussion, the teacher claimed that she asked questions using some real-life pictures at the beginning of the lesson to connect between knowledge and real-world examples and then she announced the topic 'Set'.

In the post-lesson conversation, the teacher agreed that she tried to make a meaningful connection between knowledge and real examples, but could not make the lesson interactive. The teacher also acknowledged that she could use the images of real-life things introduced in the textbook of the new curriculum 2022, where the students get engaged in discussion about the concepts of 'Set' (Figure 118).

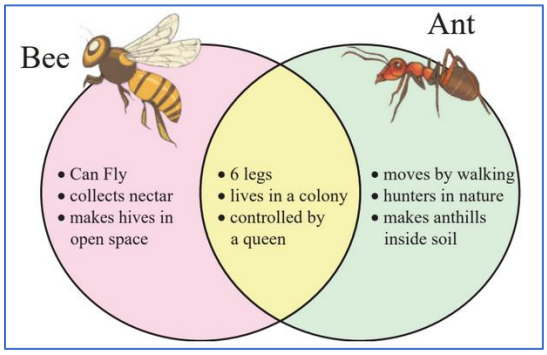
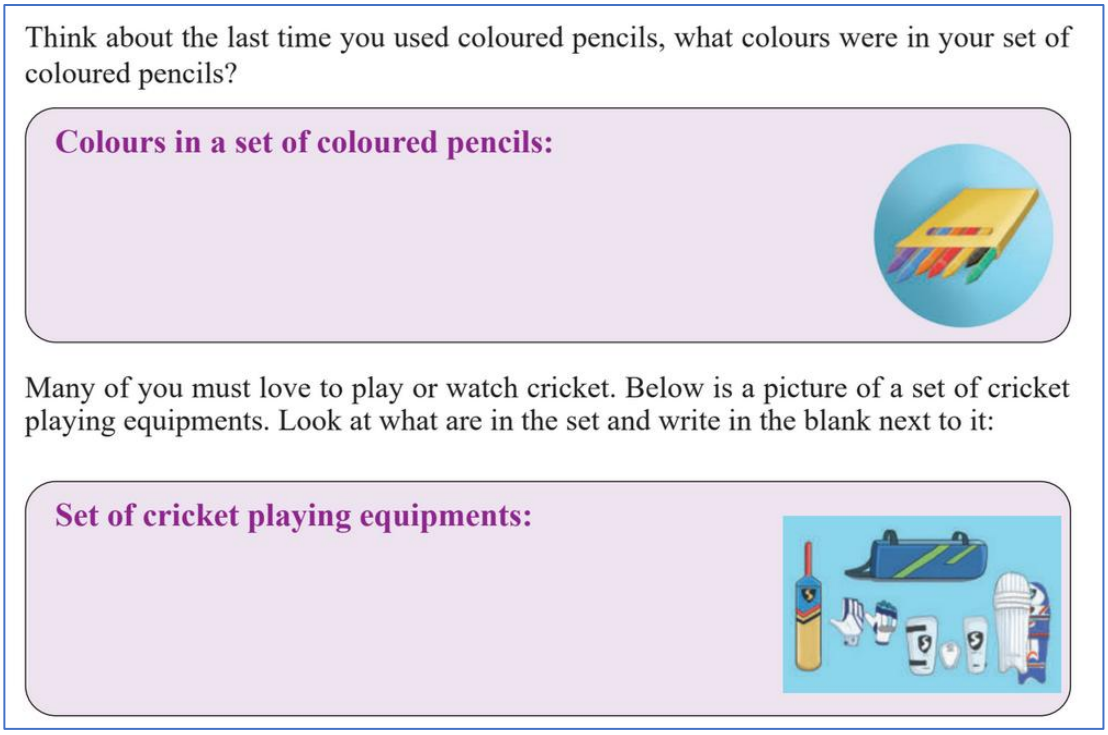


Figure 118: Concepts of Set (Collected from the new textbook)

She might have used another activity introduced in the new textbook, where the students were required to struggle with the concepts of Set from daily life things (Figure 119).


Think about the last time you used coloured pencils, what colours were in your set of coloured pencils?

Colours in a set of coloured pencils:

Many of you must love to play or watch cricket. Below is a picture of a set of cricket playing equipments. Look at what are in the set and write in the blank next to it:

Set of cricket playing equipments:

Figure 119: Activity of Set (Collected from the new textbook)

The teacher claimed, "In her lesson, this was an introductory activity to introduce the topic, rather than assessing student's prior knowledge. The goal was to grab students' attention and relate the topic to real-life situations. She added that it would require more time to use the activities introduced in the new textbook.

Discovery Learning

The teacher explained one by one about the definition of the Set, types of the Set, finite set, and infinite set showing the images on the screen by using digital content (Figures 34 to 36). She also explained A/B, AUB, and B/A and made links to the Venn diagram shown on the presentation slide, but she could not make it interactive and innovative (Figure 37).

In the post-lesson discussion, the teacher agreed that there was scope for discovery learning in her lesson but she explained most. The teacher agreed that she should include interactive and innovative mathematical activities such as in Figures 120 and 121, where the students could

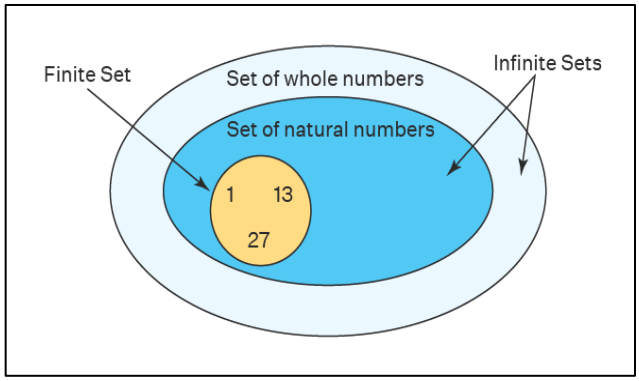


Figure 120: Finite and Infinite Set (Collected from Google)

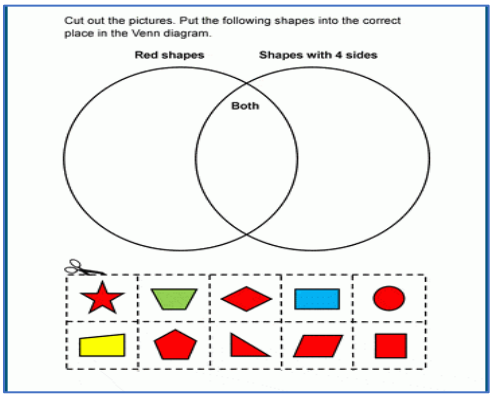


Figure 121: Venn-diagrams (Collected from Google)

analyze and create the definition of Sets and types of Sets. The students could also analyze the Venn diagrams tasks about the universal set, the union of the set, the intersection of the set, and the differences between the sets. They could make mistakes and engage in discussion making arguments while analyzing and creating the facts. The students would be able to explore new knowledge about finite and infinite sets, identify key concepts or rules of different Sets, and create new knowledge by applying their own thoughts.

However, the teacher acknowledged, “Actually mam, my class was mostly lecture-based, we used to transform knowledge to the students through lectures. There was less interaction in my class and I needed more time to make a participatory session”.

FGD with Students

During the focus group discussion, the students expressed a sense of disappointment with their experience of learning about Set. Student S4 mentioned, “I enjoyed watching the pictures of glass-set and tea-set, but did not get the scope to explain my own ideas of it”. Student S1 expressed her feelings, “I silently listened to the teacher’s explanation about set without having the chance to share my own thoughts and did not build a connection between my thoughts and the pictures”.

Student S5 claimed, “I did not have the opportunity to struggle with creating the definition of Set”. Other students also agreed with her. Student S7 complained, “I watched the pictures of the finite and infinite set, but did not have the chance to explore and apply my own thoughts about it”. Similarly, S3 listened to the teacher’s explanation of different types of sets, but did not have the opportunity to share their own ideas and not create new ideas. S6 and S7 also shared similar experiences, feeling that they did not have the chance to think critically about the concepts they were learning. S8 added that they did not have the opportunity to struggle with the union and intersection of sets, nor did they get to make arguments about it. Interestingly, S1 and S4 both mentioned that they drew Venn diagrams in their notebooks from the screen, but did not have the chance to apply their own thoughts about them. S5 added that she did not have the opportunity to apply her own thoughts about the Venn diagrams and not analyze it, and other students echoed these sentiments. The students also mentioned that they did not have the opportunity to apply what they learned in the lessons to real-life situations.

Observation Eight – Grade Nine

T4_Lesson 2: Function & Relation

Meaningful Learning

The teacher described the Relation uttering the words from the screen and making connections between the words (Figure 38). However, she was not able to make it interactive and engaging for the students.

In the post-lesson conversation, the teacher claimed that she asked questions about making relations among the things of the images shown on the digital content at the beginning of the lesson. She tried to connect knowledge and real-world examples to announce the topic ‘Relation’.

However, in the subsequent conversation, the teacher agreed that she tried to make a meaningful connection between student’s knowledge and real-world examples but she could not make it interactive and innovative. She also agreed that she could give the students time to think about the images such as the Figure 122, so that they could relate their knowledge and create new knowledge

about the ‘Relations’. The students would also make more relations among the things from the images on the screen with their own thoughts.

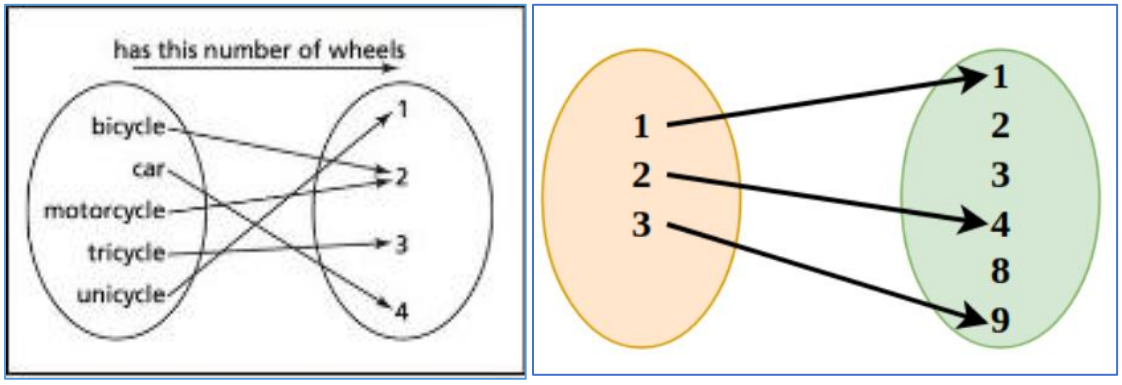


Figure 122: Concepts of Relation (Collected from Google)

Discovery Learning

The teacher described the connections between the things from the images, and it was made function or not function (Figures 39 and 40). However, she was not able to make it interactive and innovative with the student’s engagement.

However, in the post-lesson discussion, the teacher agreed that there was scope for discovery learning in her lesson but she mostly explained the mathematical images, displayed on the screen and could not create interactive opportunities for the students.

In the consequent conversations, the teacher acknowledged that the students could analyze the mathematical daily-life related tasks (Figure 123) about the function, not function, elements of domain and co-domain. They would be able to explore new knowledge about the types of Relations and Functions, identify key concepts or rules of Relation and Function, and create definitions, new knowledge and put examples applying their own thoughts.

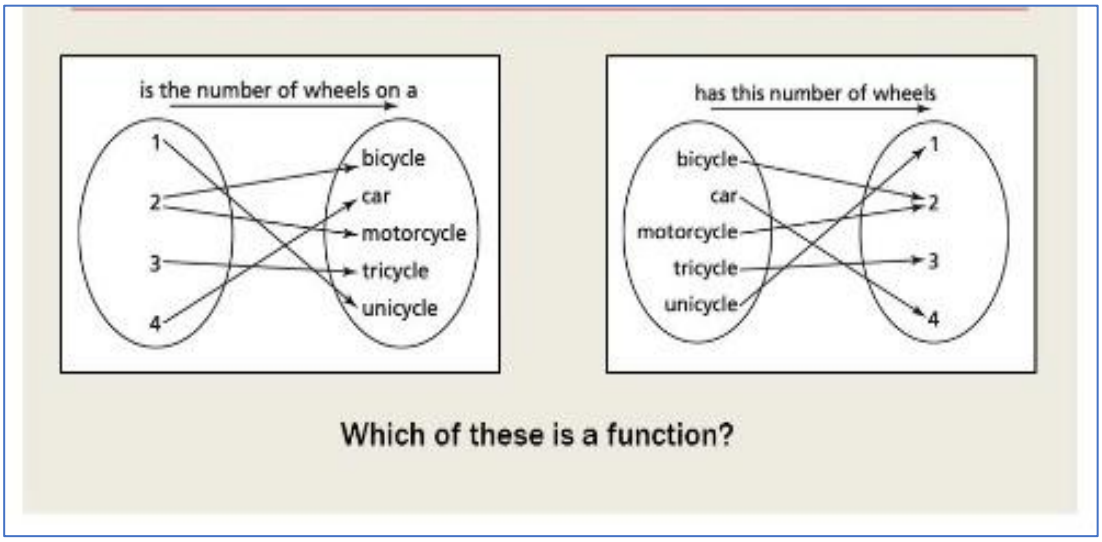


Figure 123: Concepts of Function (Collected from Google)

Nevertheless, the teacher complained, “Actually, if I had more time to make the digital content, then I could think more about how to make the lesson interactive”.

FGD with Students

In a focus group discussion, almost all the students expressed their enthusiasm for watching digital content in their lessons. However, they also shared a common concern: they did not have the opportunity to make connections between the concepts they were learning. Student S4 mentioned, “I liked viewing the images of the Relation, where the teacher made the connection between mothers and children but I did not get the opportunity to build a connection between my thoughts and the pictures”. The other students shared similar experiences, saying that they did not have the opportunity to make connections between things. Student S6 stated, “I watched the screen and listened to the teacher, but I did not have the scope to explore and explain the relations between the things”. Student S1 added, “I did not have chance to create the new relations by applying my own thoughts”. S1 also expressed her frustration, “I drew the diagrams in my notebook from the screen, but did not have the chance to explore and analyze it critically”. Student S3 also shared this experience, listening to the teacher but not having the opportunity to explore their own ideas and create new ideas. Student S8 claimed, “I did not get the chance to identify the domain and

range in the pictures, nor did I get a chance to struggle with it". S3 and S6 added that they did not get the opportunity to struggle with the function and not-function, and did not form arguments about it. Students S3 and S6 also mentioned that they did not get the opportunity to struggle with functions and non-functions, and therefore could not form arguments about it. Other students also agreed with them. The students also shared that they did not get the opportunity to apply the things that they learned in the lessons to real-life situations.

Observation Nine – Grade Nine

T5_Lesson1: Trigonometric Ratios

Meaningful learning

The teacher showed a video about the angles and sides of a rectangular triangle and explained it to the students, to announce the topic of the lesson (Figure 41). The explanation was teacher-centered and he could not make it interactive. However, during the post-lesson discussion, the teacher claimed that he made the students attentive and the video was appealing to them.

In the consequent conversation, the teacher agreed that he could try to make a meaningful connection between student's old knowledge and new knowledge and he talked most. He was not able to make the lesson interactive and did not build a connection between students' knowledge and real examples. The teacher also agreed that he could give the students time to think about the video, so they could relate their knowledge and create new knowledge about the angles and sides of a rectangular triangle. The students could analyze the video explore their knowledge and try to identify key concepts or rules of 'Trigonometric Ratios'. The teacher argued that the students were not able to understand by watching the video only, which was why he repeated explaining the video to help the students understand.

However, the teacher acknowledged that the students would be able to analyze using the real-life pictures introduced in the new textbook and make an interactive learning environment that encouraged students to engage with the concept of trigonometry (Figure 124).

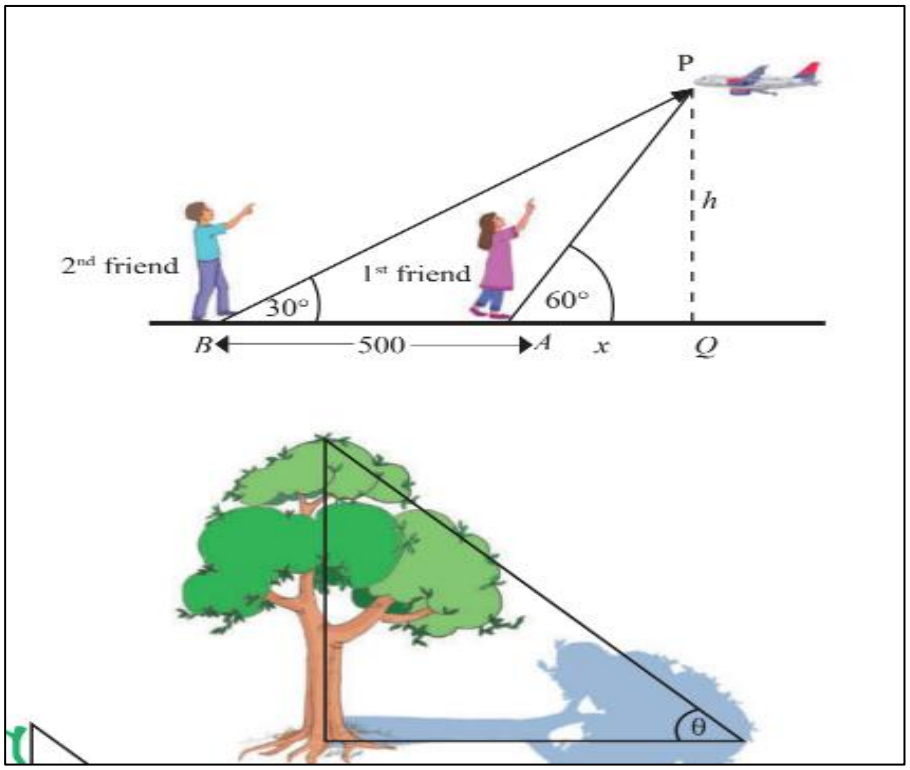


Figure 124: Concepts of Trigonometry (Collected from the new textbook)

Discovery Learning

The teacher described the right-angled triangle and the sides of a triangle shown on the screen (Figure 42). He was not able to use diversified tasks to make the students creative and innovative.

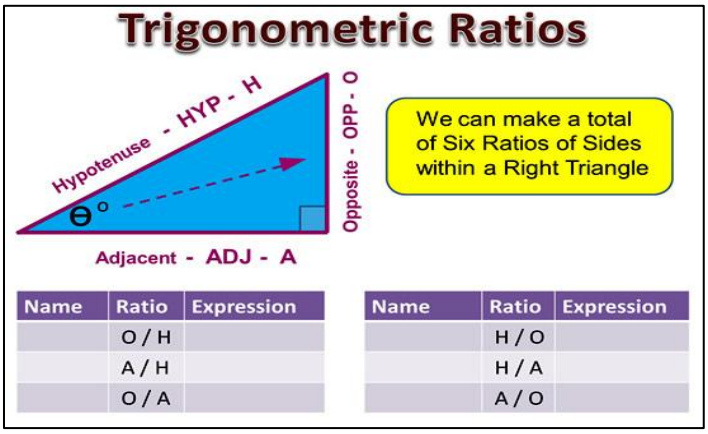


Figure 125: Trigonometric Ratios (collected from Google)

In the post-lesson conversation, the teacher agreed that there was scope for discovery learning, but he could not incorporate it in his lesson. He could make opportunities for the students by showing an interactive mathematical task (Figure 125) about the Trigonometric Ratios. The

students could analyze the task and try to make the relationships between a right-angled triangle's side lengths and angles. They would be able to explore their knowledge of the trigonometric Ratios, identify key concepts or rules to create the definition of ratios and the formulas of six trigonometric relations and create new knowledge by applying their own thoughts.

The teacher acknowledged that he could use the activity from the new textbook, where the students could be able to explore and create trigonometric ratios through collaborative learning (Figure 126).

Pair work:

Draw a right angled triangle in your notebook. You can draw the length of the sides according to your wish but the acute angle adjacent to the base has to be 30°. After drawing the triangle, measure the length of every side by using a scale and complete the following table.

(1) Adjacent side	(2) Opposite side	(3) Hypote-nuse	(4) Adjacent side / Hypote-nuse	(5) Opposite side / Hypote-nuse	(6) Adjacent side / Opposite side	(7) Opposite side / Adjacent side	(8) Hypote-nuse / Adjacent side	(9) Hypotenuse / Opposite side

Match the six ratios from number 4 to number 9 with your classmates. What have you noticed from the task?

Figure 126: Activity on Trigonometric Ratios (Collected from the new textbook)

However, the teacher claimed that the students could make mistakes, so he explained things to them to help them better understand and avoid mistakes.

FGD with Students

In a focus group discussion, the students expressed a unanimous enthusiasm for watching digital content in their lessons. Student S1 mentioned, “I liked viewing the animation that the perpendicular was coming”. Student S2 stated, “I enjoyed watching the video and seeing the base, height and hypotenuse, but I did not have the opportunity to build a connection between my thoughts and the pictures”. Student S6 said, “I copied the text of trigonometric ratios from the screen into my notebook”. Students S2, S4, and S8 also did the same. However, S6 claimed, “I did not have the opportunity to struggle to create the trigonometric ratios using my own thoughts”. Other students also complained that they did not have the chance to use their own thoughts. The students shared that they did not get the opportunity to apply what they learned in the lessons in real-life situations. Students S7 and S8 said that they simply watched the screen, without making the trigonometric ratios and did not make any arguments with their peers about it.

Observation Ten – Grade Ten
T5_Lesson2: Rectangular Solid

Meaningful learning

The teacher explained the definition and six surfaces of a rectangular solid and showed the pictures of bricks on the screen using digital content (Figures 33 and 34). However, he could not make it interactive and engage the students.

Figure 127: Rectangular Solid-shaped Pictures (Collected from Google)

In the post-lesson conversation, the teacher claimed that he explained the rectangular shapes to the students by showing the images of two bricks and three tiffin boxes, and then announced the topic ‘Rectangular Solid’ of the lesson. He tried to connect real-life things to the rectangular solid by

using digital content. The teacher agreed that he tried to make a meaningful connection between student's knowledge, but he talked most and could not make it interactive for the students. He could use interactive and attractive real-life things and images (Figure 127) and give the students time to think about the surfaces, then they could build a connection between their old knowledge and new knowledge. He countered that it was the first unit of the chapter, and he believed that he could make the lesson more effective in the second and following units of the chapter.

Discovery Learning

The teacher explained the surfaces and areas of the rectangular solid showing the picture on the screen using digital content. There were animated shapes and texts that made the whole surface area of a rectangular solid (Figure 45). He counted the surfaces from the screen, and some students repeated the text with the teacher.

In the post-lesson discussions, the teacher agreed that there was scope for discovery learning in his lesson but he explained most and could not create opportunities for the students to engage in the lesson. The teacher could use interactive mathematical tasks displayed on the screen (Figure 128) where the students could analyze and generate the length, width, height and diagonal of the rectangular solid and the definition of a Rectangular Solid. They could explore new knowledge about the surface areas of the rectangular solid, identify key concepts or rules about the diagonal and the total surface area of the rectangular solid, and create new knowledge by applying their own ideas.

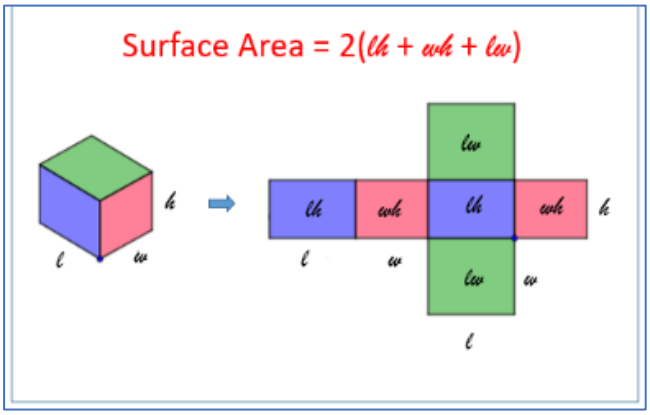


Figure 128: Surface Area of Rectangular Solid (Collected from Google)

However, the teacher claimed that if he had more time to make the digital content, he would have been able to engage the students by showing the animated images of the six planes.

FGD with Students

During the focus group discussion, all the students expressed that they always loved watching the digital content in their lessons. Student S5 noted, “I enjoyed watching the picture of bricks on the screen, but I did not have the opportunity to build a connection between my thoughts and the pictures about the rectangular solid and its surfaces”. Other students also said the same, stating that they did not have a chance to apply their own thoughts. Student S8 claimed, “I did not get the opportunity to struggle with creating the formula of the area of the rectangular solid and did not have a chance to analyze it critically”. The other students shared similar experiences, stating that they loved watching the animation of the surfaces and listening to the teacher’s explanations, but did not have the chance to engage with the material in a more meaningful way. Student S2 mentioned that they did not have the opportunity to measure any real solid objects in the lesson, while other students expressed similar sentiments. The students also mentioned that they did not get the opportunity to apply the things that they learned in the lessons to real-life situations.

Dimension- Pedagogy (Learning Objectives: Meaningful Learning and Discovery Learning)

4C.1.1.2 The Integration of Five Cases: Ten (10) Observed Lessons, Ten (10) Post-lesson Interviews with teachers, and Ten (10) FGDs with students

4C.1.1.2.1 Ten (10) Observed Lessons

In this section, all the teachers provided multimedia elements including relevant images, texts, pictures, and videos in their lessons and they all explained it to the students approaching teacher-centered strategies. There were some animated images of pi, circles of the area, arithmetic progressions, and shapes of cones which could be used to create opportunities for the students to interact and innovate their own ideas and understanding. So, there was scope for meaningful learning and discovery learning but the teachers could not make the lessons interactive and innovative by using the digital content.

4C.1.1.2.2 Ten (10) Post-Lesson Interviews with Teachers

In the consequent discussion with the teachers, they argued attempting to create a meaningful link between theoretical knowledge and practical applications using multimedia elements. However, they acknowledged that they could not create an environment where the students could try to connect their existing knowledge to the presented material. They also acknowledged that there was scope for discovery learning, but they were not able to create opportunities for the students where they could analyze and explain their own ideas about the presented materials. The teachers said that they could provide diversified and challenging tasks where the students could apply their creative thought to form arguments to explore new knowledge, identify key concepts or rules, and create new knowledge in the lessons. The teachers attributed their lack of success to various constraints, including the student's demands for the solution or information, the pressure to prepare for examinations, limited class time, the need to complete the syllabus, and mathematics practical lessons issues. As a result, they could not create meaningful and discovery-oriented learning environments for their students.

All the teachers commented that they mostly explained the learning content to the students for their understanding. They added that most students did not like to analyze the important mathematical tasks using digital content, they wanted to know the solution from the teacher to perform better in the examination. T2 and T5 claimed that the students could explore new knowledge, but that could be done in the mathematics practical lessons, however it was not possible in the theoretical lessons due to the short time duration. T2 commented about showing the real-world-based challenging tasks, "These typed pictures could be in a research work, not for the lesson work". T2 said that the students could think while watching the difficult mathematical task on the screen, but they could make mistakes. So, the teacher should explain first for their understanding, and after that, the students would be able to analyze the task. T2 asserted that he explained the previous lesson for a long time as a revision and to make the connection between old knowledge and new knowledge. T2 and T4 did not have clear ideas about checking student's prior knowledge. They both believed that students' prior knowledge needed to be checked for the second and other lessons but not for the first lesson of the chapter. T5 claimed that he repeated explaining the video to help the student understand. T5 added that the lesson Rectangular Solid

was the first unit of the chapter, his lesson could be more effective at the 2nd or other units of the chapter. T5, T3, and T4 blamed the shortage of time for developing their digital content as well as the pressure to finish the syllabus on time. T3 said that she did not have enough time to create a student-centered environment because she had to focus on finishing the syllabus. T4 asserted that she could do better if she had more time to think while preparing her digital content. T4 confessed that her class was mostly lecture-based, she usually used to transfer knowledge to the students through lectures and there was less interaction in her lessons; she needed more time to make a variety of participatory lessons.

4C.1.1.2.3 Ten (10) FGDs with Students

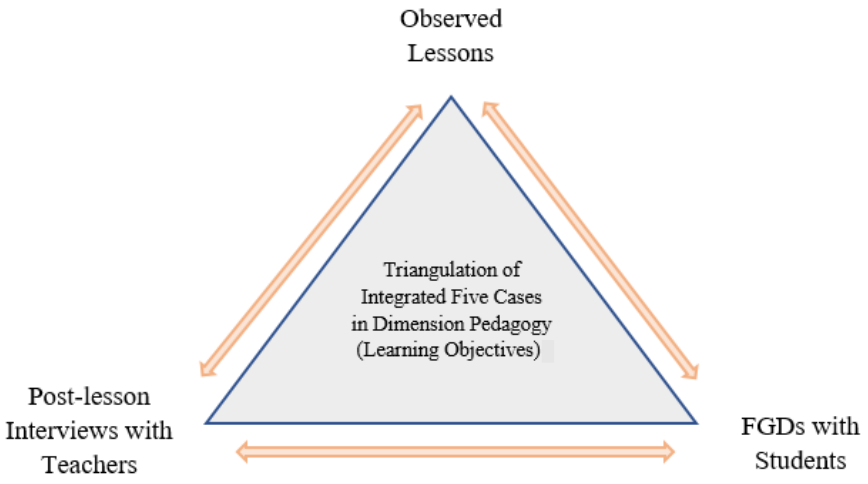
During the 10 focus group discussions with students, it was found that they consistently expressed a love for watching images and animations in their lessons. However, upon closer examination, it became clear that the students were more fascinated by the animated visuals themselves, rather than being engaged with the mathematical concepts being presented. Students shared their enthusiasm for specific animations, such as 'the perpendicular coming in the video', 'the pencil is drawing the graph', and 'the pencil and text appearing consecutively'.

Despite their initial interest, the students felt that they were not allowed to actively engage with the digital content, connect their knowledge, think critically, or express their own ideas. Instead, they were passive observers, watching and listening without any activity in the learning process. Many students mentioned that they loved watching certain visuals, such as patterns and sequences, but didn't have the chance to express their own thoughts or apply their own ideas. Some students specifically mentioned feeling restricted in their ability to think critically and solve problems. For example, one student said they didn't have the opportunity to apply and analyze mathematical facts like sequences and formulas of common differences in progressions. Another student mentioned that they didn't get to struggle with creating the formula for the area of a rectangular solid, nor did they have a chance to form arguments about it with their peers. The students also reported that they didn't create new rules or apply in real-life situations what they learned in the lessons, as they were simply watching the digital content, sometimes responded by saying one or two words such as 'round-shaped', 'cone-ice cream' and following teacher procedural instructions. Overall, the

students seemed to enjoy watching digital content but felt that they were not allowed to actively engage with the material or develop their own understanding of the concepts.

Dimension- Pedagogy (Learning Objectives: Meaningful Learning & Discovery Learning)

4C.1.1.3 Triangulation of Integrated Five Cases: Observed Lessons, Post-lesson Interviews with teachers, and FGDs with students



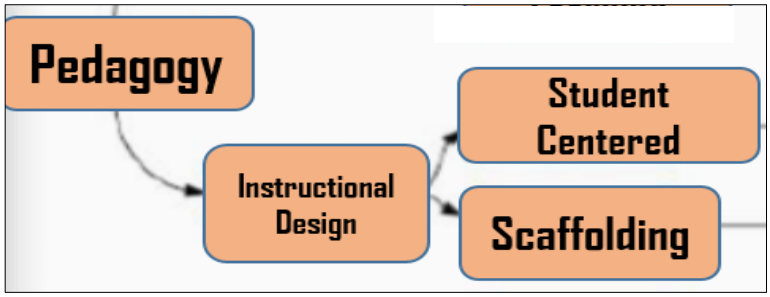
A comprehensive analysis of the lessons observed, teacher post-lesson interviews, and focus group discussions with students revealed that all teachers were unable to effectively integrate digital content into their lessons in a pedagogically sound manner, resulting in a lack of meaningful and discovery-oriented learning experiences for students. Discussions with the teachers revealed that they were aware of this, citing reasons like students' not wanting to analyze the tasks, students' demands for the solution or information, the pressure to prepare for examinations, limited class time, mathematics practical lessons issues and the pressure to finish the syllabus. Furthermore, it became clear that students were not required to build connections between their prior experiences and existing knowledge, nor were they being sufficiently challenged to apply and analyze their creative thinking and not innovate ideas in the learning process. The students mostly spent the lessons watching the images on screen.

4C.1.2 Pedagogy: Instructional Design (Student-Centered and Scaffolding)

In this dimension, the researcher delves into the codes related to Instructional Design within the dimension of Pedagogy. The exploration of Learning Objectives reveals two key areas:

1. Student-Centered: This code focuses on students having a choice in the learning process to express their sense of mathematical ideas. They will be able to struggle with important mathematical tasks with their strategies and engage as decision-makers in their learning in a technologically enhanced environment.

2. Scaffolding: This area emphasizes student engagement where the teachers systematically build on student's experience and knowledge when they are learning new skills. The students make mistakes and offer support from the teachers as they learn and develop a new concept or skill in a technologically enhanced environment.



In the observed lessons, it is evident that there were opportunities in all five cases within the lessons to apply the Instructional Design codes of Student-Centered Learning and Scaffolding teaching approach as part of the Pedagogy dimension. There were five segments in the Observation Guideline and the total scores obtained were **50N** out of 50 scores for the **10 lessons.** No scores were there for **L, M,** and **H**.

4C.1.2.1 A brief description of the observed lessons conducted by the teachers, along with insights from post-lesson interviews and FGDs with the students, is provided below:

Observation One – Grade Eight

T1_Lesson 1: Area and Circumference of a Circle

Student-Centered

The teacher described the circumference and diameter of the circle showing the shapes and text one by one on the screen (Figure 46). He also explained the area of the circle showing the animated picture on the screen (Figure 47).

In the post-lesson conversation, the teacher agreed that there was scope for a student-centered learning environment in his lesson but he explained most and could not create opportunities for the students to engage. There were attractive and interactive mathematical tasks displayed on the screen and the students could actively learn about circumference, diameter, radius, Pi and dividing the parts of the circle. The teacher acknowledged that he could create opportunities for the students struggling with that difficult mathematical task of dividing the parts of the circle and the students could form arguments based on their mistakes. The students could deeply engage in hands-on activities and collaborate by measuring the circumferences and diameters of circles, taking on the roles of problem solvers and creators.

The teacher acknowledged that he could use the activity from the new textbook, where the students were required to struggle with the Area of a Circle independently or collectively (Figure 129).

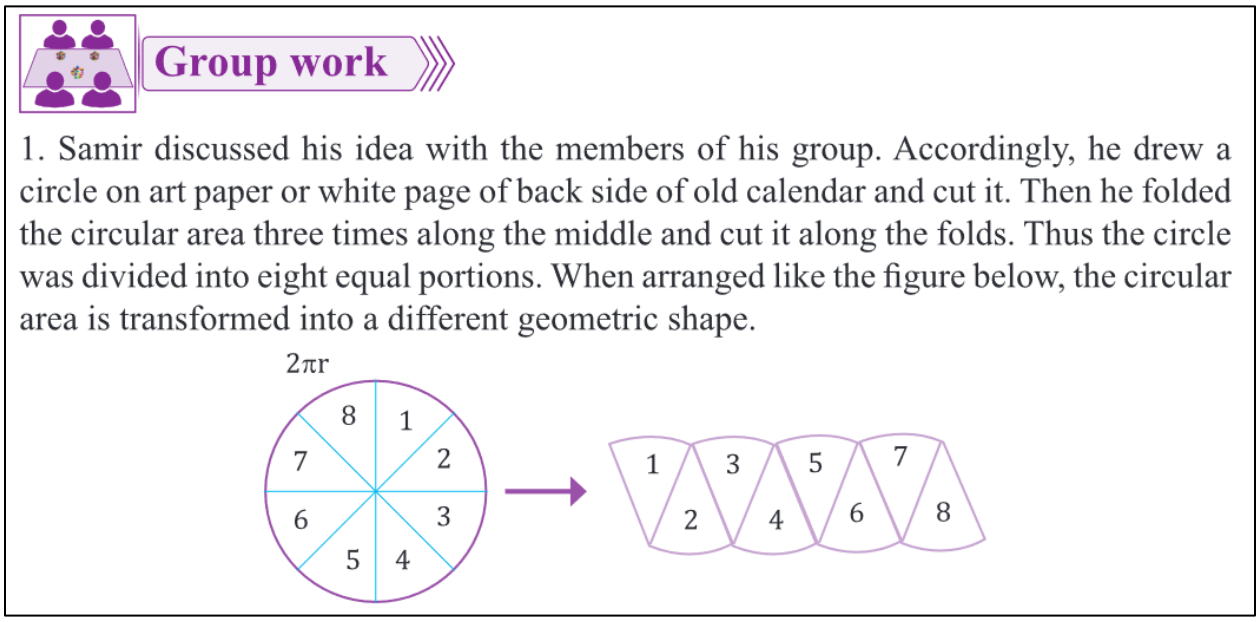


Figure 129: Area of the Circle (Collected from the new textbook)

However, the teacher argued that he had the idea to create such an opportunity for the students, but he did not have enough time in his lesson for it. The teacher added that the students could make mistakes, but they would not be able to do the diverse tasks.

Scaffolding

The teacher had described the concepts of the area of the circle to the students dividing the parts showing the screen using the digital content (Figure 48). He was not able to create opportunities for the students where they learn new skills supported by the teacher.

Nevertheless, the teacher agreed that there was space for a scaffolding teaching approach where the teacher would provide support focusing on the student's abilities. He could create a climate where students made mistakes and offer support to them as they did. The teacher could support

them gradually and help them to learn and build the new concept of the circle, creating the formula of the area of the circle, and acquiring knowledge about it.

However, the teacher complained that the students could not do it by themselves without his explanation.

FGD with Students

In the focus group discussion, student S5 stated, “I enjoyed watching the animation of the circle but I did not get the chance to grapple with the concept of the circle’s animation.” The other students shared similar experiences, they had watched the animation and listened to the teacher’s explanations. Student S1 emphasized, “I did not have the opportunity to engage with the challenging concepts of the circle’s animation to build my own ideas”. The other students concurred with him. Student S8 elaborated, “I could not engage with the animation of the circle as the problem solver.” The students expressed that they did not have the opportunity to develop their own understanding of the formula for the circle and noted that they did not make any mistakes or engage in discussions about it.

Observation Two – Grade Eight
T1_Lesson 2: Graph of a Simple Simultaneous Equation

Student-Centered

The teacher described the number line, origin, horizontal line, two perpendicular lines, axes, order-pair, four quadrants, and coordinate points showing the texts on the screen using the digital content (Figure 49). The shapes and the texts appeared one after another through animations (Figure 50).

In the post-lesson conversation, the teacher agreed that there was scope for a Student-Centered learning environment in his lesson, but he explained most and he could not create opportunities for the students to engage. He could create the environment by using challenging mathematical tasks displayed on the slide (Figure 130), where the students could actively create new knowledge of horizontal lines, two perpendicular lines, axes, order pairs, four quadrants, and coordinate points struggling with their own strategies.

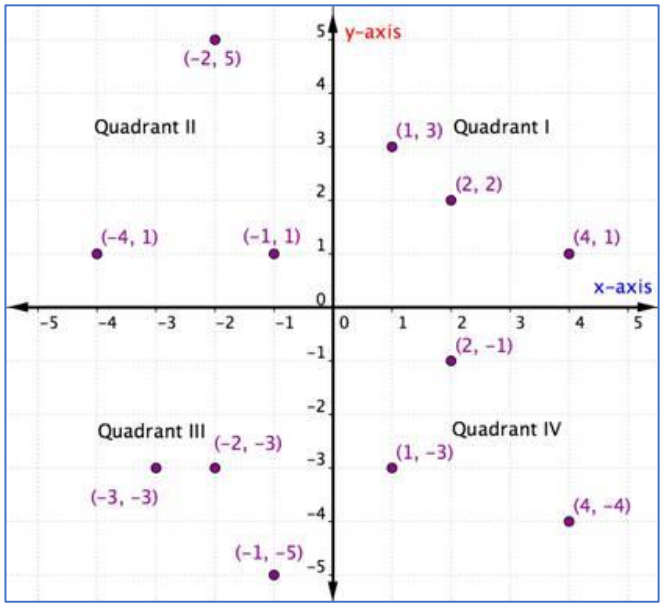


Figure 130: Graph Activity (Collected from Google)

However, the teacher argued that this topic was new to the students, and they could not solve the task if the teacher did not explain the ideas first.

Scaffolding

The teacher described drawing the graph of the given equation by using digital content. The texts and shapes appeared one by one through clicking on the mouse and the teacher was commenting on them. The animated pencil was drawing the graph on the screen. The pencils were appearing one by one through animations (Figure 51).

However, during the post-lesson discussions, the teacher agreed that there was space for a scaffolding teaching approach where the teacher would provide support focusing on the student's ability. He could create opportunities where the students could struggle with the challenging tasks introduced in the new curriculum textbook. The students could make mistakes and the teacher would offer his support as they learn and build their concepts to make the graphs (Figure 131). The teacher supported the students gradually and helped them to complete the digital task and acquire knowledge about making the graphs.

Further, the teacher argued that these type of activities needed enough time, they were not possible to do in one lesson.

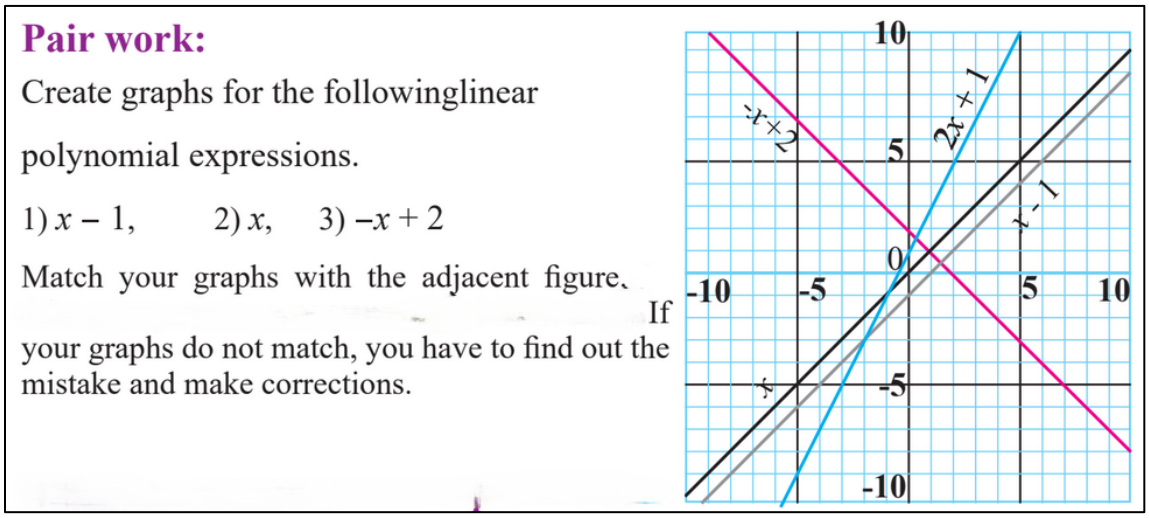


Figure 131: Activity on Graph (Collected from new textbook)

FGD with Students

In a focus group discussion, student S7 enthusiastically shared, “I liked watching the animation, the pencils were appearing one by one and drawing the lines.” Other students agreed with her sentiment. Student S8 explained, “I enjoyed watching the graph and animation, but unfortunately, I did not get the chance to grapple with my own thoughts about the coordinate points and the graph”. Student S7 claimed, “I did not have the opportunity to try drawing the graph by using my own strategies”. The other students supported this statement, saying they had simply watched the screen and listened to the teacher’s explanation about drawing the graph. Student S3 stated, “I did not make any mistakes because I did not have the chance to engage with the task; I just watched and listened to the teacher”. The other students shared similar experiences, same as S3.

Observation Three – Grade Ten

T2_Lesson 1: Draw the Parabola

Student-Centered

The teacher described a mathematical task of parabola showing it on the screen, the problem was copied from the textbook (Figure 52). He talked about the quadratic equations and coordinate points shown on the digital content slide. He asked the students to look at the textbook because the equation was there.

In the post-lesson conversation, he agreed that there was scope for a student-centered learning environment in his lesson. The mathematical tasks using digital content should be challenging, and the problem could be diversified and relevant to the textbook (Figure 132). The students could be engaging with the important mathematics tasks with their own strategies.

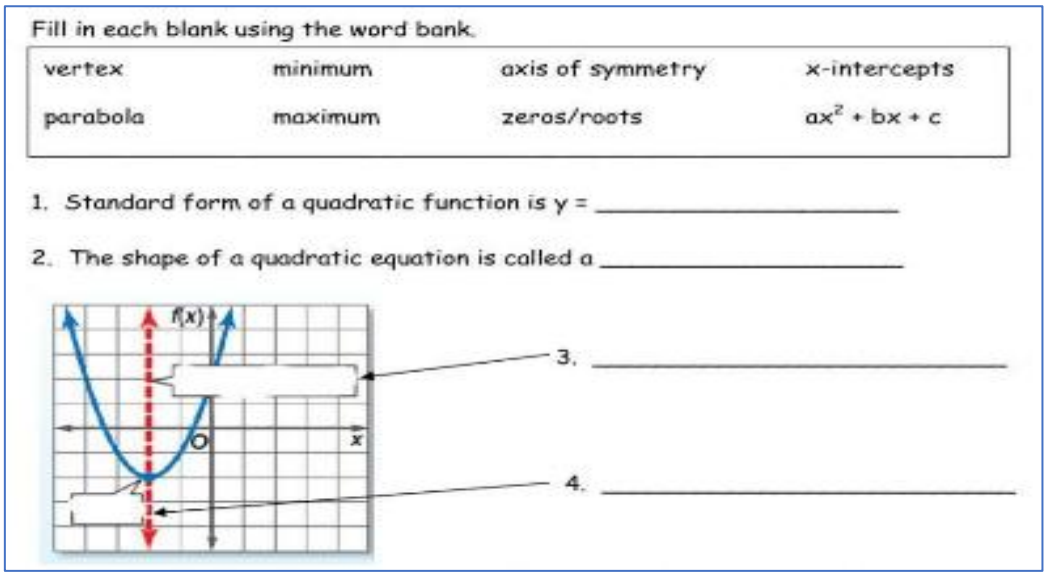


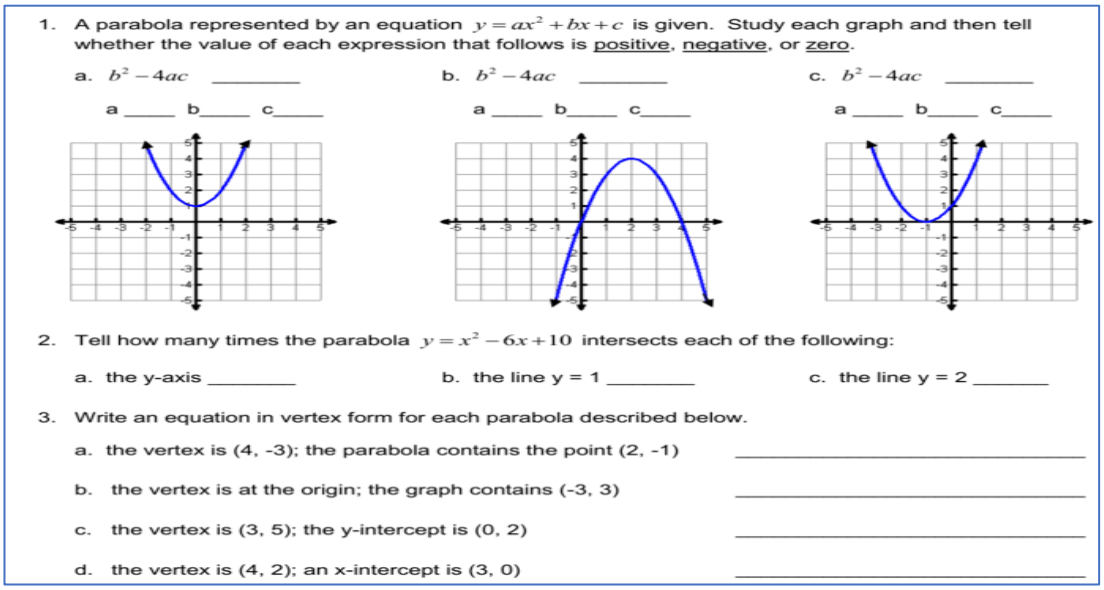
Figure 132: Activity on Parabola (Collected from Google)

However, the teacher claimed that the students could struggle with their own strategies in the practical lessons, it was not possible in the theoretical lessons due to short time duration.

Scaffolding

The teacher worked with the GeoGebra software to draw the parabola and described it to the students (Figure 53). He described the quadratic equation, the coordinate points, and the graph of Parabola using the software GeoGebra. He could not create opportunities for the students where they learn new skills supported by the teacher.

In the post-lesson conversation, the teacher agreed that there were opportunities for a scaffolding teaching approach by utilizing the diverse tasks displayed on the screen (Figure 133). The teacher could provide support by focusing on the student's ability to use the digital content. He could also provide them with diversified and challenging tasks, support them gradually, and help them acquire knowledge about drawing the parabola by applying their own thoughts.


1. A parabola represented by an equation $y = ax^2 + bx + c$ is given. Study each graph and then tell whether the value of each expression that follows is positive, negative, or zero.

a. $b^2 - 4ac$ _____ b. $b^2 - 4ac$ _____ c. $b^2 - 4ac$ _____

a _____ b_____ c_____ a _____ b_____ c_____ a _____ b_____ c_____

2. Tell how many times the parabola $y = x^2 - 6x + 10$ intersects each of the following:

a. the y-axis _____ b. the line y = 1 _____ c. the line y = 2 _____

3. Write an equation in vertex form for each parabola described below.

a. the vertex is (4, -3); the parabola contains the point (2, -1) _____

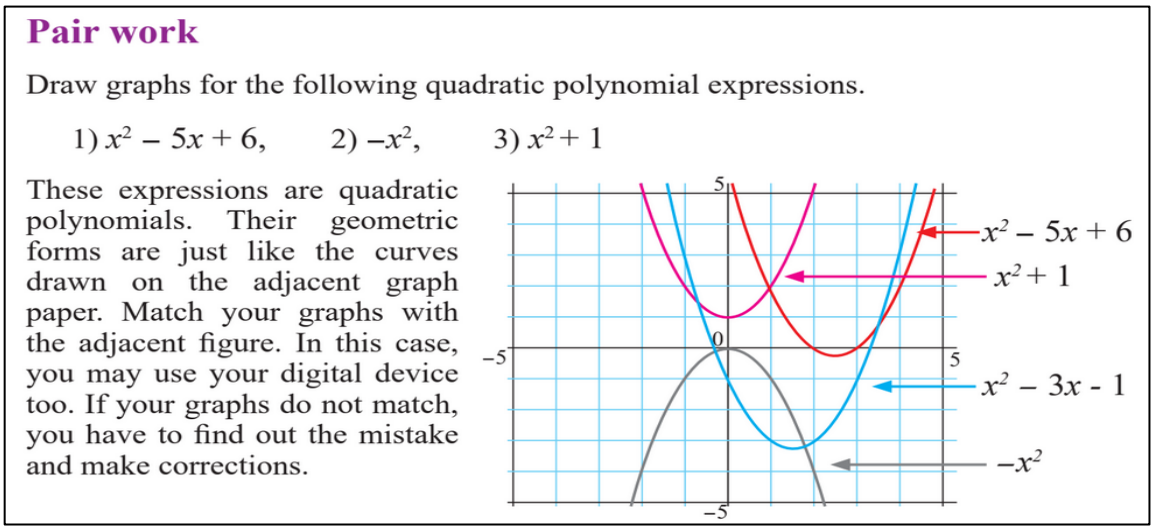
b. the vertex is at the origin; the graph contains (-3, 3) _____

c. the vertex is (3, 5); the y-intercept is (0, 2) _____

d. the vertex is (4, 2); an x-intercept is (3, 0) _____

Figure 133: Activity with the graph of Parabola (Collected from Google)

The teacher acknowledged that they could use the activity introduced in the new curriculum textbook and the students could struggle collectively to deepen their understanding (Figure 134).



Pair work

Draw graphs for the following quadratic polynomial expressions.

1) $x^2 - 5x + 6$, 2) $-x^2$, 3) $x^2 + 1$

These expressions are quadratic polynomials. Their geometric forms are just like the curves drawn on the adjacent graph paper. Match your graphs with the adjacent figure. In this case, you may use your digital device too. If your graphs do not match, you have to find out the mistake and make corrections.

Figure 134: Activity on Graph (Collected from new textbook)

However, the teacher complained that he could not finish the syllabus on time if he used these type of activities in his lessons. He added that the students loved watching the digital content and his explanations.

FGD with Students

In a focus group discussion, student S1 shared her experience by saying, “I found the equation in my textbook and I copied the table of coordinate points from the textbook, but I could not have the opportunity to struggle with my own strategies with the coordinate points”. Student S5 mentioned, “I watched the teacher create a graph using GeoGebra, but I did not have the opportunity to engage with the challenging concepts”. Student S3 also stated that they had watched the teacher’s work using GeoGebra. Student S5 added that they had also observed the teacher’s work using GeoGebra, but did not have the chance to grapple with the challenging concepts. The other students shared similar experiences, stating that they had either looked at the textbook or watched the teacher create a graph. S6 and S8 said that they had a struggle plotting the points in the graph paper, but they did it following the rules and they did not make any mistakes as a result. They added that they did not have the chance to build their own ideas about plotting the points and making the graph.

Observation Four – Grade Nine

T2_Lesson2: Draw the Triangle (Construction-1)

Student-Centered

The teacher described the construction of a triangle, the given conditions, and the measurements of the required conditions shown on the screen using the digital content (Figure 54).

In the post-lesson conversation, the teacher agreed that there was scope for a student-centered learning environment in his lesson, but he had explained most and did not create opportunities for the students to engage actively. The teacher could use interactive and challenging tasks by using digital content, where the students could try the construction of a triangle with their own strategies. They would be able to create new knowledge and deeply engage as creators about the construction of the triangles based on the conditions of the angles and the sides. However, the teacher claimed that acquiring new knowledge could be in the evaluation part.

Scaffolding

The teacher constructed the triangle by using the software Smartboard and explained it to the students (Figure 55). Most students were doing themselves in their notebooks following the teacher's Smartboard work. After drawing one step the teacher asked a student to read out the next line from the textbook and then he again started drawing the next step following the textbook line. The teacher could not create opportunities for the students where they could learn new skills.

However, in the post-lesson conversation, the teacher agreed that there was scope for a scaffolding teaching approach where the teacher would provide support focusing on the student's abilities. The teacher could support the students gradually and help them to complete the task of construction-1 and to acquire knowledge about the lines and the angles as well as make the construction with the given conditions using their own strategies (Figure 135). The teacher could create a climate where students tried to face the challenge and made mistakes, they would be offered support as they learn and develop new knowledge.

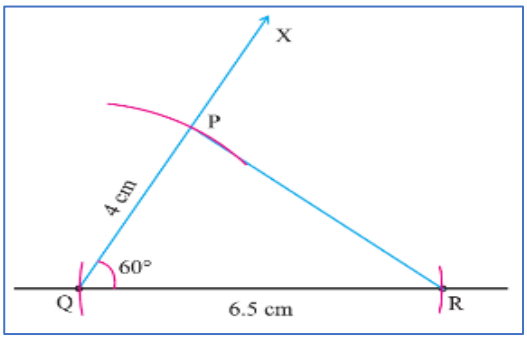


Figure 135: Activity on the Construction of Triangle (Collected from the Google)

However, the teacher claimed that he should show and describe the things first for the student's better understanding.

FGD with Students

During the focus group discussion, student S5 recounted, "I watched the teacher's work on the Smartboard and listened to the teacher's explanations". She added, "I had been drawing the triangle in my notebook following the teacher's work on the Smartboard, but I did not get the opportunity to apply my own strategies". The other students supported this statement, saying they too did not get to apply their own ideas while drawing the triangle. Student S7 mentioned, "I read the lines one by one looking at the textbook to help the teacher work on the Smartboard". Student S6 stated, "I followed the textbook to construct the triangle in my notebook". Student S3 and other students added that they did not have the opportunity to tackle the difficult concepts. S1, S2, and S4 shared similar experiences, saying they did not build their own ideas about the rules of constructing the triangle. Instead, they followed the teacher's work and constructed the triangle in their notebooks avoiding any mistakes.

Observation Five – Grade Eight

T3_Lesson1: Cone

Student-Centered

The teacher described the curved area and the surface area of the cone, the circle, and the proportion indicating to the screen and using digital content (Figure 56). She drew a circle on the Smartboard with the help of a technician and explained the formula for the area of a circle, which is πr^2.

In the post-lesson conversation, the teacher agreed that there was scope for a student-centered learning environment in her lesson, but she explained most and did not create opportunities for the students to engage in the lesson themselves. The teacher could make the environment with the mathematical task that is used in the digital content. The students could struggle with that task about the curved area, surface area, and curved surface area of Cone with their own strategies.

However, the teacher claimed that she did not have enough time to make such opportunities for the students. Due to time limitations, these types of activities were not possible, as she had to finish the syllabus on time.

Scaffolding

The teacher described the shapes of the Cone, the words from the screen, the base area and the curved surface area, the total surface area, and the formula of the cone shown on the presentation slide (Figures 57 and 58). She could not create any opportunities for the students where the students learn new skills about the cone.

In the post-lesson discussion, the teacher agreed that she could not make the lesson interactive. However, she noted that there was scope for scaffolding teaching approaches where the teacher would provide support focusing on the student's abilities of the concepts related to the Cone. She could give them time to discuss the challenging task displayed on the screen where the students could make mistakes and the teacher would offer support to them as they learn. The teacher would

support them gradually and help them create the concepts about the formulas of Cones using the task from the digital content.

However, the teacher claimed that student-centered learning made the class undisciplined.

FGD with Students

In the focus group discussion, student S2 expressed both positive sentiments and frustration regarding the lesson by saying, “I liked watching the shapes of areas of the cone and listening to the teacher’s explanations, but I did not have the opportunity to struggle with the parts of a cone”. The other students also said the same that they did not grapple with the concepts and did not build their own ideas. Student S3 added, “I did not have the chance to encounter the surface area and curve area of the cone with my own strategies”. Students S1 and S5 said that they did not have the chance to try identifying and drawing the surface area of the Cone, and they did not engage to deepen their understanding. Students S8 and S7 shared similar experiences, saying they did not have the opportunity to struggle with the challenging concepts of the cone and creating the formula for its area. The other students also shared similar experiences that they did not have the chance to build their own ideas about the formula of the area of the cone, and as a result, they did not make any mistakes.

Observation Six – Grade Eight

T3_Lesson2: Arithmetic Progression

Student-Centered

The teacher continuously described the sequences, common differences, the first term, and the arithmetic progressions indicating the screen (Figure 69). She uttered and explained the texts line by line indicating to the screen with her finger.

However, in the post-lesson conversation, the teacher agreed that there was scope for a Student-Centered learning environment in her lesson, but she explained most and did not create the opportunities for the students to engage. She could use the mathematical task displayed on the screen where the students had the opportunity to struggle with arithmetic progression with their own strategies (Figure 136). The teachers could help them to engage as problem-solvers about the sequences, common differences, the terms, and the formula of the nth-term.

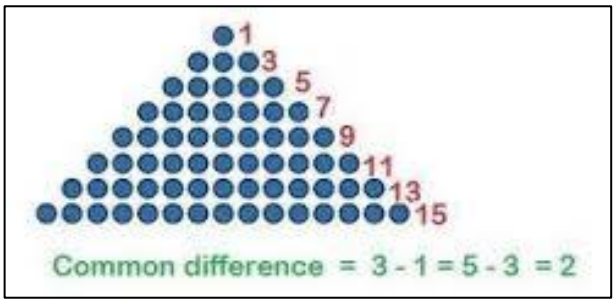


Figure 136: Concepts of Arithmetic Progression (Collected from Google)

However, the teacher claimed that they did not have enough time because they had to finish the syllabus on time.

Scaffolding

The teacher uttered and described the texts line by line, indicating to the screen with her finger, commenting about the first term of arithmetic progression, common differences, and sequences (Figure 60). She also described the general form of arithmetic progression, but she could not create any opportunities for the students to learn new skills (Figure 61).

However, in the post-lesson conversation, the teacher agreed that there was space for a scaffolding teaching approach where the teacher would provide support focusing on the student's abilities. She could use diversified and challenging tasks displayed on the screen to support them gradually and help them to create the formulas of the arithmetic progression (Figure 137).

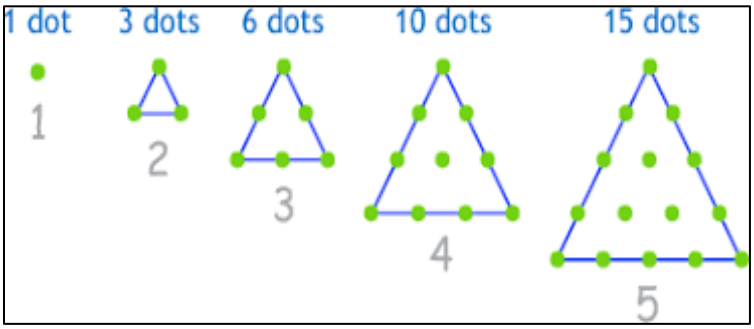


Figure 137: Concepts of Arithmetic Progression (Collected from Google)

FGD with Students

In the focus group discussion, student S5 said that he watched the screen and listened to the teacher's explanation, but he did not have the opportunity to encounter the common differences of the arithmetic progression. Student S6 and other students added that they did not get the opportunity to create arithmetic progressions and common differences with their own strategies. Student S4 claimed, "I did not have the chance to build my own ideas about the nth term of the arithmetic progression and the formula". Other students shared similar experiences, saying they did not have the opportunity to struggle with the challenging concepts in making the formula of the arithmetic progression, and as a result, they did not make any mistakes. Students S2 and S5 mentioned that they simply copied the texts from the screen into their notebooks. Student S7 added, "I wished I could share my ideas, but I did not feel comfortable doing so, because I was not asked".

Observation Seven – Grade Eight

T4_Lesson1: Set Theory

Student-Centered

The teacher described the union set, disjoint set, and universal set indicating the screen with the digital content but she could not make the lesson student-centered (Figure 62).

In the post-lesson conversation, the teacher agreed that there was scope for a student-centered learning environment in her lesson but she explained most and could not create opportunities for the students. She could use interactive tasks in her digital content (Figure 138), where the students would have the opportunity to struggle with set operation tasks and Venn diagrams with their own strategies. They could actively create knowledge by seeking new information from the digital tasks and gain new knowledge about the Van diagrams. However, the teacher argued that most students want to memorize without understanding. So, she explained to them for their better understanding.

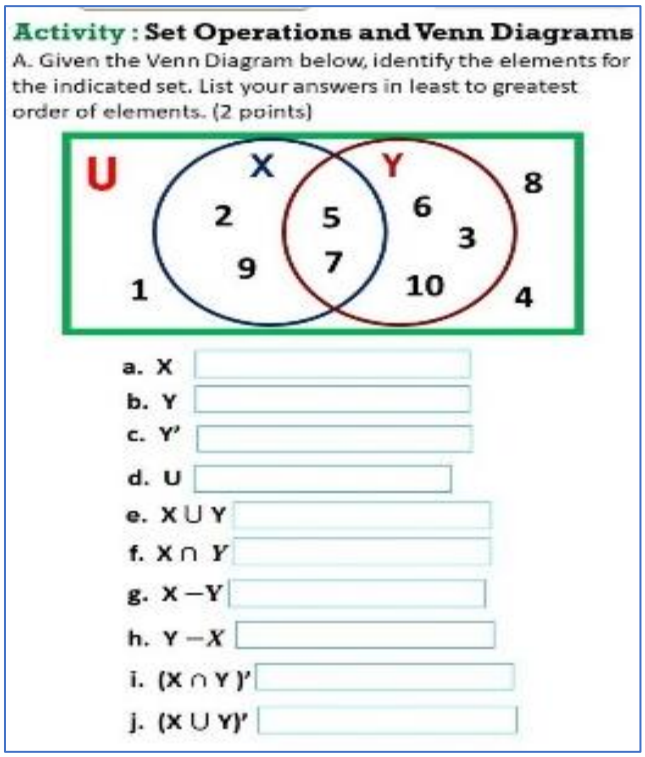


Figure 138: Activity on Van-diagram (Collected from Google)

Scaffolding

The teacher described the universal set and Venn diagram indicating the screen using digital content but could not make the opportunities where the students learned new skills (Figure 63).

In the post-lesson conversation, the teacher agreed that there was scope for scaffolding teaching approaches to provide support focusing on the student's abilities. The students would have challenges with the difficult concepts of Venn diagrams using the diverse tasks displayed on the slide (Figure 139), and the teacher could support them gradually and help them to complete the task about the universal set, union set, the intersection of the set, as well as acquire knowledge about the types of sets and Venn diagrams adding with diversified examples.

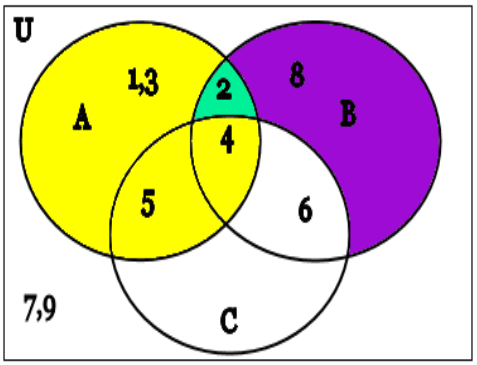


Figure 139: Activity on Van-diagram (Collected from Google)

However, she complained that they did not have enough time to create the environment due to the short class-time duration.

FGD with Students

In the focus group discussion, student S5 stated, "I watched the pictures and listened to the teacher's explanations, but did not have the opportunity to struggle with creating the different types of sets". S3 and other students also expressed the same feeling, saying that they did not get to create a union set, disjoint set, or universal set with their own strategies. Student S8 added, "I had no opportunities to engage deeply and build on new ideas". Student S4 pointed out, "I simply copied the Venn diagram from the screen into my notebook but did not get the opportunity to struggle and build my own ideas about drawing the Venn diagram". Student S3 and other students also expressed similar sentiments, stating that they didn't get to build their own ideas about drawing the Venn diagram. Students S2, S7, and others shared similar experiences, stating that they did not get the scope to encounter the challenges of making Venn diagrams of different sets and as a result, they did not make any mistakes.

Observation Eight – Grade Nine

T4_Lesson2: Relation & Function

Student-Centered

The teacher continuously described the domain, co-domain, image, range, relation, and the function. There was an interactive task in the digital content slide, but she could not make it interactive and student-centered (Figures 64 and 65).

In the post-lesson conversation, the teacher agreed that there was scope for a student-centered learning environment in her lesson, but she explained most and did not create the opportunities for the students to engage. She could let the students use the interactive and innovative tasks displayed on the screen (Figures 140 and 141), where they could struggle with finding the domain, the co-domain, the image, the range, the function, and the relation with their own strategies. The students could create new knowledge about the functions and the relations by seeking new information watching and discussing the challenging and diverse tasks by using the digital content.

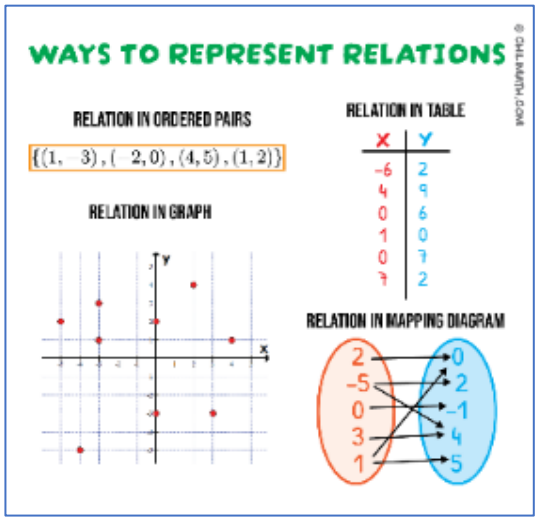


Figure 140: Activity on Function and Relation (Collected from google)

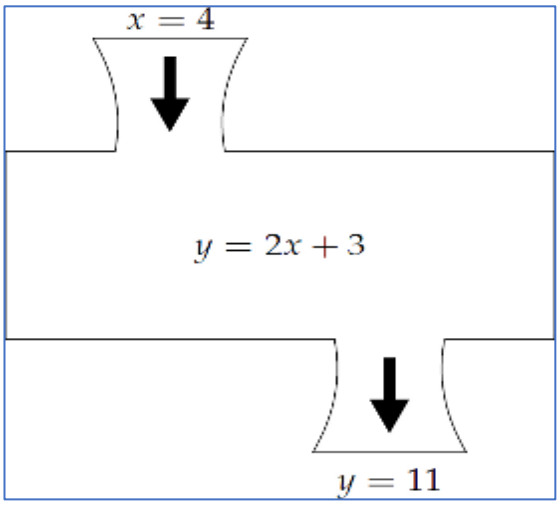


Figure 141: Concepts of Function (Collected from google)

Scaffolding

The teacher described the function, not function, one-one function, not one-one function by using digital content slides, but could not make it interactive and innovative for the students (Figure 66).

However, in the post-lesson conversation, the teacher agreed that there was space for a scaffolding teaching approach where the teacher would provide support focusing on the student's abilities. The students could use diversified and challenging tasks displayed on the screen, where they could build on their own ideas with the domain, co-domain, relation, function, and not function. The teacher could support the students gradually and help them acquire knowledge about the functions and the types of functions (Figure 142).

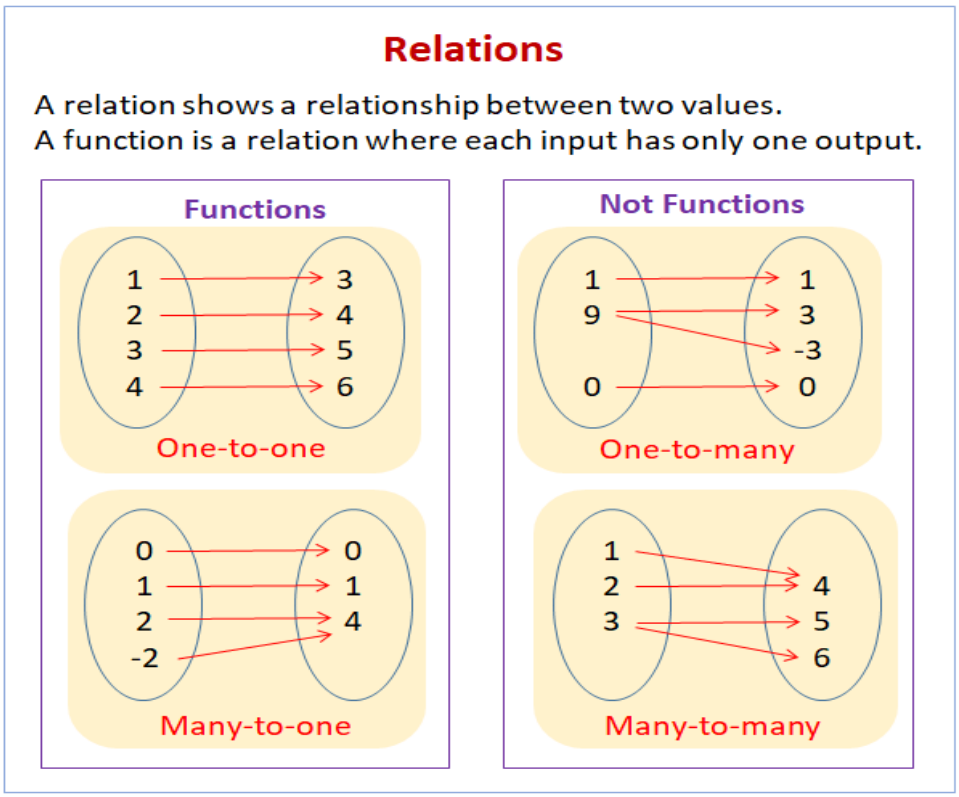


Figure 142: Types of Function (Collected from Google)

Furthermore, the teacher claimed that most students wanted to know the information from the teacher. She confessed that, as a teacher, she explained the concepts to the students for their better understanding. She also added, “We mostly used the traditional lecture method in the lesson”.

FGD with Students

In the focus group discussion, student S5 expressed her feelings saying, “I watched the screen and listened to the teacher’s explanations, but I did not have the opportunity to struggle with creating the diagram of function and relation”. Other students shared similar experiences, saying they simply watched the screen and listened to the teacher without engaging in the activity. Student S3 claimed, “I copied the diagram from the screen into my notebook”. Student S2 also copied the same. Student S7 expressed frustration, “I did not have the opportunity to try making the function and relation diagram and to build on new ideas about it”. Other students also echoed this sentiment, stating they did not get the chance to make their own diagrams and engage in deeper understanding. Student S3 pointed out, “I did not get the opportunity to engage deeply with the challenges of the domain, codomain, and function”. Students S4, S6, and others shared similar experiences, stating they did not get the opportunity to struggle and build their own ideas about different types of functions, and as a result, they did not make any mistakes.

Observation Nine – Grade Nine
T5_Lesson1: Trigonometric Ratios

Student-Centered

There were texts about trigonometric ratios and a right-angle triangle in the digital content slide (Figure 67). The teacher asked questions one by one about the right-angled triangle, but did not wait for the students to respond. The trigonometric ratios and the answers appeared on the screen by clicking the mouse on the laptop. The teacher explained the trigonometric ratios uttering the words from the screen of the digital content and asked the students to copy in their notebooks from the screen. However, he did not make it interactive and student-centered.

In the post-lesson conversation, the teacher agreed that there was scope for a student-centered learning environment in his lesson, but he did not create the opportunities for the students to engage. He asked questions, but the answers were already provided on the screen. He could use challenging tasks shown in the digital content, where the students could have the opportunity to struggle with the tasks of trigonometric ratios with their own strategies (Figure 143). The teachers could help students to engage as the problem-solvers or creators in their learning.

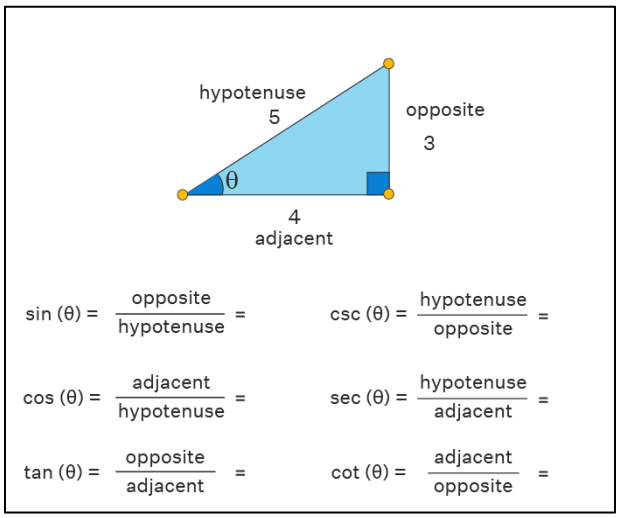
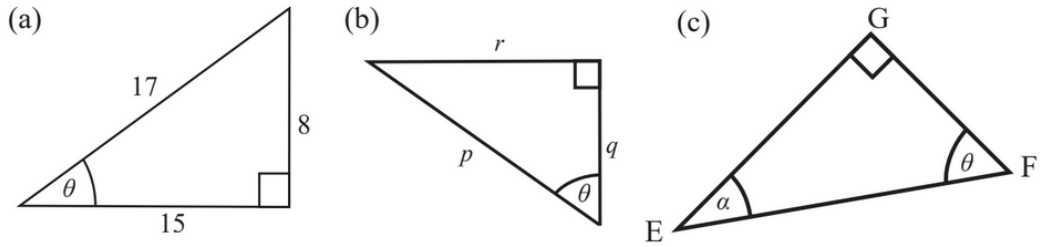


Figure 143: Activity on Trigonometric Ratios (Collected from Google)

However, the teacher claimed that the students could not solve this type of task and they could make mistakes. He added that the students should measure the real object in their practical lessons only, it would not be possible in the regular theoretical lessons.

Nevertheless, the teacher acknowledged that they could also use the activity introduced in the new curriculum textbook, where the students were required to engage in the lesson individually or collectively (Figure 144).

Trigonometry in Measurement



Name of right angled triangle	Acute angle	Hypotenuse	Opposite side	Adjacent side
a	θ	17		
b	θ			
c	θ			
d	α	EF		

Figure 144: Individual-Work on Trigonometric (Collected from new textbook)

Scaffolding

The teacher explained the trigonometric angles and ratios shown on the presentation slide of the digital content (Figure 68). He was uttering the texts himself pointing to the screen. Sometimes he asked questions to the students and the words (answers) appeared on the screen one by one through animation.

However, in the post-lesson conversation, the teacher agreed that there was space for a scaffolding teaching approach where the teacher would provide support focusing on the student's abilities of the concepts related to the trigonometric ratios. He could use diversified tasks, support the students gradually, and help them to complete the task and acquire knowledge about the ratios, making the trigonometric ratios, making the formulas, and making the

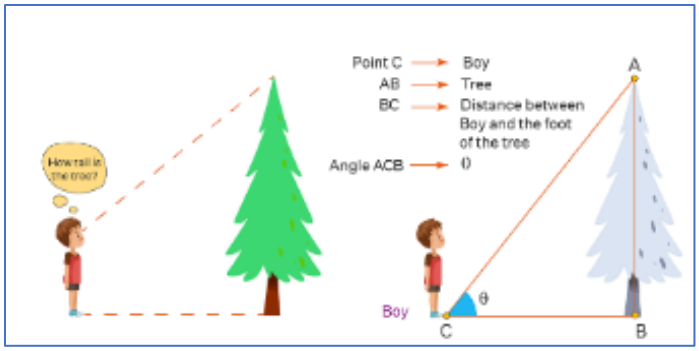


Figure 145: Activity on Trigonometric Ratios (Collected from Google)

relations with more examples (Figure 145). The students could make mistakes when struggling with difficult tasks and offered support from the teacher as they learn and develop their concept of ratios. However, the teacher claimed that he explained the things to the students for their better understanding, and he repeated his explanations so the students understood well.

Nevertheless, the teacher agreed that they could use the activity featured in the new textbook, where the students struggled with the difficult concepts and developed their own ideas individually or collectively (Figure 146).

Pair work

You are standing on the bank of a river and looking at a tree on the other side of the river. Move 50 m in such a way that the intersection of your current position with that tree makes an angle of 30°. What is the distance of your previous position from the tree across the river?

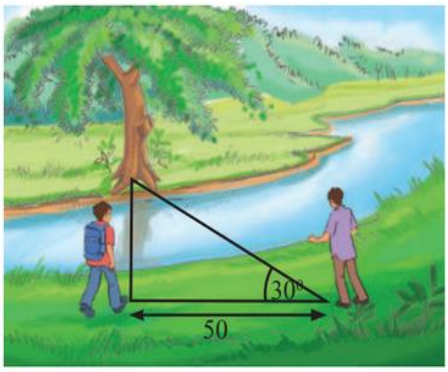


Figure 146: Activity on Trigonometric Ratios (Collected from the new textbook)

FGD with Students

During the focus group discussion, student S6 expressed both positive sentiment and frustration regarding the lesson by saying, “I watched the screen and listened to the teacher’s explanations, but I did not have the opportunity to create the trigonometric ratios with my own ideas”. Student S2 and other students also claimed the same, saying they did not get the chance to encounter trigonometric ratios. Student S4 claimed, “I copied the diagram and the formula from the screen into my notebook”. S1 pointed out that she also copied the same as S4. Student S3 and others shared similar experiences, stating they did not have the chance to struggle with the challenging task of making trigonometric ratios from the diagram using their own strategies. Students S5 and S7 agreed that they did not get the opportunity to struggle with the challenges of trigonometric ratios and the sides of the right-angle triangles to deepen their understanding. Student S8 said, “I

did not get the opportunity to build my own ideas about how to create the formula of the trigonometric ratios from the diagram". Student S6 and others shared similar experiences, stating that they did not get the opportunity to build their own ideas and make any mistakes. Instead, they simply copied the task from the screen, without engaging in any creative or problem-solving processes.

Observation Ten – Grade Ten

T4_Lesson2: Rectangular solid

Student-Centered

The teacher played a video about the volume and surface area of a rectangular triangle and he described the video content to the students (Figure 69). In the next slide of the digital content, there was a rectangular shape and text about the formula of the surface area and volume of the rectangular solid (Figure 70). The teacher asked questions about the formula and some students replied together quoting the formula.

Even though the teacher agreed in the post-lesson conversation that there was scope for a student-centered learning environment in his lesson, he could not make it interactive and student-centered. He could use challenging tasks shown on the digital content where the students would have the opportunity to struggle with the tasks with their own strategies (Figure 147). The teachers could help students to engage as problem-solvers or creators in their own learning and build on new knowledge about the formula of the volume of the rectangular solid.

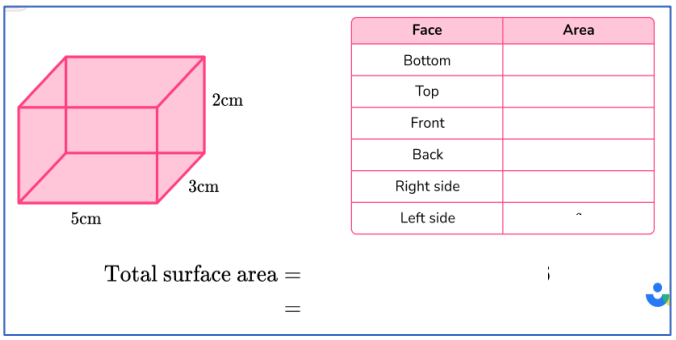


Figure 147: Surface Areas of Rectangular Solid (Collected from Google)

Scaffolding

The teacher asked the student about the formula of the diagonal of the rectangular solid showing it on the presentation slide (Figure 71). He read the text from the screen and described the formula of the diagonal of the rectangular solid.

However, in the post-lesson conversation, the teacher agreed that he could not make the lesson interactive and innovative. There was space for a scaffolding teaching approach where the teacher would provide support focusing on the student's abilities on the concepts related to the rectangular solid. He could use diversified and challenging mathematical tasks shown on the slide (Figure 148). The teacher could gradually help the students build their ideas about the diagonals of the rectangular solid. The teachers would create a climate where students could make mistakes doing the challenging tasks, learn from their mistakes, and develop new concepts.

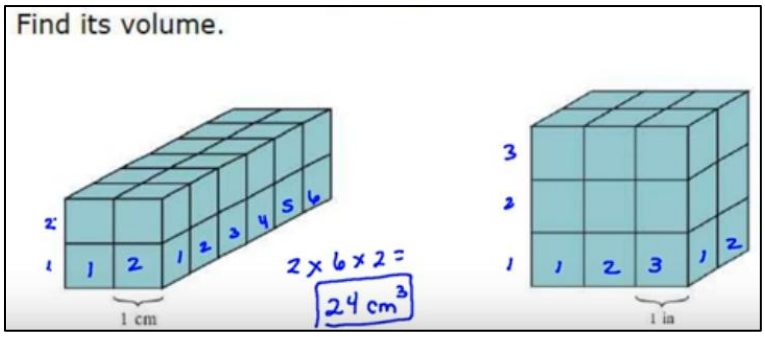


Figure 148: Activity of Rectangular Solid (Collected from Google)

Nevertheless, the teacher claimed that he explained the things to the students because they were not capable of developing the formula on their own. He added that it was important to memorize the formulas.

FGD with Students

During the focus group discussion, student S3 expressed that they enjoyed watching the video and animation, but did not get the opportunity to explain their own ideas about the video content. Student S5 claimed, "I watched the video and listened to the teacher's explanations, but there was no opportunity for me to encounter the tasks shown in the video with my own ideas". Students S2, S4, and some other students also echoed, stating that they did not get the chance to engage with the video content to build on their ideas. Student S1 pointed out, "I responded to the teacher saying

the formula of volume". Students S3 and S7 also mentioned that they replied to the teacher together, reciting the formula of the area. They added that they had no opportunities to think about the formula independently or develop their own understanding of the concept. Students S6 and S7 claimed they did not have the opportunity to try to create a diagram of a rectangular solid and identify the surface areas with their own strategies. Students S5 and S7 also claimed that they did not have the chance to make the diagonal of the rectangular solid. Student S6 confessed, "I did not get the opportunity to build my own ideas about the formula of the volume of the rectangular solid and the diagonal". The other students also complained that they did not have the opportunity to struggle with the tasks, so they did not make any mistakes or form any arguments about them.

Dimension- Pedagogy (Instructional Design: Student-Centered and Scaffolding)

4C.1.2.2 The Integration of Five Cases: Ten (10) Observed Lessons, Ten (10) Post-lesson Interviews with teachers, and Ten (10) FGDs with students

4C.1.2.2.1 Ten (10) Observed Lessons

In this section, all the teachers provided difficult mathematical concepts with multimedia elements including relevant images, texts, and pictures. However, they all explained it to the students approaching teacher-centered strategies in their lessons. There were some mathematical tasks of pi, circle of the area, arithmetic progressions, shapes of cone, and Venn diagrams where the students could struggle with the challenges of the difficult concepts and the teacher could support them gradually and help them to complete the task. The teachers could make an environment for the students where they learn new skills, create new ideas and make mistakes when dealing with challenging tasks shown on the slide. The teachers could help the students to engage as problem-solvers or creators in their own learning. So, there was scope for student-centered and scaffolding instructions but the teachers were not able to apply it using the digital content.

4C.1.2.2.2 Ten (10) Post-lesson Interviews with Teachers

In the subsequent discussion, all the teachers acknowledged that there was scope for a student-centered and scaffolding teaching approach in their lessons. The teachers also recognized that they could create opportunities for students by incorporating diversified and challenging tasks displayed on the screen. This approach would allow students to grapple with problems, make mistakes, and learn through those experiences. The teachers would provide support and guidance, gradually helping students to understand concepts and develop their own understanding based on their experiences and mistakes. They also confessed that they were not able to make an environment where students could struggle with important mathematics with their own strategies. The teachers attributed their lack of success to various constraints, including the student's demands for solutions or information, the pressure to prepare for examinations, limited class time, the need to complete the syllabus and classroom indiscipline issues. As a result, they were unable to create student-centered and scaffolding-oriented learning environments that catered to their students' needs.

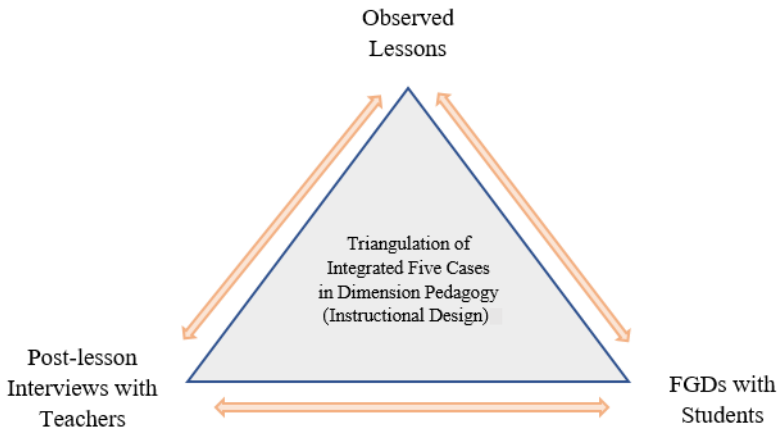
All the teachers commented that they mostly explained the learning content to the students for their better understanding. The teachers T1, T2, and T5 claimed that the students could not struggle with their own strategies. They also made similar comments that they first should provide the whole idea to the students about the mathematical tasks displayed on the screen; if needed, the teacher would repeat it and then the students would be able to solve the tasks. Even though teacher T3 expressed that there were possibilities to make the lesson more student-centered, they ultimately felt unable to implement those strategies effectively during the lesson. However, T3 demanded more training to learn to create diversified mathematical tasks using digital content. Teacher T4 pointed out that most students wanted to memorize without understanding, so she explained the mathematical concepts and rules to the students for their better understanding using a teacher-centered approach. The teacher asserted that they could not make the lesson student-centered due to high numbers of the students and less class time duration.

4C.1.2.2.3 Ten (10) FGDs with Students

During the 10 focus group discussions, students expressed their enthusiasm for watching digital content and listening to teacher explanations. However, they also revealed a lack of opportunities to engage deeply with the mathematical concepts. Many students shared their feelings about not being able to struggle with mathematical tasks using their own strategies, such as one student who said they 'loved watching the animation of the circle', but did not get the chance to 'grapple with the concept of the circle's animation'. Another one also mentioned they, 'watched the teacher create a graph using GeoGebra', but did not have the opportunity to 'engage with the challenging concepts'. Some students reported simply copying information from the textbook or screen, rather than attempting to understand or apply it. For example, one student said they copied the table of coordinate points from the textbook and another student mentioned 'reading the lines one by one, following the textbook' to help the teacher prepare for the lesson. Students also expressed a sense of discomfort with sharing their own ideas and insights, as they felt they were not encouraged to do so. One student shared, "I wished I could explain my ideas, but I did not feel comfortable doing so". The students felt that they were not allowed to engage actively and deeply as problem-solvers or creators with the digital content. As a result, students felt they were not building on their own mathematical ideas or creating their own formulas or rules in the lessons. Instead, they were simply following along, making no mistakes, and forming no arguments.

Dimension- Pedagogy (Instructional Design: Student-Centered and Scaffolding):

4C.1.2.3 Triangulation of Integrated Five Cases: Observed Lessons, Post-lesson Interviews with teachers, and FGDs with students



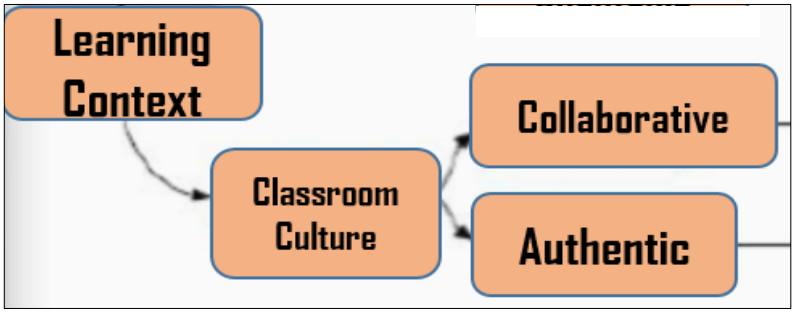
A comprehensive analysis, comprising observations of lessons, teacher interviews, and focus group discussions with students, revealed that all teachers were unable to effectively integrate digital content into their lessons in a pedagogically sound manner. This resulted in a lack of student-centered and scaffolding-oriented learning experiences for students. The teacher confessed that they did not provide support focused on students' ability to build on their mathematical ideas. They were not able to create an environment for the students to struggle with the difficult mathematical concepts with their own ideas and understanding. The teachers acknowledged these issues, citing various reasons, including students' demands for instant solutions or information, pressure to prepare for examinations, limited class time, the need to complete the syllabus and classroom indiscipline issues. The analysis also revealed that students were not given opportunities to struggle with difficult mathematical concepts and challenging problems. Moreover, students were not meaningfully engaged in the learning process and did not actively participate in developing their own understanding of mathematical concepts as well as did not create new ideas through student-centered approaches and scaffolding.

4C.1.3 Learning Context (Classroom Culture: Collaborative and Authentic)

In this dimension, the researcher explores the codes related to Classroom Culture within the dimension of Learning Context. The investigation of the Classroom Culture highlights two key areas:

1. Collaborative: This code focuses on forming groups of students that learn together, solve problems, build strategies, and ideas, and create tasks and the environment also requires joint intellectual effort by the students and with the help of the teacher.

2. Authentic: This code emphasizes an environment of peer interaction, teacher-student interaction and collaborative learning through a variety of activities including pair work, group projects, and interactive inquiry-based learning by using educational technology. There will be an opportunity to capture other students' thoughts and characterize them.



In the observed lessons, it is evident that there were opportunities in all five cases within the lessons to apply the codes of collaborative and authentic culture as part of the Learning Context dimension. There were four segments in the Observation Guideline and the total scores obtained were **14L** and **36N** out of 40 scores for the **10 lessons.** No scores were there for **M** and **H**.

4C.1.3.1 A brief description of the observed lessons conducted by the teachers, along with insights from post-lesson interviews and FGDs with the students, is provided below:

Observation One – Grade Eight

T1_Lesson 1: Area and Circumference of a Circle

Collaborative and Authentic Culture

There was a task in the presentation slide titled 'Group Work' to determine the area of the circle (Figure 72). The teacher instructed the students to do the task individually. The students seemed trying to do it in their notebooks, yet only two students were doing it seriously. He was walking among the students. In the next slide, the teacher included three procedural questions to evaluate the students in the presentation slide of the digital content (Figure 73). The questions were just to recall the definition and the formulas of the Circle.

In the post-lesson conversation, the teacher agreed that there was scope to create an environment of a collaborative learning culture with the learning tasks shown on the digital content, but he could not create it. The students tried to solve the problem by memorizing the formula in their lesson. The task did not require students to understand the concepts and it did not build the student's ideas; the students were not required to be deeply engaged. The teacher acknowledged that creating an authentic classroom culture was possible by using interactive mathematical tasks. He could use

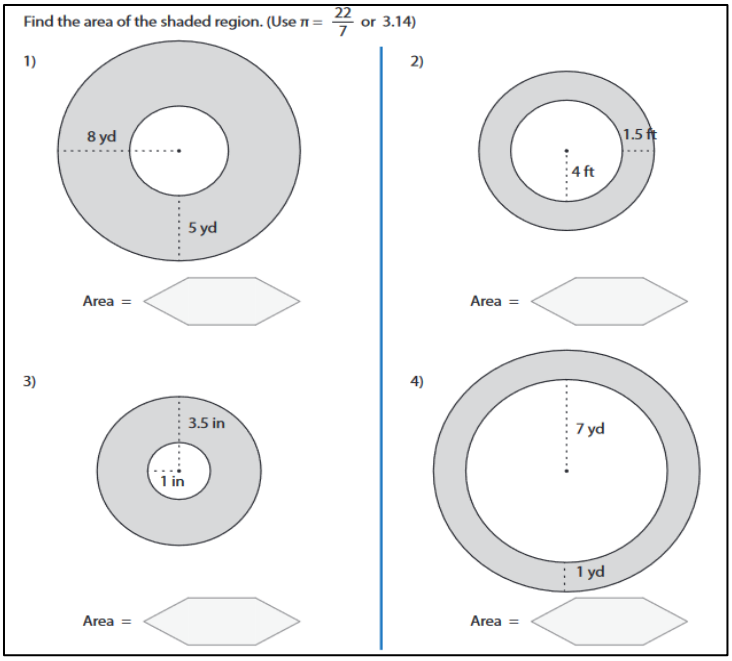


Figure 149: Activity on the area of the Circle (Collected from Google)

diversified mathematical tasks by using digital content and the students would be challenged. The teacher could include diversified tasks to create an environment of interactive learning through a variety of activities, such as peer interaction, teacher-student interaction, pair, collaborative, and group learning meaningfully. There could be an opportunity to capture other students' thoughts and characterize their ideas. The students could arrive at an understanding through collaborative learning about the concepts of the area of the circle requiring joint intellectual effort among themselves facilitated by the teacher (Figure 149). So, they could learn together, solve problems, build strategies, and create new ideas and tasks.

The teacher acknowledged that they could use the learning activity introduced in the new textbook, and students were required to engage collaboratively and to be active and interactive in the lesson (Figures 150 and 151).

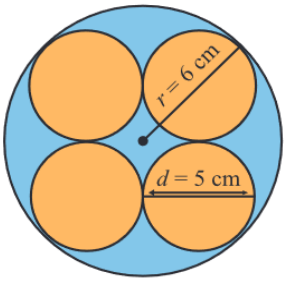
1. Each of you to draw some circles of different radii as you like. Measure the radius, diameter and circumference of the circular area. Then fill up the table determining the area by graph paper and formula.

Circle	Radius	Diameter	Circumference (using yarn or rope)	Circumference (Using using formula)	Area (Using graph paper)	Area (Using formula)	Comparison Between area found using graph paper and formula
1							
2							
3							
4							

Figure 150: Pair work on Circle (Collected from the new textbook)

Cut a circular area of radius 6 cm from a paper drawing. Now, cut four circular areas of radius 5 cm.

Now, colouring small circles as you like, set them inside the big circle with glue like the above figure. Then draw the following table on your exercise book and fill up the blanks.



Serial No.	Radius of circle	Diameter	circumference	Area
1.	6 centimetres			
2.		5 centimetres		
3.	**The area of the large circle that is not painted**			

Figure 151: Group activity on Circle (Collected from the new textbook)

Even though the teacher confessed, "There are various interactive and inquiry learning activities I could include for the students. Yet I do not have enough time in the lesson to give them these types of activities". However, the teacher claimed, "Actually, we have to look at the student's low standard family background. The students and their parents seek more solutions and information from us to help them perform better in the examinations".

FGD with Students

In a focus group discussion, students shared their experiences with solving mathematical problems. S1 reported, "I solved the task individually by recalling the formula 'Area = πr^2', and I did not discuss it with others". Meanwhile, S5 and S6 mentioned that they worked together to solve the problem using the formula, but did not finish the calculation. S8 admitted, "I could not solve the problem because I forgot the formula". S2 also shared a similar experience. S7 and S3 also admitted that they did not try to solve the problem as it was a procedural task, it did not need any

interaction, only to put the formula. S4 claimed, “I responded to the teacher saying the formula for the area of the circle, ‘Area = πr^2’, and attempting to solve the problem by using the formula”.

Observation Two – Grade Eight

T1_Lesson 2: Graph of a Simple Simultaneous Equation

Collaborative and Authentic Culture

The teacher showed a procedural task in the presentation slide titled ‘Group Work’, but he skipped it and gave students the homework (Figure 74). The homework was related to drawing the graph of the quadratic equation, it was from the textbook and the students were asked to copy it from the screen.

In the post-lesson interview, the teacher agreed that there was scope for creating an environment of a collaborative and authentic learning culture, but he did not do that. He could use diversified tasks shown on the screen to engage the students with collaboration and peer interaction and to make interactive and inquiry learning (Figures 152 and 153). The students would be deeply engaged in the learning process and would arrive at an understanding through discussion collaboratively and they would be able to create the equation and the graph with real-world digital examples. Then the students could learn together, solve problems, build strategies, and ideas, and create tasks. There could be an opportunity to capture other students’ thoughts and characterize them.

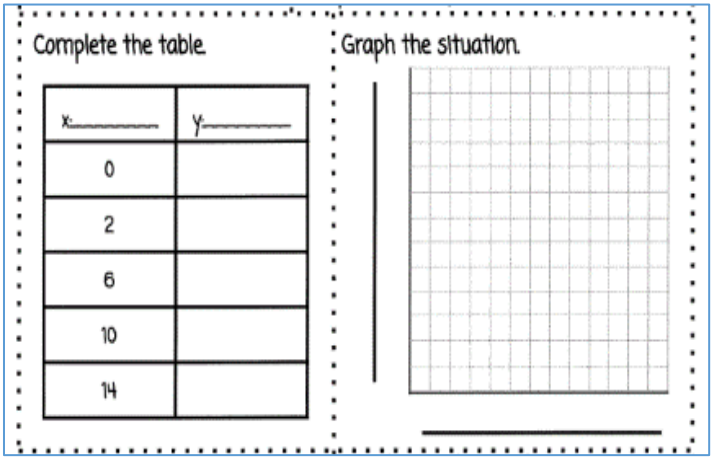


Figure 152: Activity on Graph of Equation (Collected from Google)

However, the teacher claimed the limited class time and the student's needs, stemming from their low socioeconomic backgrounds, as obstacles to implementing a more student-centered approach.

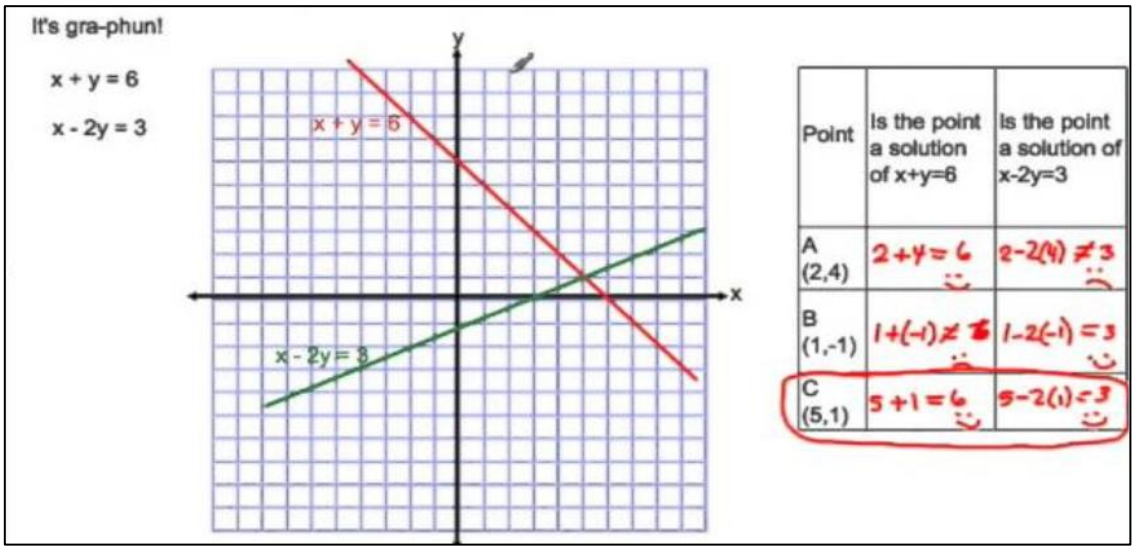


Figure 153: Activity on Graph of Equation (Collected from Google)

FGD with Students

In the focus group discussion, the students claimed that they had no tasks to do in the lesson.

Observation Three – Grade Ten

T2_Lesson 1: Draw the Parabola

Collaborative and Authentic Culture

There was an individual task on the slide related to the quadratic equation from the textbook, and two more tasks about the quadratic equation on the next slide from the textbook titled 'Evaluation' (Figures 75 and 76). However, the teacher skipped the slides and provided homework displayed on the screen. The homework was from the textbook and the students were asked to copy it from the screen (Figure 77). All the tasks were simply procedural and did not require student engagement.

In the post-lesson conversation, the teacher agreed that there was scope for creating the environment of a collaborative and authentic learning culture with diversified tasks, but he did not create such an environment. He could provide the students with diversified and challenging mathematical tasks shown on the digital content to engage with collaboration and peer interaction (Figures 154 and 155). The students would arrive at an understanding through joint intellectual effort about making the equation and the graph of the parabola with real-world digital examples. They could learn together, solve problems, build strategies and ideas, and create tasks through interactive and inquiry learning. There could be an opportunity to capture other students' thoughts and characterize them.

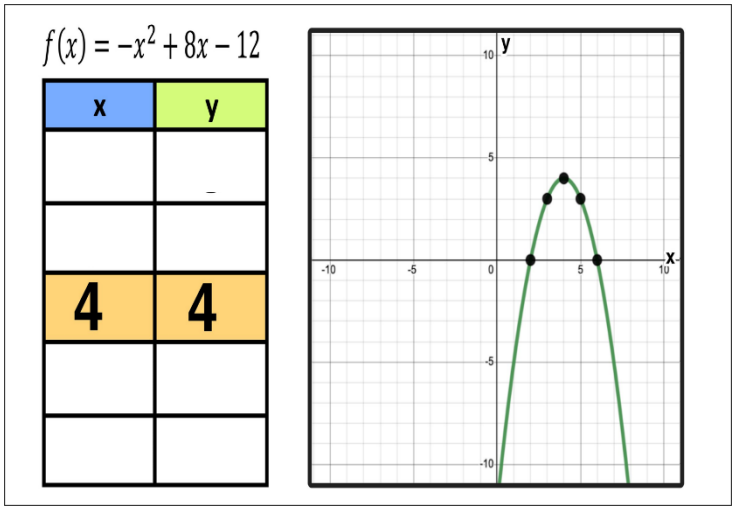


Figure 154: Graph activity on Parabola (Collected from Google)

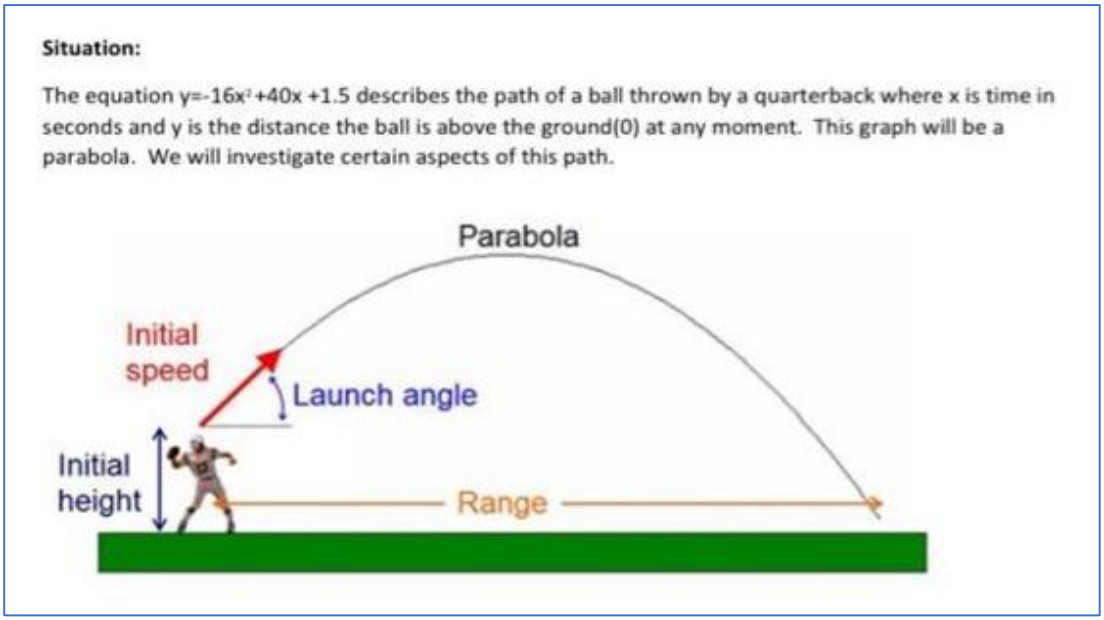


Figure 155: Activity on Parabola (Collected from google)

However, the teacher claimed that he did not provide group work usually. He added that it would not be possible to maintain discipline and cover class time if he would provide group work.

FGD with Students

In the focus group discussion, the students claimed that they just copied the homework task from the screen and had no tasks to do in the lesson.

Observation Four – Grade Nine
T2_Lesson 2: Draw a Triangle (Construction-1)

Collaborative and Authentic Culture

The teacher uttered the words from the presentation slide, there were some procedural questions as well as included answers on the screen (Figure 78). He asked the first question to the students about the parts of a triangle. Three students responded incorrectly. Then the teacher started explaining the facts of the first question and moved on to the next question. There was a homework displayed on the next slide from the textbook, and the students were asked to copy that.

In the post-lesson conversation, the teacher agreed that he could provide activity-based tasks where the students could engage in collaboration and peer interaction through joint intellectual effort. The teacher could use diversified mathematical tasks displayed on the screen and the students could arrive at an understanding through interactive and inquiry learning about constructing the triangle using the digital content (Figure 156). They could learn together, solve problems, build strategies and ideas, and create tasks. There could be an opportunity to capture other students' thoughts and characterize them.

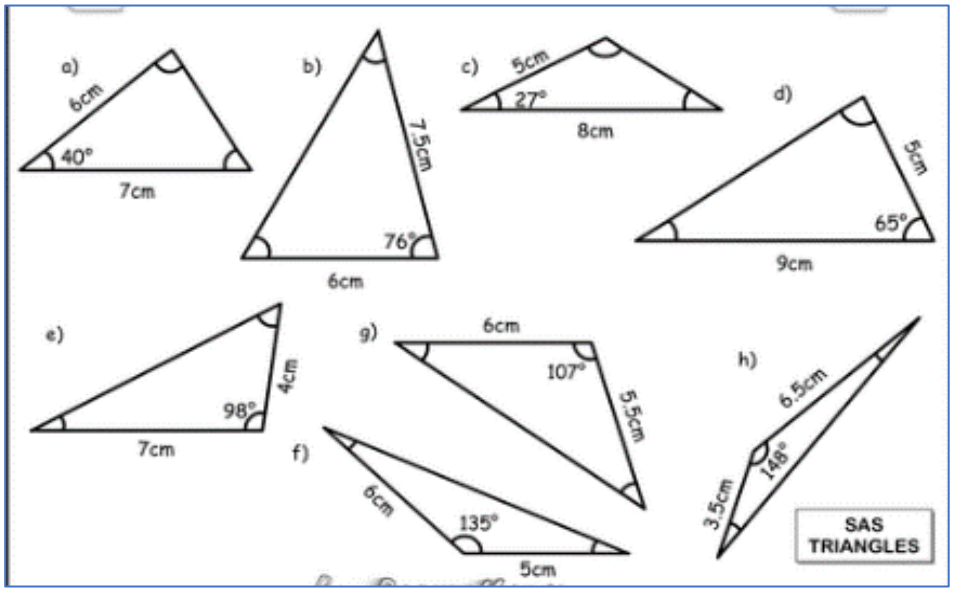


Figure 156: Activity on Triangles (Collected from Google)

The teacher claimed that the students could make mistakes. So, he explained the subject to the students for their better understanding. He added that group work and collaborative learning made the class undisciplined.

FGD with Students

In a focus group discussion, students shared their experiences with responding to the teacher's questions. S1 reported, "I responded to the teacher by saying that there are three parts in a triangle, but that was not the right answer, I wished I had taken a moment to think more about the question before answering". S4 and S7 also shared that they gave the same response to the teacher. In addition, the students mentioned that they responded to the teacher by saying all together, and the answer was 180^0, which is the sum of the angles of a triangle. S5 pointed out, "I replied saying that the sum of two sides of a triangle is greater than the other side". However, the students mentioned that they had no tasks related to triangles to do in the lesson, and instead responded to the teacher's procedural questions. S3 and S6 reported that they wrote down the homework task from their textbook, which was also displayed on the screen. S8 stated, "I did not write the homework task in my notebook, because it was in the textbook". S2 commented the same as S8,

stating that they also did not write down the homework task in their notebook. The students disclosed that they did not do any task individually or in groups, nor did they interact with other students.

Observation Five – Grade Eight

T3_Lesson 1: Cone

Collaborative and Authentic Culture

There were five similar procedural tasks on the presentation slides related to the areas of a cone (Figures 79 and 80). The teacher showed them one by one and asked the students to solve them. She explained the words looking at the screen. The tasks were simply procedural and did not require student engagement. There was homework from the textbook displayed on the screen, the task was from the textbook and the students were asked to copy that (Figure 81).

In the post-lesson conversation, the teacher agreed that there was scope for creating an environment of a collaborative and authentic learning culture, but she did not do so. She could use diversified and challenging tasks shown on the slide where the students engaged with collaboration and peer interaction and the environment required joint intellectual effort (Figure 157). The students could arrive at an understanding through interactive and inquiry learning about the area of the cone. They could learn together, solve problems, build strategies and ideas, and create tasks.

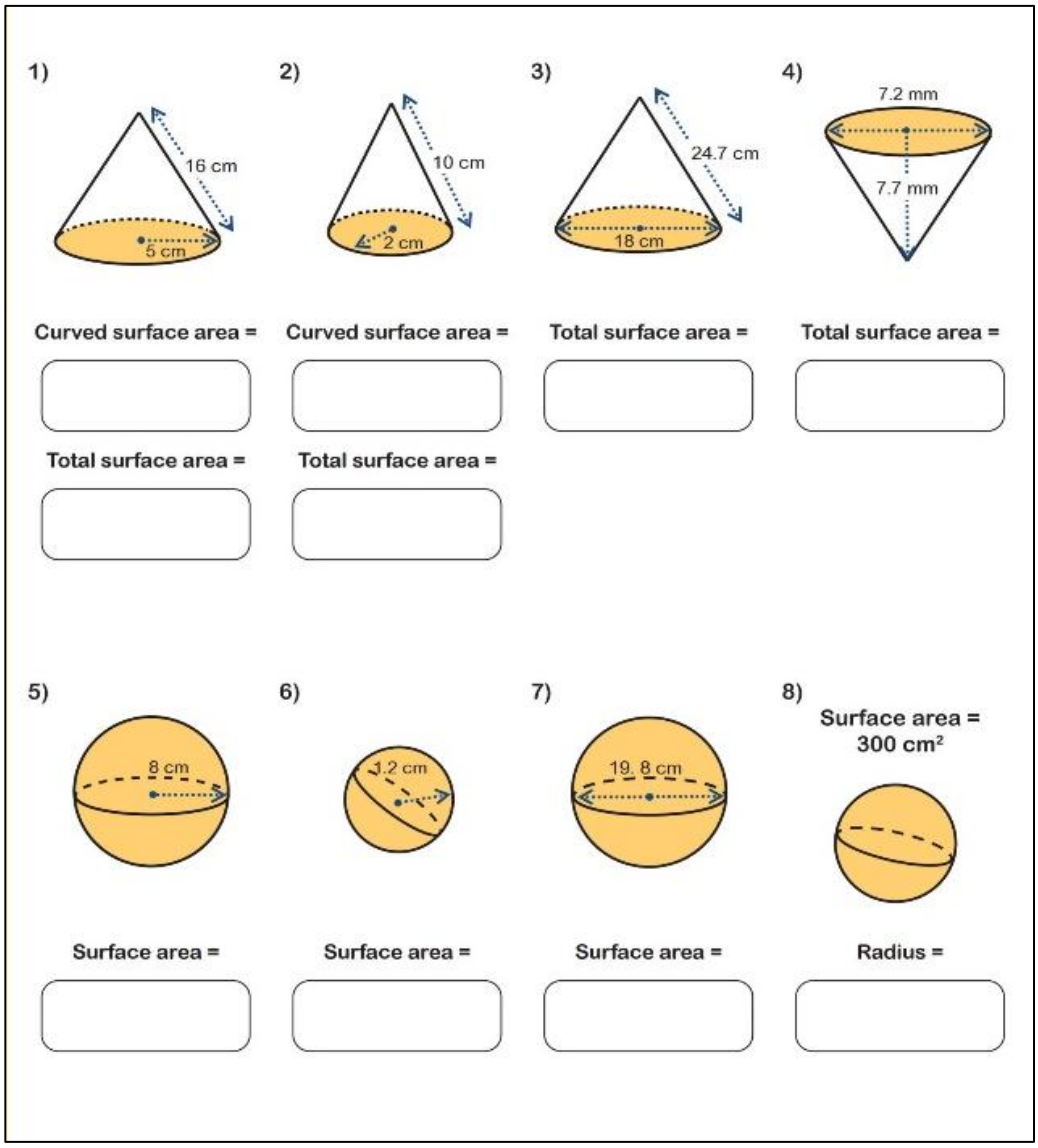


Figure 157: Activity on Cone (Collected from Google)

However, the teacher expressed concerns that assigning group work to students had a negative impact on the classroom environment. Group work made the class undisciplined and took more time. Furthermore, the capable students wanted to solve the task individually in groups to show off their own abilities.

FGD with Students

In the focus group discussion, the students shared their experiences with the mathematical tasks on the screen. S1 reported, “I solved two tasks on the total surface area and slant height of a cone by recalling the formula, which I did not discuss with others”. S3 and others, including S7, echoed that they worked individually, as the tasks did not need to be discussed with others. S8 added, “We did not need to complete the tasks with peers because we could do it individually”. S6 revealed that they did not take any notes during the activity. In contrast, S4, S5, and S2 confessed that they could not solve the problems and did not feel like discussing them with others. S8 also expressed, “I did not enjoy solving the easy problems and wanted to do something new instead”.

Observation Six – Grade Eight
T3_Lesson 2: Arithmetic Progression

Collaborative and Authentic Culture

The teacher explained the formulas of the arithmetic progressions shown on the screen (Figure 82). She also displayed some similar exercise slides with the same procedural mathematics problems (Figures 83 to 85). Then she provided the home tasks showing on the slide; the tasks were from the textbook and the students were asked to copy that. All the tasks were simply procedural and did not require student engagement. The teacher also showed a music video that was not relevant to the topic.

In the post-lesson conversation, the teacher agreed that there was scope for creating the environment of a collaborative and authentic learning culture with challenging tasks by using digital content but she was not able to create such an environment. The teacher could use diversified mathematical tasks and the students would be challenged with the tasks and gain understanding through interactive and inquiry learning (Figure 158).

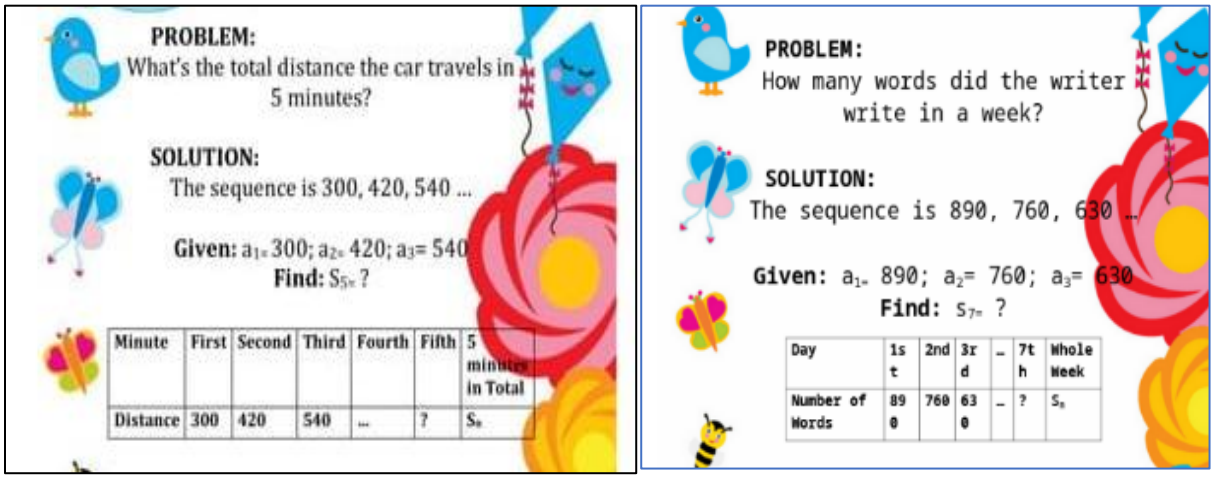


Figure 158: Group activity on Arithmetic Progression (Collected from Google)

The teacher acknowledged that they could use the collaborative tasks introduced in the new curriculum textbook and create a learning environment that requires joint intellectual effort; the students could build strategies and ideas by solving the real-world problems of the arithmetic progression and creating new tasks on them (Figure 159).

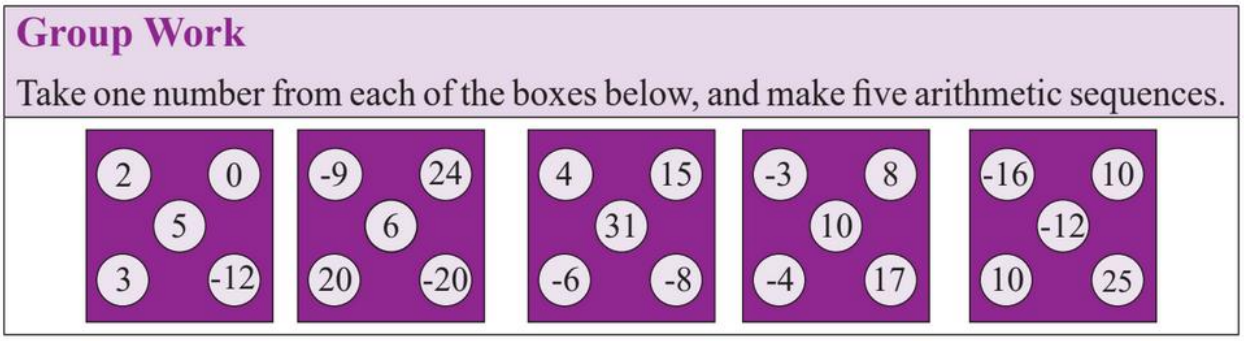


Figure 159: Group activity on Arithmetic Progression (Collected from new textbook)

However, the teacher claimed, "Group work made the class undisciplined and the capable students solved the task individually, not wanting to discuss in the group". The teacher added that they did not have many ideas, and they needed more training to make an effective lesson.

FGD with Students

In the focus group discussion, student S7 stated, “I solved one problem individually using the formula, and I did not need to discuss it with others”. Students S1, S2, and S5 reported a similar process in which they usually solved the nth -term problem individually by using the formula. S4 and S6 claimed that they did nothing, and did not enjoy doing the task. S8 said, “I did not want to do the task, because I did not find it enjoyable”. S3 and S8 indicated that they did not attempt to solve the problem because it was a procedural task and they did not feel motivated to do it.

Observation Seven – Grade Eight
T4_Lesson 1: Set Theory

Collaborative and Authentic Culture

There were learning tasks related to the Set of unions and intersection in the digital content slides, designed for individual work, pair work, and group work, as well as the evaluation slide with some questions (Figures 86 to 89). All the tasks were procedural and did not require student engagement, just recalling the rules. The questions also did not require student’s explanations and thoughts.

In the post-lesson conversation, the teacher agreed that there was scope for creating the environment of a collaborative and authentic learning culture with diversified tasks, but she was not able to create such an environment. The teacher could use challenging and diversified tasks by using digital content where the students would be challenged and gain an understanding through collaborative learning about the use of the properties of Set through real-life examples (Figure 160). They could do it themselves through collaborative and group learning, interactively, as well as inquiry learning. That way, they could build strategies and ideas and create tasks with their own understanding and authentic activities.

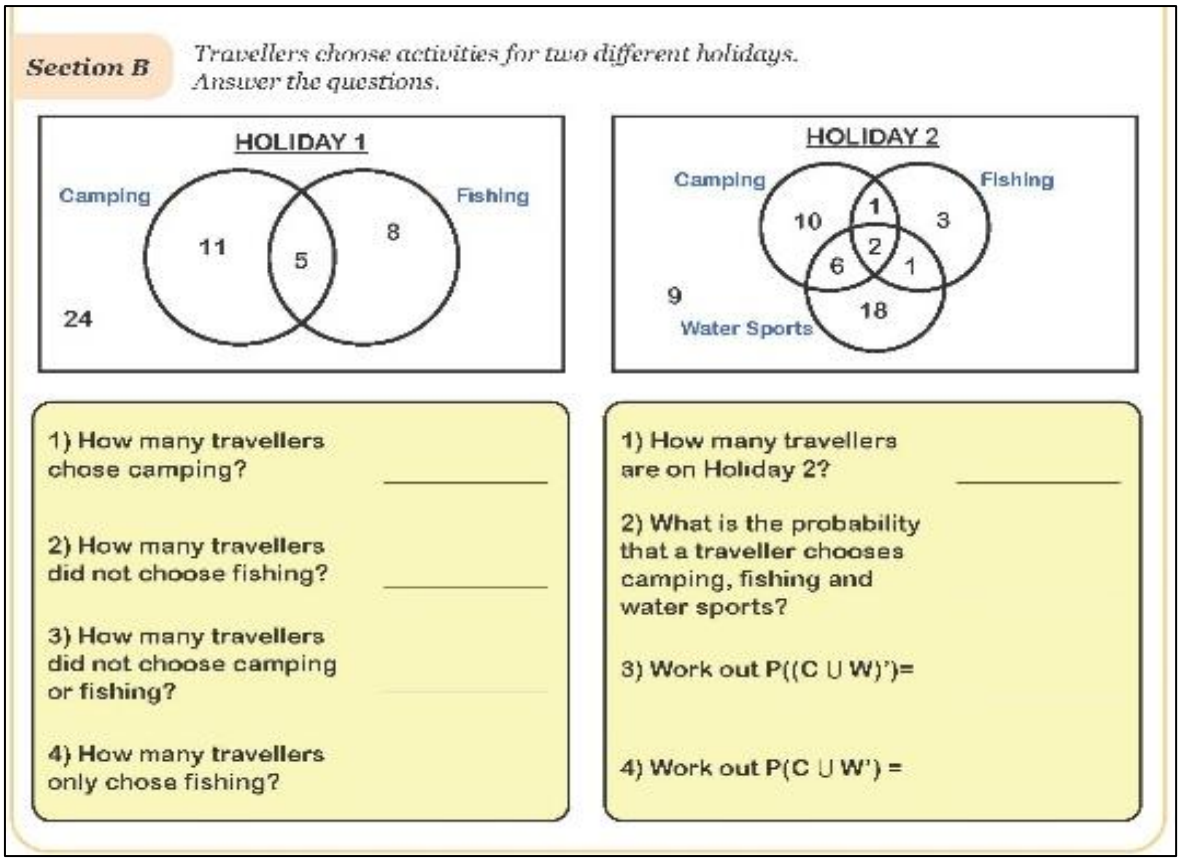


Figure 160: Activity of Set Operations (Collected from Google)

However, the teacher claimed that most students wanted to memorize without understanding. So, the teacher explained the learning concepts to the students for their better understanding. She added that they could not make the activity-based environment due to high student numbers and limited class time duration.

FGD with Students

During the focus group discussion, student S3 reported, “I solved three problems individually recalling the rules of properties of Set, as the tasks did not require collaborative learning”. S1 and S7 told the same as S3, also solving individually. S5 shared, “I did not feel motivated to attempt the procedural problems”. S8 and S4, however, expressed a more reserved attitude, with S8 admitting they did a little work but did not enjoy solving the problems, and S4 similarly stating they did not complete the task.

Observation Eight – Grade Nine

T4_Lesson 2: Relation and Function

Collaborative and Authentic Culture

Some mathematical tasks related to Function and Relation were in the digital content, designed for individual work, pair work, and group work, as well as an evaluation slide with some procedural questions (Figures 90 to 95). The tasks required student engagement, but the teacher was not able to do it. The questions did not require student's explanations. The tasks on the presentation slide were congested with scattered images.

In the post-lesson conversation, the teacher agreed that there was scope for creating the environment of a collaborative and authentic learning culture with interactive tasks using digital content, but she explained most. She confessed that it was necessary to use clear and systematic images where the students could interact, were challenged with the tasks and gain an understanding through discussion about the domain, co-domain, range, function not function, and the types of Relations and Functions through collaborative and group learning, interactive and inquiry learning (Figure 161).

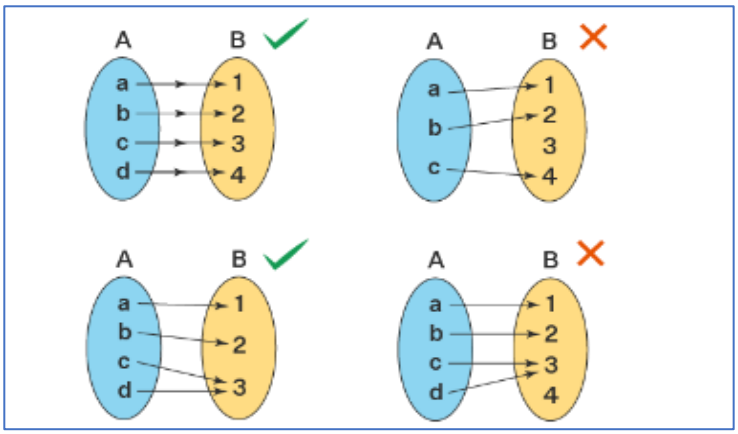


Figure 161: Activity on Function and Relation (Collected from Google)

However, the teacher acknowledged that they mostly used the lecture method, only to transfer knowledge to the students rather than fostering interactive or hands-on learning experiences. She added that a lengthy time is needed for collaborative learning.

FGD with Students

During the focus group discussion, student S7 agreed, “I solved some tasks individually, but did not complete them. He added, “I knew the formulas to solve and did not need to collaborate with others”. S1 and S3 echoed the same as S7, also solving some tasks individually by recalling the rules and formulas. S8 pointed out a similar experience, “I did some tasks and knew the rules earlier, but I did not enjoy solving the tasks”. S5 and S6 reported that they did some tasks and checked their answers by looking at the screen, as the teacher displayed the answer there. In opposite, S2 and S4 stated that they did not attempt to solve any tasks.

Observation Nine – Grade Nine
T5_Lesson1: Trigonometric Ratios

Collaborative and Authentic Culture

There were tasks related to trigonometric ratios, designed for individual work and group work, as well as the evaluation slide, which included some procedural questions (Figures 96 to 98). The tasks did not require student engagement and the questions also did not require student’s explanation.

In the post-lesson conversation, the teacher agreed that there was scope for creating an environment of a collaborative and authentic learning culture with diversified tasks using digital content. The teacher could use real-life-based mathematical tasks where the students could interact and were challenged with the interactive and attractive tasks (Figure 162). They could gain an understanding through discussion about trigonometric ratios and problem solving.

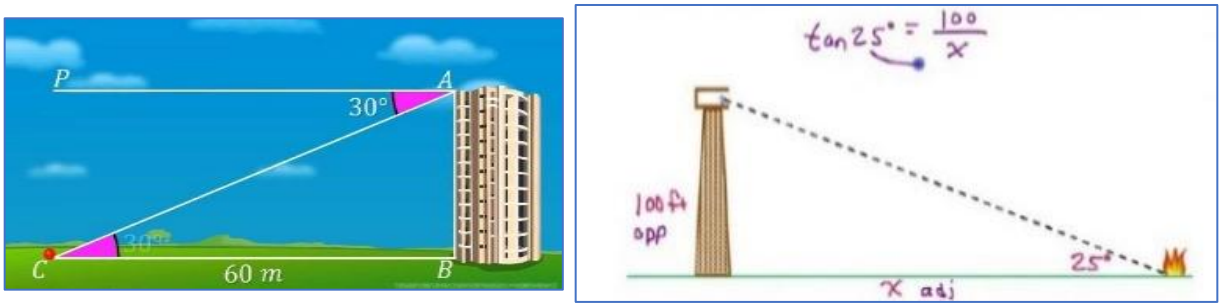
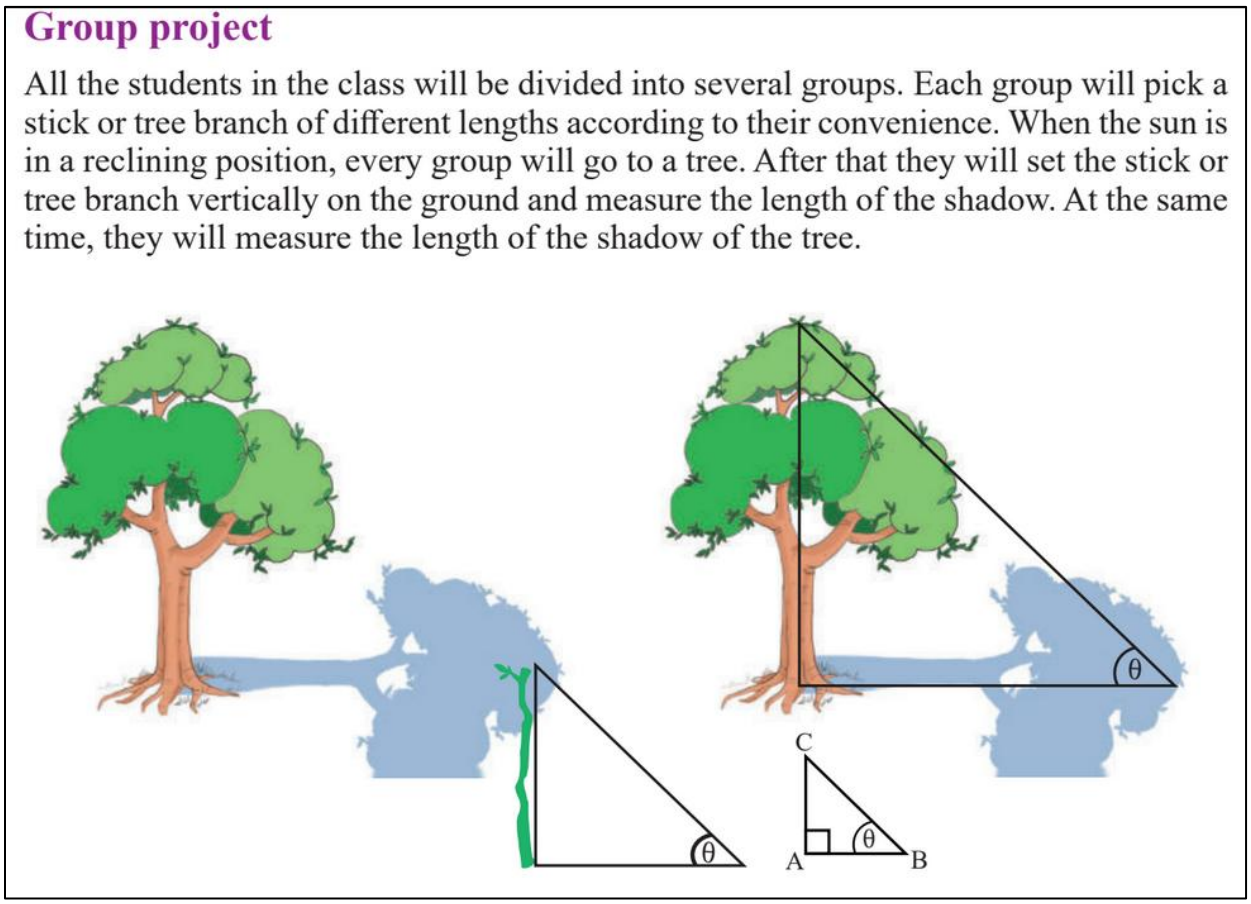


Figure 162: Activity on Trigonometric Ratios (Collected from Google)

The teacher also acknowledged that they could use the activity of group project introduced in the new textbook, where the students were required to be deeply engaged with real-world problems and collaborate through joint intellectual effort (Figure 163).



Group project

All the students in the class will be divided into several groups. Each group will pick a stick or tree branch of different lengths according to their convenience. When the sun is in a reclining position, every group will go to a tree. After that they will set the stick or tree branch vertically on the ground and measure the length of the shadow. At the same time, they will measure the length of the shadow of the tree.

Figure 163: Activity on Trigonometric Ratios (Collected from new textbook)

However, the teacher claimed that the students did not want to solve the task in groups and they usually liked to do the task individually.

FGD with Students

During the focus group discussion, students S3 and S5 said that they copied the trigonometric ratios from the screen, as they found the task unappealing and did not require collaborative learning. S7 and S8 shared similar sentiments, stating they did the same, as the task was to draw the triangles from the screen. The students collectively expressed that they did not attempt to complete the tasks because they were not enjoyable, so they would just copy the diagram. On the other hand, S1 reported, "I responded to the teacher by saying the angle 'sinθ'. S2 pointed out, "I did not do anything in my notebook, and there were no tasks to discuss with others". Student S4 concurred with S1, stating that they did not complete any tasks and there were no opportunities to discuss with others.

Observation Ten – Grade Ten
T5_Lesson2: Rectangular Solid

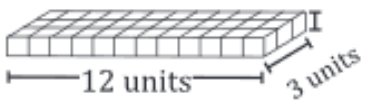
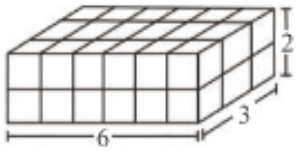
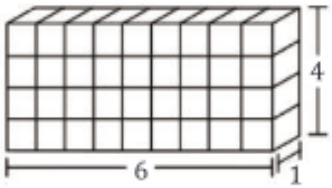
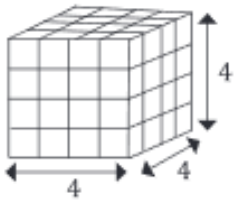
Collaborative and Authentic Culture

There were mathematical tasks related to the rectangular solid, designed for individual work, pair work, group work, and the evaluation slide, which included some procedural questions, as well as the homework task in the digital content slides (Figures 99 to 102). The tasks required student engagement, but the teacher could not achieve it. However, the questions were procedural and did not require student's explanations. The teacher said the words from the screen and sometimes asked the students the formulas.

In the post-lesson conversation, the teacher agreed that there was scope for creating an environment of a collaborative and authentic learning culture with the tasks that he used in the digital content. But he could not make it. The students could interact with the tasks and arrive at an understanding through discussion about the surface area, volume, diagonal of a rectangular solid and they could be capable to apply in real-life problems.

The teacher also acknowledged that they could use the group project introduced in the new textbook, where the students were required to be deeply engaged with real-world problems and collaborate through joint intellectual effort (Figure 164).

1. Fill in the following table.

Serial no.	cuboid	Length (1)	Width (b)	n Height (h)	Whole surface area	Volume
1.		12	3	1		
2.						
3.						
4.						

2. Calculate the total surface area and volume of the math book measuring its length, width and height.
3. Three metal cubes have edges 3 cm, 4 cm and 5 cm respectively. Three cubes are melted to form a new cube. Determine the total surface area and volume of the new cube.

Figure 164: Group work on Rectangular Solid (Collected from the new textbook)

However, the teacher claimed that challenging and real-life-based tasks would be suitable for the practical lessons, but it was not possible in the regular theoretical lessons due to the shortage of class time.

FGD with Students

During the focus group discussion, student S3 shared, "I solved the tasks individually by applying the formula for the volume and diagonal of the rectangular solid, which I learned earlier". S7 added, "I solved the task individually, as the tasks did not require collaborative learning, but I checked my answer with others". S1 reported that they solved the task of finding the area by recalling the relevant formula. S6 and S8 mentioned that they did some tasks, but knew the formulas beforehand. S4 confessed, "I did not complete any of the tasks, as I did not enjoy solving them". S5 and S7 expressed the same feeling as S4, stating that they also did not enjoy solving the tasks.

Dimension- Learning Context (Classroom Culture: Collaborative and Authentic)

4C.1.3.2 The Integration of the Five Cases: Ten (10) Observed Lessons, Ten (10) Post-lesson Interviews with teachers, and Ten (10) FGDs with students

4C.1.3.2.1 Ten (10) Observed Lessons

In this section, all the teachers provided some mathematical tasks such as individual work, pair work, and group work in their digital content slides in the lessons. The mathematical tasks using digital content were mostly procedural and to recall the formulas. There were some procedural questions in the evaluation and homework slide, which did not require any explanation. Teacher T1 skipped the group-work presentation slide in a lesson and instructed the student to do individually the group-work task in another lesson. T2 also skipped the individual-task slide in a lesson and another lesson, he explained the questions of the evaluation slide through a teacher-centered approach. There were some mathematical tasks in the lessons 'Function and Relation' and 'Rectangular Solid' using digital content, where the tasks required students' engagement through creating the environment of collaborative and authentic classroom culture, but the teachers did not do it. The students could interact with the tasks and gain an understanding through

discussion with collaboration and peer interaction as well as the environment required joint intellectual effort in solving the problems, building strategies and ideas, and creating tasks. Hence, there was scope for a collaborative and authentic classroom culture using diversified and challenging tasks with digital content but the teachers could not incorporate it into their lessons.

4C.1.3.2.2 Ten (10) Post-lesson Interviews with Teachers

In the post-lesson discussion, all the teachers acknowledged that there was scope for creating a collaborative and authentic classroom culture but the teachers could not include it in their lessons. They also acknowledged that the provided mathematical tasks using digital content were mostly procedural and just for recalling the formulas to solve. The teachers agreed that there were no meaningful interactions between the teachers and the students in their lessons, and the students were not deeply engaged as problem solvers and were not required to provide explanations, only pro forma answers to procedural questions. The teacher agreed that there was scope for creating a collaborative and authentic classroom culture providing diversified and challenging mathematical tasks using digital content in their lessons.

However, all the teachers attributed their lack of success in promoting collaborative learning to various constraints, including limited class time, high student-to-teacher ratios, difficulties in managing classroom behavior during group work, and the reluctance of top-performing students to participate in group activities. As a result, they could not create collaborative and authentic classroom culture and learning oriented environments that catered to their students' needs.

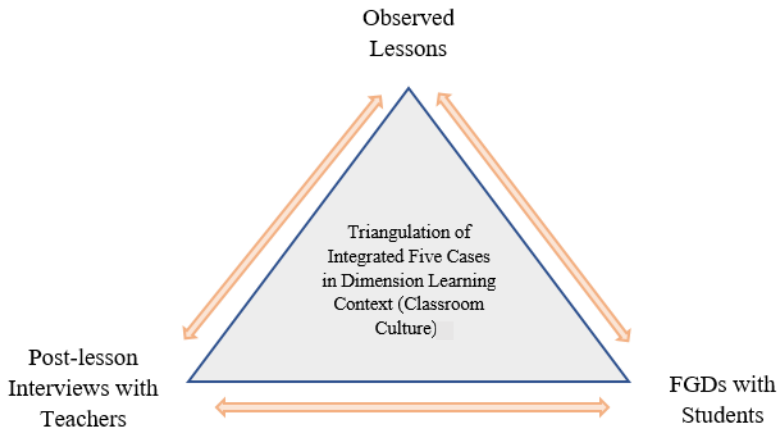
T1, T2, and T5 also claimed that it was not possible for collaborative learning in groups for the students to struggle with the mathematical tasks, because it made the class undisciplined. All teachers added that the collaborative learning would take more time and the class time duration would need to be increased. T1 focused on the student’s low-standard family background and the fact that they wanted more information from the teachers in order to perform well in the examination. T4 confessed that they mostly used the lecture method only to transfer knowledge to the students rather than creating an interactive environment.

4C.1.3.2.3 Ten (10) FGDs with Students

During 10 focus group discussions with students, the students shared that they enjoyed watching the images and animations in their digital lessons. However, they mentioned that the mathematical tasks were designed as individual or group work, but they mostly completed them individually by recalling procedural methods. The students reported that they did not engage in any collaboration or peer interaction. Some students stated that they simply responded to the teacher with a one- or two-word answer. Some students revealed that they solved the tasks individually using formulas learned earlier, as the tasks did not require collaborative or peer learning. Some students did not attempt to complete the tasks because they found them too procedural. Others expressed a preference for more enjoyable activities, which led to a lack of motivation to solve the problems. Additionally, some students admitted that they simply did not feel motivated to tackle the tasks or enjoy the process of solving them. Some students reported that they wrote down homework tasks from their textbook, which was also displayed on the screen. However, others claimed in two focus group discussions that they had no tasks to do in the lesson. The students generally reported that they were not deeply engaged with the mathematical tasks and did not provide explanations. Overall, the students expressed a lack of enjoyment and engagement with the mathematical tasks in the context of a collaborative and authentic classroom culture.

Dimension- Learning Context (Classroom Culture: Collaborative and Authentic)

4C.1.3.3 Triangulation of Integrated Five Cases: Observed Lessons, Post-lesson Interviews with teachers, and FGDs with students



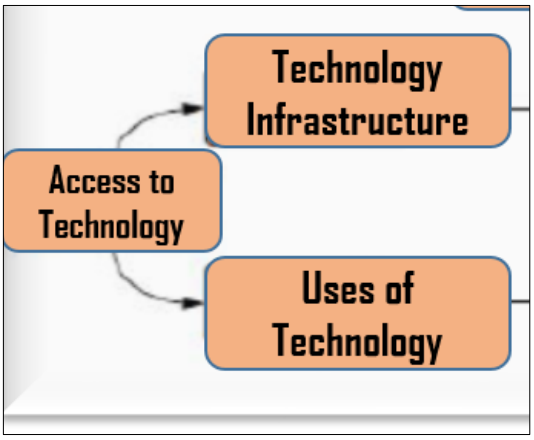
A comprehensive analysis of the lessons, teacher post-lesson interviews, and focus group discussions with students revealed that all teachers could not effectively integrate digital content into their lessons providing a learning-context environment, resulting in a lack of collaborative and authentic classroom culture. The teachers confessed that they did not provide an environment where the students could engage in the mathematical task collaboratively or in peer interaction, enabling joint intellectual effort and explaining their ideas. Furthermore, the teachers acknowledged these issues, citing various reasons, including limited class time, high student-to-teacher ratios, difficulties in managing classroom behavior during group work, and the reluctance of top-performing students to participate in group activities. However, one teacher proposed that they needed additional training on how to integrate pedagogical alignment into their lesson to improve their teaching-learning practice. Furthermore, it appeared that the mathematical activities were not designed to foster collaborative learning. Students were not encouraged to work together to build on each other's ideas through inquiry-based learning. Instead, the mathematical tasks were largely procedural, requiring students to work individually using rules or formulas. This approach limited the opportunities for students to engage in peer-to-peer learning, develop their problem-solving skills through shared thinking and discussion, and cultivate a sense of collaborative and authentic classroom culture.

4C.1.4 Access to Technology (Technology Infrastructure and Uses of Technology)

In the dimension of Access to Technology, the researcher explores two key areas that underscore the significance of technological resources in the educational environment:

1. Technology Infrastructure: This code focuses on the variety and quality of technological tools and resources available in the classroom for both teachers and students.

2. Uses of Technology: This code highlights the importance of access to technology and the proficiency of both teachers and students in utilizing these resources effectively. It recognizes that technology access is not uniform and may vary across different content areas, phases of a lesson, and specific student needs.



In the observed lessons, there were opportunities in all five cases for teachers within the lessons to apply the code of Uses of Technology as part of the Access to Technology dimension. There were four segments in the Observation Guideline and the total scores obtained were **2M**, **18L** and **20N** out of 40 scores for the **10 lessons.** No scores were there for **H**.

4C.1.4.1 A brief description of the observed lessons conducted by the teachers, along with insights from post-lesson interviews and FGDs with the students, is provided below:

Teacher 1 (Case 1)

In the observed mathematics lessons, teacher T1 used a laptop and projector while using digital content. The teacher incorporated the digital content by showing and explaining the slides one after another to the students but did not vary between diverse content areas and students' individual needs. In addition, there were no technologies for the students in the classroom.

In the post-lesson interview, teacher T1 reported that he had created the digital content himself, which he incorporated into his lessons. He used laptops and projectors to display the content, explaining each slide individually to the students. However, he revealed that the access to digital content varied on the stages of the lesson as per slides, but did not vary between diverse content areas and students' individual needs. However, he agreed that he could create a collaborative learning environment using diversified and challenging mathematical tasks in the lesson. Furthermore, the teacher blamed the lack of success on the physical constraints of the classroom, limited class time, and high student-to-teacher ratios. He reported that they had no technologies for the students to use in the classroom.

In the focus group discussion with the students, the students expressed that they watched the images, pictures, text, animation, and video in the lessons and listened to the teacher's explanation. They added that they did not use technology and no technologies were available in the classroom for the students. They said that they were not allowed to choose what they wanted to watch on the screen or to do and share their own thoughts and ideas.

Teacher 2 (Case 2)

In the observed lessons, teacher T2 used a laptop and projector while using digital content. The teacher incorporated the digital content by showing and explaining the slides one after another to the students. He used software, the GeoGebra in one lesson and the Smartboard in another lesson as per content needs. However, access to technology did not vary between diverse content areas and students' individual needs. Also, there were no technologies available for the students in the classroom.

In the post-lesson interview, the teacher T2 reported that he used his own created digital content in his lessons. He used laptops and projectors to display the content, explaining each slide individually to the students. He added that he also incorporated the software GeoGebra in the lesson and Smartboard in another lesson. However, he revealed that the access to digital content varied on the stages of the lesson as per slides but did not vary between diverse content areas and student's individual needs. However, the teacher agreed that he could make it creating a collaborative learning environment using diversified and challenging mathematical tasks in the lesson that he was not able to do. Furthermore, the teacher blamed the lack of success on the physical constraints of the classroom and high student-to-teacher ratios. He reported that they had no technologies for the students to use in the classroom.

In the focus group discussion with the students, they expressed that they watched the images, pictures, text, animation, and video in the lessons and listened to the teacher's explanation. They also watched the teacher's work using the software GeoGebra in the lesson 'Draw the Parabola' and the smart board in the lesson 'Draw the Triangle'. They added that they did not use technology and no technologies were there for them. They expressed that they were not allowed to choose what they wanted to watch on the screen or to do and share their own thoughts and ideas.

Teacher 3 (Case 3)

In the observed lessons, teacher T3 used a laptop and projector to use digital content. She used the Smartboard in her one lesson with the help of a technician. The teacher incorporated the digital content by showing and explaining the slides one after another to the students. However, access to technology did not vary between diverse content areas and student's individual needs. There were no technologies for the students in the classroom.

In the post-lesson interview, teacher T3 reported that she used his own created digital content in her lessons. She used laptops and projectors to display the content, explaining each slide individually to the students. However, she pointed out that access to digital content varied on the stages of the lesson as per slides but did not vary between diverse content areas and student's individual needs. However, she agreed that she could create a collaborative learning environment using diversified and challenging mathematical tasks in the lesson. Furthermore, the teacher blamed the lack of success on the limited class time and high student-to-teacher ratios. She reported that they had no technologies for the students to use in the classroom. She lamented, "I wish I could use digital content more frequently, but unfortunately; our school lacks available multimedia resources".

In the focus group discussion with the students, they expressed that they watched the images, pictures, text, animation, and video in the lessons and listened to the teacher's explanation. They added that they did not use technology and no technologies existed for them. They expressed that they were not allowed to choose what they wanted to watch on the screen or to do and share their own thoughts and ideas.

Teacher 4 (Case 4)

In the observed lessons, teacher T4 used a laptop and projector while using the digital content. The teacher incorporated digital content by showing and explaining the slides one after another to the students. However, access to technology did not align with the diverse content areas or meet the individual needs of students. Furthermore, there were no technologies for the students in the classroom.

In the post-lesson interview, teacher T4 reported that she used his own created digital content in her lessons. She used laptops and projectors to display the content, explaining each slide individually to the students. She pointed out that access to digital content varied on the stages of the lesson as per slides but did not vary between diverse content areas and students' individual needs. However, the teacher agreed that she could create a collaborative learning environment using diversified and challenging mathematical tasks in the lesson. Furthermore, the teacher blamed the lack of success on the physical constraints of the classroom, limited class time, and high student-to-teacher ratios. She reported that they had no technologies for the students to use in the classroom.

In the focus group discussion with the students, they expressed that they watched the images, pictures, text, and animation in the lessons and listened to the teacher's explanation. They added that they did not use technology and no technologies were available for them. They expressed that they were not allowed to choose what they wanted to watch on the screen or to do and share their own thoughts and ideas.

Teacher 5 (Case 5)

In the observed lessons, teacher T5 used a laptop and projector in his lesson while using digital content. The teacher incorporated the digital content showing and explaining the slides one after another to the students. However, access to technology did not respond between diverse content areas and student's individual needs. There were no technologies available for the students in the classroom.

In the post-lesson interview, teacher T5 acknowledged that he collected the digital content from the Shikkhok Batayon which he used in his lessons. He had no time to develop the digital content for his lessons. He used laptops and projectors to display the content, explained each slide individually to the students. He pointed out that access to digital content varied on the stages of the lesson as per slides but did not vary between diverse content areas and student's individual needs. However, he agreed that he could create a collaborative learning environment using diversified and challenging mathematical tasks in the lesson. Furthermore, the teacher blamed the lack of success on the physical constraints of the classroom, limited class time, and high student-

to-teacher ratios. The teacher reported that they had no technologies for the students to use in the classroom.

In the focus group discussion with the students, they expressed that they watched the images, pictures, text, animation, and video in the lessons and listened to the teacher's explanation. They added that they did not use technology and no technologies existed for them. They expressed that they were not allowed to choose what they wanted to watch on the screen or to do and share their own thoughts and ideas.

Dimension- Access to Technology (Technology Infrastructure and Uses of Technology)

4C.1.4.2 The Integration of the Five Cases: Ten (10) Observed Lessons, Ten (10) Post-lesson Interviews with teachers, and Ten (10) FGDs with students

4C.1.4.2.1 Ten (10) Observed Lessons

In this section, all the teachers incorporated multimedia into their lessons presenting the slides one by one of the digital contents. Four teachers used their own created digital content and one teacher collected the digital content from the teacher's portal Shikkhok Batayon. He acknowledged that he could make the digital content himself but he did not have enough time to do it. T2 was also capable of using the software GeoGebra and Smartboard in the lesson. However, all these five teachers were not proficient in integrating digital content into their instructions with the pedagogical alignment. They accessed technology just by showing the slides one by one and explaining them to the students, but they did not respond to diverse content needs and students' individual needs. The students were not allowed to choose what they wanted to watch on the screen or to do and share their own thoughts and ideas in the multimedia classroom using digital content. Also, they had no technologies for students to use in the classrooms.

4C.1.4.2.2 Ten (10) Post-Lesson Interviews with Teachers

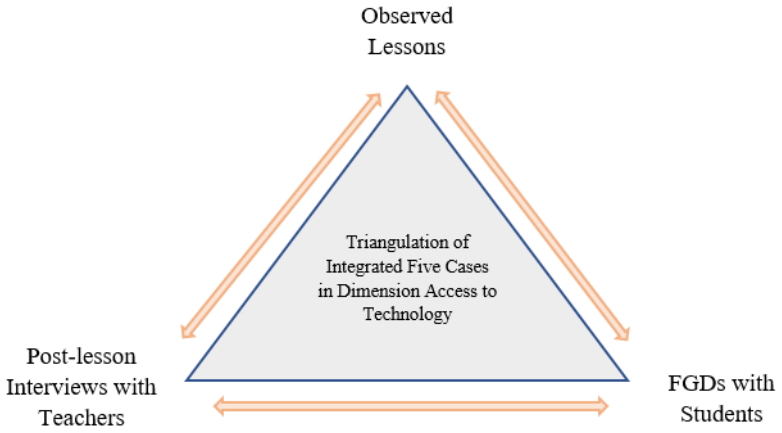
In the subsequent discussion, all the teachers acknowledged that they could create a collaborative learning environment using diversified and challenging mathematical tasks in their lessons. However, the teachers blamed the lack of success on the physical constraints of the classroom, limited class time, and high student-to-teacher ratios. They expressed concerns about the lack of technology available in the classrooms, which hindered opportunities for collaboration and observational learning. Without access to interactive tools and resources, students were unable to engage in group projects or benefit from modern teaching methods that could enhance their learning experience.

4C.1.4.2.3 Ten (10) FGDs with Students

In the 10 focus group discussions (FGDs) conducted with students, the students expressed their feelings that they watched the images, pictures, text, animation, and video in their lessons and listened to the teacher's explanation. They also added that they did not use technology because there were no technologies available for them in the classrooms. They claimed that they were not allowed to choose what they wanted to watch on the screen or to do and share their own thoughts and ideas.

Dimension- Access to Technology (Technology Infrastructure and Uses of Technology):

4C.1.4.3 Triangulation of Integrated Five Cases: Observed lessons, post-lesson interviews with teachers, and FGDs with students



To do a triangulation, it appeared that the trained mathematics teachers were confident about developing and using digital content in their lessons. However, in the lesson observed, the use of digital content was not interactive and innovative. Discussions with the teachers revealed that they were confident of their proficiency using digital content but they acknowledged that they were not able to use diversified and challenging tasks with pedagogical alignment. Furthermore, the teachers blamed the lack of success on the physical constraints of the classroom, limited class time, and high student-to-teacher ratios. From the consequent discussion with students, it was evident that no technologies were available for the students in the classrooms. They claimed that they were not allowed to choose what they wanted to watch on the screen or to do and share their own thoughts and ideas.

4C.2 Chapter Summary

The findings of the study indicate that teachers primarily view digital content as a tool for presenting mathematical facts and concepts, rather than as a means for promoting deeper learning experiences. They believe that students learn mostly from teacher explanations and that digital content can enhance student engagement through visual aids. However, when students were asked to explain what they enjoyed about digital content, their responses were vague and lacked detail. While they may enjoy watching digital content, such as images, animations, and videos, they may not fully understand or comprehend the material presented.

An analysis of the post-lesson discussions across the five cases revealed that teachers mostly employed traditional lecture methods while utilizing digital content, which often failed to foster deeper learning experiences for students. While teachers acknowledged the necessity of integrating real-world examples, diverse and challenging mathematical tasks, and appropriate animations and images into their lessons, they recognized that their current approaches were not effectively achieving these goals. Moreover, the discussions highlighted the significance of developing learner-centered, collaborative, and interactive learning environments through the use of digital content. However, teachers faced numerous challenges that hindered their ability to fully implement these pedagogical strategies. Among these challenges were students' tendencies to seek immediate solutions, which limited opportunities for exploration and critical thinking. Additionally, constraints such as time limitations, large class sizes, and heavy workloads further complicated lesson planning and execution. Teachers pointed out that many of their students came from low socioeconomic backgrounds, which could impact their engagement and resources available for learning. The pressure to complete the syllabus often left little room for incorporating innovative teaching methods, while discipline issues in the classroom created further obstacles to effective teaching. One teacher specifically noted a lack of adequate training in integrating information and communication technology (ICT) with pedagogical practices, expressing a desire for professional development opportunities to better equip them in this area. Overall, although teachers recognized the benefits of using digital content in their teaching, they faced several challenges. These included sticking to traditional methods, dealing with specific issues in their environment, and not aligning their teaching methods with new approaches. As a result, they found

it difficult to create the engaging and interactive learning experiences they wanted for their students.

In the analysis of the focus group discussions under all the dimensions, students expressed their enjoyment of watching digital content and listening to the teacher. However, they noted that they were not encouraged to connect their prior experiences with existing knowledge, nor were they sufficiently challenged to apply creative thinking in the learning process. Much of their lesson time was spent passively viewing images on the screen. Their comments reflected frustration and distraction caused by the digital content, with some students specifically mentioning how animated images and sequences hindered their focus and comprehension. One student expressed a desire to share their thoughts but felt uncomfortable doing so, while others indicated a preference for new and varied mathematical activities over procedural tasks. Furthermore, many students admitted to a lack of motivation for engaging in procedural tasks and found the problem-solving process unenjoyable, which contributed to their overall disinterest in the subject. They often did not have opportunities to struggle with challenging mathematical concepts or problems, preventing them from developing their own mathematical ideas and critical thinking skills. Additionally, students were not encouraged to work together to build on each other's ideas through inquiry-based learning. Instead, the mathematical tasks were largely procedural, requiring students to work individually using rules or formulas. This may suggest a deficiency in confidence or understanding of the material being presented.

Overall, the study's findings suggest that while digital content may be engaging, it may not necessarily lead to deeper learning or comprehension of mathematical concepts. These results underscore the critical need for comprehensive teacher training and pedagogical support to facilitate the effective use of digital resources. Teachers must be equipped with the skills and strategies necessary to integrate digital content meaningfully into their instruction, ensuring that it fosters not just engagement but also substantial learning experiences that enhance students' comprehension and analytical capabilities in mathematics.

4C.3 Key Findings

RQ 1: How do teachers develop their understanding of digital content in mathematics from the digital content development training programs?
RQ 2: How do teachers use digital content in secondary mathematics classrooms?
RQ 3: How does the use of digital content affect the secondary mathematics teaching-learning process?

The significance of the comprehensive investigation lies in the fact that the researcher discovered nearly identical findings across these five different cases, and the following findings emerged:

1. The five (5) teachers believed that digital content has attracted the students to be attentive and enjoy watching the images, animations, and videos on the screen. However, the teachers were unaware of integrating pedagogy strategies into their lessons. They have all developed their understanding of digital content in mathematics incorporating text, image animations, and videos to show and describe it to the students using the digital content of PowerPoint presentations.

2. The five teachers primarily relied on traditional lecture methods while incorporating digital content of PowerPoint presentations and other software into their mathematics lessons. Additionally, they lacked the skills to create well-structured digital content for mathematics lessons. The mathematical tasks the teachers employed were often neither challenging nor varied and did not provide opportunities for students to engage in creative and innovative thinking. Furthermore, the classroom environment in these five cases did not provide sufficient physical space or effective technological infrastructure to support the teaching-learning efforts.

3. The five teachers struggled to integrate digital content effectively into their lessons in a way that aligned with appropriate pedagogical practices, which often did not promote deeper learning experiences for students. Consequently, students missed the opportunity to develop a deeper understanding of concepts, as well as critical thinking and problem-solving skills, which are essential for enhancing their comprehension and analytical capabilities in mathematics.

Chapter Five

Discussion and Recommendation

5.1 Discussion

This study provides an in-depth exploration of the real situation of secondary mathematics classrooms where teachers use digital content to enhance their mathematics lessons in multimedia classrooms (MMCs). The aim is to investigate the effective use of digital content resources in secondary mathematics classrooms, focusing on the integration of ICT, pedagogy and mathematics content after getting the training of digital content development training programs. Furthermore, this research provides valuable insights into using the digital content of PowerPoint presentations as teaching and learning tools and identifying the potential areas for improvement in their mathematics instructions.

In this section, the discussions are organized around the three main findings of the study. Each finding is examined in detail, allowing for a comprehensive understanding of its implications. Additionally, the research questions are explored with the existing literature, which helps to validate and contextualize the findings. By aligning the discussions with the key findings and relevant literature, this section aims to provide a thorough analysis that underscores the significance of the research.

5.1.1 RQ 1: How do teachers develop their understanding of digital content in mathematics from the digital content development training programs?

The first key finding, based on the triangulation of teacher-educator interviews, teacher interviews, and document analysis (training manual) on teachers' understanding of digital content in mathematics lessons reveals that teachers can create digital content for mathematics lessons, but may not always effectively integrate pedagogy to promote deeper learning experiences for students. However, it has appeared that teachers have gained a significant amount of valuable ICT skills from digital content development training. From the perspective of the teacher educators, it

is evident that while teachers are confident in developing digital content aligned with their lesson plans and have seen a boost in student enjoyment and engagement, they struggle to combine effective teaching methods with the use of technology. In the interviews, all the teachers emphasize that digital content is primarily used to showcase multimedia elements, including images, texts, videos, and animations, to make lessons more effective for students, rather than focusing on interactive and innovative lessons that integrate pedagogy. The teachers explain that while they incorporate digital content into their lessons and students enjoy the visual elements such as images, animations, and videos, there may be a lack of emphasis on the meaningful integration of technology to enhance mathematical learning. However, teachers recognize the value of using digital content to keep students engaged and attentive during lessons. According to the sessions of the training manuals, the learning materials do not delve deeply into the integration of pedagogy with ICT, which could have provided a more comprehensive understanding and application of digital content.

A recent study by Viberg et al. (2023) highlights the importance of teachers' thorough understanding of digital tools in mathematics education. The findings suggest that teachers should not only learn about digital tools but also carefully design learning situations to create a more effective and engaging learning environment for students. To enhance mathematics learning, integrating technology in classrooms requires fostering a culture where secondary school teachers are encouraged to combine their knowledge of effective technology integration with the mathematics curriculum and their pedagogical skills (Yanuarto et al., 2023). Hennessy et al. (2010) explain that effective teacher education and continuing professional development are the two of the most important supports for ICT integration into teaching-learning practice. According to Vandeyar & Adegoke (2024), teachers need to adapt their pedagogical approaches to effectively integrate technology into their teaching practices by acquiring relevant knowledge and skills. However, the trained teachers' approach to integrating ICT into their mathematical lessons appears to be limited, as they have not adopted pedagogical approaches that effectively integrate technology to enhance student learning. They have developed an understanding of incorporating digital content in mathematics by using text, image animations, and videos in PowerPoint presentations to show and describe concepts to the students, but this approach may not empower the learners to develop a deeper mathematical understanding. Habler et al., (2016) emphasize that

teacher education programs should prioritize the integration of technology into teaching and learning practices, focusing on developing teachers' pedagogical knowledge and skills rather than just technical skills. On the contrary, the training sessions in the training manuals primarily focus on building the participant teachers' foundational ICT knowledge and skills, which is crucial given their limited understanding of ICT at the time. The training manual aims to equip the teachers to create digital content using PowerPoint presentations, aligning it with their lesson plans and providing opportunities for practice and improvement through simulations and feedback from teacher educators. However, it is noted that the training does not include sessions dedicated to in-depth learning and practice of pedagogy integration in the lessons. This lapse may have challenged the teachers to apply their newly acquired ICT skills pedagogically. Moreover, the trained teachers did not receive any monitoring, mentoring, or observation from the trainers following the completion of their training. Fry et al. (2025) highlight that successful mentoring, coaching, and observation helped teachers alter their preconceived views and beliefs about inquiry and effective pedagogies, especially when the relationships were built on trust. Lotter et al. (2014) also emphasized that building trust in learning communities with school-based instructional trainers is essential for teachers to feel comfortable in sharing their strengths and weaknesses, which supports teachers in implementing changes in classroom practice.

This triangulation may have resulted in teachers being able to develop digital content, but not capable enough integrating pedagogy in developing and using it in a way that promotes deeper learning experiences for students. It appears that while the teachers have a basic understanding of using digital content like texts, images, and online materials in their lessons, they may not be fully aware of how to effectively integrate these resources with appropriate pedagogical strategies. This gap in understanding can limit the potential benefits of using digital content in the classroom. So, to enhance the teacher's understanding of mathematics digital contents in the lessons, exploring and practicing a strong focus on pedagogical strategies would be beneficial. This would enable the teachers to better understand how to integrate technology meaningfully into their mathematics lessons. Nago & Sang (2024) note that it is crucial to develop teachers' capacities and expertise through Professional Learning Communities (PLCs) to enhance their confidence and competence in integrating ICTs effectively into their instructional practices. Vieira and Pedro (2023) suggest

that policymakers should focus on improving the use of technology in their curriculum so that future teachers can master digital tools, pedagogical knowledge, and teaching skills.

5.1.2 RQ 2: How do teachers use digital content in secondary mathematics classrooms?

The second key finding, based on the pre-lesson interviews with the five teachers and in-depth observations of ten mathematics lessons, is analyzed through the lens of three components: pedagogy, learning context, and access to technology- it can be concluded that the teachers do not facilitate opportunities for students to participate in meaningful problem-solving tasks or enhance their grasp of mathematical concepts by using digital tools. All five teachers employ a traditional lecture method, using digital content in the form of PowerPoint presentations. A recent study by Jahangir et. al. (2021) also cited that Bangladeshi educational institutions heavily rely on traditional methods and written examinations, despite the potential of digital technologies to enhance learning; however, poor infrastructure and affordability pose challenges. The analysis of the classroom observations reveals that teachers often fail to establish an environment where students can grapple with challenging concepts independently using their own strategies. Even with the integration of digital content, the instructional approach mostly remains teacher-centered. Teachers typically present slides in a sequential manner, largely reading from them and providing explanations for the images and videos shown, which significantly restricts student interaction. The activities students engage in mainly center around recalling mathematical facts presented in the slides; however, these activities do not promote meaningful engagement. Consequently, students tend to adopt a passive role, primarily observing and listening to the teacher throughout the lessons. Furthermore, teachers struggle to visualize complex mathematical concepts and do not cultivate an environment that encourages student innovation and idea generation. Genuine discussions about mathematical concepts are noticeably absent in the lessons. While teachers do occasionally ask procedural questions, students typically respond by recalling steps and formulas rather than exploring deeper conceptual understandings. There is a lack of development in creating a classroom atmosphere where students can make mistakes, which would allow them to formulate arguments and the teachers could more effectively guide students in constructing their mathematical ideas and enhancing their understanding.

In line with Uzun (2024), the study found that classroom discussions were often individualistic and did not possess a robust argumentative structure in mathematics instruction. Given that teachers play a crucial role in designing the learning environment, it is essential for them to understand the dimension of learning. They should also use a variety of activities and methods to keep students engaged and help them understand the material better. Liljedahl et al. (2016) noted that verification in mathematical problem-solving serves not only to check correctness, but also to re-engage with the problem at the level of details. It allows the solver to examine ideas and concepts more closely, refining their understanding during the unconscious work. Stapf & Martin (2019) explain that teachers can become more innovative in their teaching practices and envision themselves as future role models for other teachers and students. They comment that technologies paired with mathematical concepts should be chosen strategically, as they can assist students in engaging and understanding often difficult or abstract mathematical content. The proper use of ICT in mathematics can increase student achievement and motivation and encourage them to become active participants in the classroom (Raines& Clark, 2011).

The analysis of the PowerPoint presentation slides reveals that they are largely filled with excessive and unorganized text, cluttered images, unnecessary animations, textbook excerpts, and mathematical formulas, with only a few interactive mathematical tasks included. Furthermore, the interactive mathematical tasks using digital content are found to need refinement and to incorporate diverse and challenging mathematical tasks that make the students interactive and innovative. Zubairi et. al. (2021) indicate that there is a need for teacher professional development to improve digital content creation skills in Bangladesh, as well as a lack of understanding of how to use technology to manage diverse classrooms. Lester (2013) emphasizes that students need to consistently work on challenging tasks over time to improve their problem-solving skills and they must also have opportunities to tackle diverse types of problems. It is essential for teachers to incorporate digital technologies into their lessons to create interactive, dynamic, contextualized, and motivating learning experiences where students can explore new applications of mathematical concepts and ultimately transform the classroom environment (Souza et al., 2023). Bicalho et al. (2023) found in their study that analyzing teachers' use of ICT, specifically how they integrated technologies into their teaching practices, can lead to a greater focus on pedagogical intentionality.

The trained mathematics teachers expressed confidence in their ability to create and utilize digital content for their mathematics lessons during the discussions in the pre-lesson interview. However, the subsequent classroom observations highlighted a gap in their ability to integrate pedagogical practices effectively. The analysis of the interview data further revealed a lack of understanding and implementation of pedagogical integration within their classrooms. Specifically, they struggled to develop and effectively use of well-designed digital PowerPoint presentations that included real-world examples, challenging tasks, complex mathematical problems, as well as appropriate animations and images. Raines & Clark (2011) emphasized the importance of well-designed PowerPoint presentations in mathematics classrooms, as they provide different learning styles and can enhance student learning. Kresnadi (2018) explained in his research that the PowerPoint presentation provided a fun learning experience for students, the students were invited to jump directly into the real world by viewing images, videos, and animations. According to the recent study of Putra and his team (2023), teachers use digital tools like PowerPoint to make learning more exciting. This has been shown to help students learn more effectively, be more creative, and stay focused. The interactive content makes lessons more enjoyable and keeps students from getting bored. Ogochukwu (2010) also commented that the classes were to be more interesting and exciting with multimedia as the combination of text, images, sound, video, and animations that offered remarkable opportunities and challenges for the mathematics teaching-learning approach. In these five cases, the classroom space and furniture were not conducive to these types of learning activities, which can hinder the effective use of digital content and pedagogy in the classroom. The classroom must be equipped with technology resources and skills to provide learning experiences effectively (Voogt & Knezek, 2008). According to Kennedy's study in 2023, teachers need to be equipped to instruct and facilitate learning in ICT-enabled classrooms, where effective pedagogy is crucial for high-quality teaching and learning practices.

The use of mathematical ICT seemed to be limited to simply displaying information, with no significant pedagogical integration. The teachers must possess the skills facing the potential of information and communication technology to foster problem-solving, collaborative, creative learners who can apply their knowledge effectively in real-world situations (UNESCO, 2011). This aligns with the TPACK and UNESCO ICT CFT model, as the teachers seemed to lack the

ability to integrate technological, pedagogical, and content knowledge in their lessons. The digital content was not being used effectively to enhance learning or promote student engagement in all five cases. This is due to a strong lack of teachers' understanding about developing and using digital content in the mathematics lessons as well as due to not supportive physical space with technology infrastructure. The strategy of using technology can help to facilitate the students to improve their skills establishing a more active collaboration with innovative and critical thinking (Habler et al., 2016). Incorporating effective pedagogical practices, supportive physical spaces and student-centered technology infrastructure in the lessons will ultimately lead to more engaging, interactive, and innovative mathematics lessons that maximize the potential benefits of using digital content in the classroom. The scores in the observation guideline were mostly the same in all ten lessons of the five cases, even though they were selected by multiple variation techniques across Bangladesh. The total obtained scores were 48L, 2M, 160N, and no scores for H out of 210; where L for low, M for medium, H for high, and N for not done. It shows that 160 segments out of 210 have not been done in the lessons. The fact that all teachers received the same scores in every lesson suggests a lack of variation and creativity in their teaching approaches to cultivate deeper learning experiences for students.

5.1.3 RQ 3: How does the use of digital content affect the secondary mathematics teaching-learning process?

The third key finding, based on the combined evidence from classroom video data, the teacher's post-lesson interview and focus group discussion with the students led to the conclusion that students did not derive significant benefits from the digital content in terms of problem-solving, conceptual development, and critical thinking in mathematics. This finding suggests that the current digital materials and instructional strategies may not be effectively supporting students in deepening their understanding and application of mathematical concepts.

However, the teachers agreed in their post-lesson interviews that there were possibilities in their lessons to provide opportunities for students and to engage them with mathematical tasks by using digital content to make the lesson interactive and innovative. They also noted that collaborative learning would require more time and that the duration of class periods would need to be increased.

Shifting classroom culture to foster student participation required a lengthy time frame, which allowed for critical reflection on teacher beliefs about student abilities and enabled teachers to engage in new instructional practices, facilitating their own productive struggle rather than relying solely on guidance (Fry et al., 2025; cited in Hunter, 2014; Fitzgerald et al., 2021; Witherspoon et al., 2021). However, it is concerning that all five teachers tended to blame external factors, such as students' family backgrounds, class loads, students' needs, completing the syllabus, and time constraints, for not making their lessons interactive and innovative. Furthermore, there was a lack of technological support to facilitate student-led learning or encourage independent exploration. As a result, the use of digital content did not have a significant impact on the student's learning experiences. The classes resembled traditional lecture-based instruction in mathematics, with the digital content serving merely as supplemental resources in the form of PowerPoint presentations. Overall, the use of technology in these classes did not enhance the student's learning style or promote deeper engagement with mathematical concepts. Analysis of the focus group discussions revealed that while students enjoyed watching digital content, they also expressed frustration and often found themselves distracted by it. Their comments indicated that animated images and sequences during class interfered with their focus and comprehension. Overall, students reported that they were not deeply engaged in the digital material, struggled with mathematical tasks, and did not provide their own explanations. Additionally, some students admitted that they felt unmotivated to engage with the procedural mathematical tasks, which further impacted their overall motivation. Overall, the students expressed a lack of enjoyment and engagement with the mathematical tasks, and many did not attempt to solve them or collaborate with peers. This could indicate a lack of confidence or understanding of the material being taught.

Stark (2019) emphasized that teachers must understand that while a specific problem context may initially engage students, repeated exposure can diminish its effectiveness. Students generally prefer new and diverse problem contexts. Additionally, allowing students to have a say in their classroom experiences can enhance their sense of empowerment and improve their learning (Job, 2018). Teachers play a crucial role in student-centered mathematics classrooms in stimulating critical thinking through questioning, facilitating and guiding mathematical investigations, and creating an environment that encourages collaboration, discussion, debate, and knowledge construction among students. (Anthony et al., 2015; Artigue & Blomhoj, 2013; Barron & Darling-

Hammond, 2010; Fielding-Wells et al., 2014; Goos, 2004; Scardamalia & Bereiter, 2010; Yackel & Cobb, 1996, as cited in Fry et al., 2025). Furthermore, Higgins, Xiao, & Katsipataki (2012) explained that the students will benefit if the activity of technology is effectively aligned with the appropriate pedagogical frame. The strategy of using technology can help to facilitate the students to improve their skills establishing a more active collaboration with innovative and critical thinking (Habler et al., 2016). Das (2019) explained in his research that digital contents are the most powerful tools used for problem-solving, conceptual development, and critical thinking in mathematics. Drijvers & Sinclair (2024) suggested that digital technology in mathematics education has become more comprehensive and interconnected, focusing not only on the digital technologies themselves but to consider their relationship with teaching practices and assessment methods. To empower learners with a deeper understanding and develop their higher-order skills, teachers should know to integrate powerful technology, appropriate pedagogy, and rich content in their teaching practices (Mishra & Koehler, 2014). Holden & Rada (2008) found in their study that teachers had come to realize the value of using technology to enrich their students' learning experiences. However, teachers may still rely on traditional teaching methods and be neutral about technology being beneficial for improving mathematics class activities. This is important to reform the pedagogical ideologies to engage students with innovative work, project work, collaboration, and active participation for effective use of technology in education (Almas & Krumsvik, 2008). Aggarwal and Bal (2020) emphasized the importance of ICT integration as a necessary tool for both students and teachers. They suggested a range of ICT applications that can enhance learning and teaching, including smart classrooms and social media platforms. GeoGebra is an interactive, web-based software that integrates geometry and algebra. It is created as an educational tool, it offers diverse resources for learners and teachers alike (Hohenwarter & Jones, 2007). In a recent study, Yildiz & Arpaci (2024) found that participant teachers considered mathematical software such as GeoGebra essential for their professional development, valued it for mathematics instruction, and intended to integrate it into their practice. Furthermore, effective training and support aligned with the TPACK model can enhance their motivation to incorporate GeoGebra into their teaching toolkit. Dasari et al., (2024) also emphasized the importance of a balanced approach, proposing that ChatGPT can also be a valuable tool in the learning process when used with teacher guidance.

From the discussion above, five key areas emerge where further action could be considered. First, mathematics teacher training might be designed to ensure the effective use of ICT in aligning mathematical content with strong pedagogical strategies, thereby making it easier for teachers to understand this relationship; Second, possibly changes in the classroom that would support more effective use of ICT resources; Third, class time duration might be extended for effective collaborative learning; Fourth, diversified tasks with ICT resources might be incorporated into the mathematics curriculum and textbooks, accompanied by a variety of challenging mathematical tasks that foster creativity and innovation in students; Fifth, a strong monitoring and mentoring system might be established to support the trained teachers in transforming their beliefs about teaching mathematics while adjusting and improving classroom practice integrating ICT with pedagogical strategies.

5.2 Recommendations

1. Training for Mathematics Teachers: Professional development training for mathematics teachers should be designed to integrate mathematical digital resources and software, emphasizing effective pedagogical strategies. This approach should be easily comprehensible, empowering teachers to leverage mathematical ICT resources in their instruction effectively.
2. Classroom Environment and Design: The classroom environment can be enhanced to foster effective use of digital content and software in mathematics classrooms by creating learning spaces that promote student collaboration and ensure access to essential technology for students and teachers.
3. Extending Class time duration: The duration of mathematics class time can be extended to at least one hour to foster student participation and collaboration by integrating digital resources and effective pedagogies in mathematics.
4. Incorporating diversified tasks with ICT resources into the mathematics textbooks: The mathematics textbooks and curriculum could be modified to incorporate diversified and challenging mathematical tasks, allowing students to engage with mathematics digital

content and software, develop problem-solving skills and tackle a variety of complex mathematical challenges. Additionally, comprehensive guidelines should be provided for effectively using ICT resources in mathematics classrooms.

5. Monitoring and Mentoring System: Establishing a robust monitoring and mentoring system by the trainers can foster trust within learning communities and provide essential support for trained teachers as they implement changes in classroom practices. This system should include regular observations, constructive feedback sessions, and collaborative planning opportunities to ensure that trained teachers feel supported and empowered in their transition to student-centered mathematics teaching with effective pedagogical strategies.

The findings can significantly contribute to policy initiatives aimed at designing ICT training courses for mathematics teachers, with a strong focus on establishing pedagogical alignment. Policymakers should emphasize the creation of technologically enhanced classroom environments and extend the class time duration that promote effective student participation and collaborative learning. Moreover, the integration of mathematical tasks with ICT resources into the textbooks and curriculum is essential, encouraging the implementation of diversified and challenging tasks that engage students in critical thinking and problem-solving. A strong and systematic monitoring and mentoring system can be established to support the trained teachers in making a relatively smooth change in their traditional teaching beliefs after training. By addressing these areas, policymakers can foster a more effective use of technology in mathematics classrooms to enhance student learning and prepare students for the demands of the future.

5.3 Contribution to Policy

- The findings of the study may assist policymakers in designing the ICT training courses for mathematics teachers. These training courses should be simplified to help mathematics teachers better understand the concept and effectively utilize digital content and software, ensuring alignment with strong pedagogical strategies.

- The policymaker should focus on creating supportive physical spaces and student-centered technology infrastructure in classrooms (multimedia projector, whiteboard, Smartboard, movable chairs, desks, and adjustable light).
- The policymaker should consider increasing the duration of mathematics lessons to a minimum of one hour to facilitate collaborative student learning using mathematical ICT resources with effective pedagogical strategies.
- Using the study's findings, curriculum experts and policymakers can modify the mathematics textbooks and curriculum by integrating mathematical ICT resources with the content and incorporating diversified and challenging mathematical tasks. Additionally, they can provide comprehensive guidelines for effectively using ICT in the mathematics teaching-learning process.
- The policymaker should emphasize establishing a strong monitoring, mentoring and observation system by the trainers that specially supports and empowers the trained teachers to reconstruct their pedagogical and ICT practices through various activities including collaborative planning, regular feedback exchanges and making actionable plans.

5.4 Limitations of the Study

This study was conducted with trained mathematics teachers in secondary schools from urban, semi-urban, and rural areas in Bangladesh who had received digital content development training programs. Qualitative data was collected from diverse and authentic settings of secondary mathematics classrooms, providing a rich and contextual understanding of the phenomenon. The study aimed to explore how teachers develop their understanding from the training programs and how they utilize digital content in mathematics classrooms at the secondary level of education. However, it is essential to note that this qualitative study was conducted with a non-representative sample of trained teachers, limiting the generalizability of the findings to the broader population of teachers. Therefore, the results may not provide a complete or representative picture of the targeted practice.

5.5 Conclusion

The researcher's aim at the beginning of this study was to explore how ICT is being utilized in current secondary mathematics classrooms in Bangladesh. It was positive to see that all teachers were able to use digital content, such as PowerPoint presentations, but this was limited to emphasizing the integration of digital content to enhance mathematical learning outcomes. The students enjoyed the visual elements, such as images, animations, and videos, and the teachers' understanding was to incorporate text, images, animations, and videos to show and describe them to the students, rather than using effective learning strategies. The digital content development training program was designed with mostly basic ICT skills. It became clear that basic ICT skills and in-depth pedagogical alignment with learning content posed difficulties for participant teachers to learn both simultaneously. Mastering both areas simultaneously could be overwhelming, and it was essential to approach this kind of education with a clear understanding of the participants' needs and capabilities. The teachers could not create effectively designed digital content for mathematics classrooms that aligned with pedagogical approaches. As a result, they failed to create opportunities for students to engage with mathematical digital materials. Consequently, students did not benefit from increasing their deeper understanding, making connections and applying mathematical concepts. The in-depth classroom observation revealed that mathematical tasks or problems using digital content were mostly procedural and focused on recalling formulas. The teachers were not capable of using diversified and challenging mathematical tasks with pedagogical alignment to make lessons interactive and innovative. Moreover, the classroom space was not designed for collaborative learning, and the furniture was not easily adjustable in a technologically enhanced classroom. However, teachers acknowledged that they could make lessons interactive and innovative by using diverse and challenging tasks in their presentation slides. Nevertheless, they attributed their lack of success to various constraints, including limited class time, high student-to-teacher ratios, difficulties in managing classroom behavior during group work, student demands for solutions or information, pressure to prepare for examinations, the need to complete the syllabus, student family background, as well as classroom indiscipline issues.

The results from the analysis of five cases highlighted the need for more training and support for mathematics teachers to help them better understand how to use digital content in a way that

supports student learning and engagement through more interactive and student-centered approaches. To enhance the overall effectiveness of the training, incorporating sessions that explore and practice pedagogy integration strategies would be beneficial. The researcher envisions that training courses focused on the use of digital mathematical content and various software applications in mathematics classrooms need to be simplified to help teachers effectively understand and utilize these tools. The training sessions could involve discussing various mathematical technology tools and their potential applications in mathematics education, analyzing real-life examples, and successful technology integration aligning with pedagogy. This would enable teachers to better understand how to integrate technology meaningfully into their mathematics lessons while maintaining a strong focus on pedagogical strategies and content knowledge. This would lead to more engaging, interactive, and innovative mathematics lessons that maximize the potential benefits of using digital content.

In the future, it would be desirable to see teachers becoming aware of proper ICT implementation in mathematics classrooms. They would be competent in aligning pedagogy with their mathematics lessons using diverse and challenging mathematical tasks with digital content and software, ensuring that students engage collaboratively with innovative and creative problems. There would be supportive physical space and effective technology infrastructure in classrooms. Students could use ICT as a tool to discover things, solve problems, or understand what is happening; they could use graphing calculators or plotters to solve equations graphically, draw diagrams, and analyze collected information with a deeper understanding (Budhathoki, 2023). Teachers empower students to recognize their individual strengths and weaknesses in mathematics learning, a critical component of effective mathematics teaching that fosters student growth and development (Alfageh et al., 2024). Moreover, teachers' innovative abilities play a crucial role in nurturing learners' potential by imparting new knowledge and preparing them for lifelong learning in a constantly changing and transforming society (Devetak et al., 2010). The students would be equipped with critical and creative skills and in-depth mathematical concepts knowledge needed to succeed in an increasingly digital world.

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Dhaka University Institutional Repository

Appendix A

Blank Consent Letter from the Supervisor

শিক্ষা ও গবেষণা ইনস্টিটিউট
ঢাকা বিশ্ববিদ্যালয়
ঢাকা-১০০০, বাংলাদেশ

Institute of Education and Research
University of Dhaka
Dhaka-1000, Bangladesh
Fax: +880-2-9667222
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27 July 2022

To

The Principal / Headmaster

.....

Subject: **Request for providing support to a PhD student of IER, University of Dhaka**

Dear Sir,

Receive greetings from the Institute of Education and Research (IER), University of Dhaka. I would like to inform you that my PhD student Ms Razia Begum, Lecturer, Teachers' Training College Dhaka needs to collect data from your Institution for her study titled "**Digital Content Development and their uses in Secondary Mathematics Classroom.** Ms Razia Begum needs to interview Mathematics teachers of secondary level, observe Mathematics class and conduct a Focus Group Discussion with students. I request you and your colleagues to provide her with all kinds of support in this regard. Please feel free to contact me if you have any questions regarding her research work.

Thanking you,

Mohammad Nure Alam Siddique
Professor
Institute of Education and Research, University of Dhaka
Mobile: 01733544037
Email: siddique.mna@du.ac.bd

Scanned with CamScanner

Appendix B

Blank Informed Consent Form

T1: Participant teacher of Case-1

Razia Begum
Institute of Education and Research
University of Dhaka
Dear Teacher,

RE: INFORM CONSENT

As a research student at the University of Dhaka, I am conducting a study as part of the requirements for my Doctorate in Education. This research investigates the effective use of digital content in mathematics teaching and learning to enhance students' mathematical skill. I would be grateful if you would sign below to indicate your consent for the information provided by you and the students in your class to be used in the write-up of this research study.

As a participant in this study, you have the right to respond to any number of questions, whether many or few, and to the extent that you feel comfortable. You may also request the removal of some or all data from the study at any time during the research process or within 10 days after the administration of a specific research instrument.

I want to assure you that any identifying information collected, including details about yourself, the students, and the school, will be kept confidential and will not be included in the research report. Your information will not be used or shared without your explicit prior consent.

If you have any concerns or questions regarding any aspect of this study, please feel free to reach out to me at razarfin@gmail.com, and I will be more than happy to assist you in any way I can.
Thank you for your participation; your help is greatly appreciated.

To confirm your agreement with the terms of participation outlined, please respond with 'I agree'.

Signature: Date:

I agree to the information I provide, and the information regarding the students being used in the write-up of this study.

Signature: Date:

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Appendix C

Interview Schedules for Teacher Educators

Name:

Age:

Sex: Male/Female

Institution:

Experience:

1. How many years have you been working as a trainer of digital content development training?
2. How different types of digital content training programs and projects are there?
    a) In your institution:
    b) Outside your institution: In-house training or others….
3. How effective do you think the training was (Policies/objectives)? And why?
4. What are the basic concepts of digital content development training programs? How do the trainees develop their concept of digital content in mathematics?
5. What types contents the trainees learn in the digital content training programs and how?
    a. ICT
    b. Pedagogy
    c. Content
    d. TPACK
6. What principles do the trainees follow to develop mathematics digital content in the training session?

7. What do you think about the learning content of the training sessions? Are there any challenges in developing digital content that integrates pedagogy (during develop their own digital content and its presentation)?
8. Do you think using digital content in mathematics classrooms is important for effective teaching? How?
9. Could you please explain your experience about an effective mathematics lesson using digital content?
10. What changes would you like to see in a training program for mathematics teachers?
11. Have you conducted any refresher courses for the trained teachers? Have you ever monitored, mentored or observed the trained teachers?
12. What changes would you like to see in math curriculum and math teaching with the use of DC/technology?

Appendix D

Interview Schedules for Trained Mathematics Teachers

Name:

Age:

Sex: Male/Female

Institution:

Experience:

1. What different types of ICT materials do you use personally?
2. What types of ICT do you use in the mathematics lessons?
3. Where did you learn these ICT skills for use in the mathematics lessons?

4. Where did you get the training about digital content in mathematics lessons and when, what are the objectives?
5. What contents did you learn from the training programs?
6. What do you mean by digital content in mathematics lessons?
7. Do you think the use of digital content in mathematics classrooms is important for effective teaching? How?
8. Could you pls explain a mathematics digital content that you like most?
9. What principles do you follow to develop the mathematics digital content?
10. How often do you use digital content in the classroom in a week and why?
11. In a mathematics class, which part of the lesson do you usually use digital content? why?
12. Could you pls explain, from which sources did you get the digital content? And how? (national/international training, self-made, teacher's forum, others)
13. Did you use any mathematical software in the mathematics class? Which one is more effective for the class?
14. Have you had any refresher courses after receiving the training? Have you ever been monitored, mentored or observed by the trainers or teacher educators after training?
15. Do you have further plan about the use of digital content for mathematics class? What is that?
16. What changes would you like to see in the mathematics curriculum and mathematics teaching with the use of digital content or ICT?

Appendix E

Training Manual 1

Figure 165- Cover page of Training Manual (2010)

Appendix F

Training Manual 2

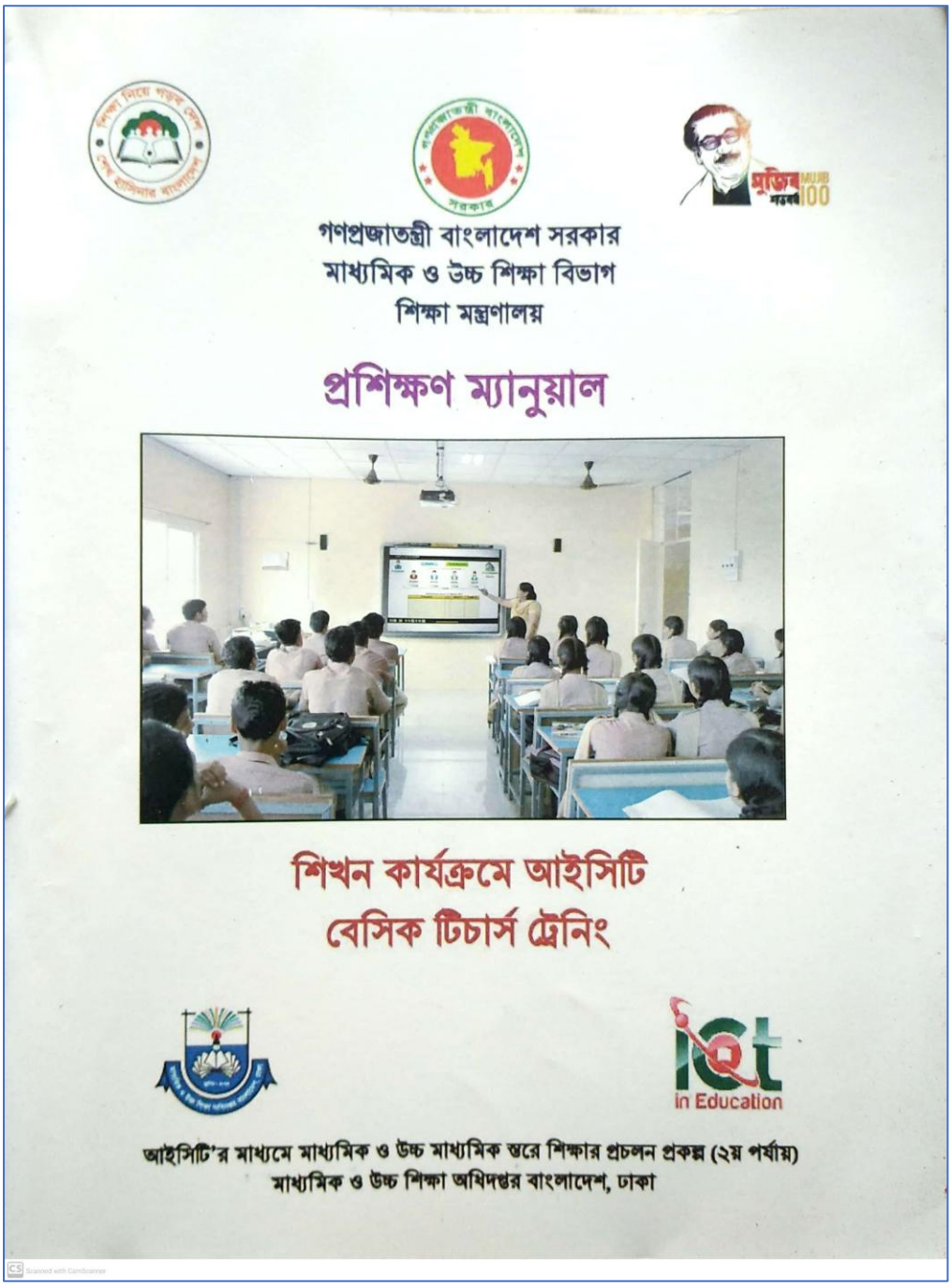

Figure 166- Cover page of Training Manual (2019)

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Appendix G

Pre-lesson Interview Schedules for Trained Mathematics Teachers

1. Pedagogy

   a. Learning Objectives (Meaningful Learning & Discovery Learning)

      i. How do you build connections between student's experience and knowledge? Can you give an example?
      Do you think the use of digital content helps to do that more efficiently/ smoothly/effectively? How? Could you please give an example?

      ii. How do you explore student's knowledge and extend their knowledge by connecting with their prior knowledge? Can you give an example?
      Do you think the use of digital content helps to do that more efficiently/ smoothly/effectively? How? Can you give an example?

      iii. How can you offer mathematical challenges to the students to analyze the concepts and for a critical thinking environment?
      Do you think the use of digital content helps to do that more efficiently/ smoothly/effectively? How? Can you give an example?

      iv. How do you create opportunities for the students to struggle with mathematical ideas in real-world examples?
      Do you think the use of digital content helps to do that more efficiently/ smoothly/effectively? How? Can you give an example?

      v. How do you create opportunities to explore mathematical information and innovate their own ideas?
      Do you think the use of digital content helps to do that more efficiently/ smoothly/effectively? How? Can you give an example?

   b. Instructional Design (Student Centered and Scaffolding)

      i. How do you open the scopes for the students to struggle with the mathematical tasks with their own strategies/ approaches/...? Could you give an example? Do you think the use of digital content helps

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to do that more efficiently smoothly/ effectively? How? Can you give an example?

ii. How do you create an environment where the students struggle with difficult concepts and challenging problems individually/collectively to deepen understanding? Could you give an example?

Do you think the use of digital content helps to do that more efficiently smoothly/ effectively? How? Can you give an example?

iii. How do you plan to provide different challenges for different achiever students? Give an example pls. Do you think DC helps to make this environment more favorable? Example pls.

iv. How do you create an environment where to value students' struggles and mistakes? Do you think DC helps to make this environment more favorable? Example pls.

v. How do you engage the students deeply in the mathematical task as problem-solvers or creators?
Do you think DC helps to make this environment more favorable?
Example pls.

vi. How do guide students to offer support so they can transfer knowledge and skills to a new context? Do you think DC helps to make this environment more favorable? Example pls.

2. Learning Context

a. Physical Space

i. Is the learning space flexible and adaptable?

ii. Does the classroom space design support collaboration and observation learning?

b. Classroom Culture

i. How do you create opportunities to engage the students individually, through peer interaction and collaboration? Example pls.

Do you think DC helps to make this environment more favorable? Example pls.

ii. Which students are more active in what ways and what type of mathematical tasks do you use? Example pls.

Do you think DC helps to make this environment more favorable? Example pls.

iii. How do you interact with the students? Example pls.

Do you think DC helps to make this environment more favorable? Example pls.

iv. How do you create opportunities where the students deeply explain their own ideas and respond to other ideas meaningfully?

Do you think DC helps to make this environment more favorable? Example pls.

3. Access to Technology

a. Technology Infrastructure and Uses of Technology

i. What different types of ICT equipment are in the multimedia classroom?

ii. What types of ICT are used by the students in the classroom?

iii. What types of ICT do the students use and how?

iv. What types of ICT or digital content do you use? And how?

Appendix H

Classroom Observation Guidelines

Teacher's Name: ……..

Class: ……..…….

Subject: …….

Topic: …….

Number of students: ……

Class duration: ……..

Date:…….

SL No	Aspects of Observation	Scores					Descriptions
		T1	T2	T3	T4	T5	
1.1	Pedagogy (Learning Objectives: Meaningful learning and Discovery learning)						
1.1.1	Build connections between student's experience and knowledge.						
1.1.2	Extent knowledge connecting with prior knowledge.						
1.1.3	Apply mathematical concepts and analyze critically.						
1.1.4	Struggle with mathematical ideas in real-world examples.						
1.1.5	Explore mathematical information and innovate ideas.						
1.2	Pedagogy (Instructional Design: Student-Centered and Scaffolding)						

1.2.1	Students struggle with important mathematical ideas and practice with their own strategies/approaches.											
1.2.2	Struggle with difficult concepts and challenging problems individually/collectively to deepen understanding.											
1.2.3	Different challenges for different achievers.											
1.2.4	Value to student's struggles and mistakes.											
1.2.5	Deeply engaged as problem solvers or creators of mathematical ideas											
1.2.6	Support to build on student's mathematical ideas where students transfer knowledge and skills to a new context.											
2.1	Learning Context (Physical Space: Learning Context (Physical Space: Collaborative and Transparent & Flexible and Adaptable)											
2.1.1	Learning space and furniture.											
2.1.2	Classroom space design supports collaboration and observation learning.											
2.2	Learning Context (Classroom Culture: Collaborative and Authentic)											

2.2.1	The environment of individual work, peer interaction, and collaboration.											
2.2.2	Students become more active in math tasks that necessitate joint intellectual effort.											
2.2.3	Create a climate of teacher and student interaction.											
2.2.4	Create opportunities to explain deeply student's own ideas and respond to other ideas in a meaningful way.											
3	Access to Technology (Technology Infrastructure and Uses of Technology)											
3.1	Teachers use types of ICT equipment.											
3.2	Students use technology.											
3.3	Student's proficiency in using technology.											
3.4	Teacher's proficiency in using technology.											

Notes:

……..

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Appendix I

Post-lesson Interview Guidelines for Trained Mathematics Teachers

1. Pedagogy
    a. Learning Objectives (Meaningful Learning & Discovery Learning)
        i. Build meaningful connections between student's experience and knowledge using Dc
        ii. Connect with prior knowledge, and extend their knowledge through DC.
        iii. Students Struggle with real-world examples with digital tasks.
        iv. Offer challenges for analyzing and critical thinking through DC.
        v. Create opportunities to explore mathematical information and innovate ideas through digital tasks.
    b. Instructional Design (Student Centered and Scaffolding)
        i. Scopes for the students so that they can struggle with important mathematical tasks with their own strategies/ approaches/...
        ii. Create opportunities to struggle/grapple with the difficult concepts of the challenging digital tasks to make the students engage individually or collectively to deepen their understanding.
        iii. Use of different challenging mathematical tasks for different achiever students using digital content.
        iv. Create an environment to value students' mistakes with mathematical tasks, something wonderful happens when they make mistakes.
        v. Deeply engage in mathematical ideas as problem-solvers or creators.
        vi. Offer support to build on student's mathematical ideas so they can transfer knowledge and skills to a new context.
2. Learning Context
    a. Classroom Culture
        i. The environment of individual tasks, peer interaction, and collaboration with the digital content.
        ii. Students participate more actively in mathematical tasks using digital content.

iii. Interaction with the students through the mathematical tasks.
iv. Students deeply explain their own ideas and respond to other ideas in meaningful ways during the tasks.

3. Access to Technology
   a. Technology Infrastructure and Uses of Technology
      i. Different ICT equipment in the classroom.
      ii. ICT equipment for the students.
      iii. Students use digital tasks.
      iv. Teachers use different digital contents in the classroom and how.
      v. Opportunities to encourage students to use digital content in the classroom.

Appendix J

FGD Schedules for Students

1. What is the big idea in this lesson?
2. How does it connect to what you already know?
3. How long are you given to think, and to make sense of things?
4. What happens when you get stuck?
5. Are you invited to explain things, or just give an answer?
6. Do you get to participate in mathematical activities? How?
7. Can you hide or be ignored? In what ways are you kept engaged?
8. What opportunities do you have to explain your ideas? In what ways are they built?
9. Do you struggle with mathematical difficult concepts? How?
10. Do you get to make arguments with the mathematical concepts? In what ways are you kept engaged in the arguments?
11. How is your thinking included in classroom discussion?
12. Do you get to participate in real-life-based mathematical activities? How?
13. Does instruction respond to your ideas and help you think more deeply? Do you please explain?
14. Do you use technology? Please explain.