

HOW DO I IMPROVE MY MATHEMATICS PEDAGOGY THROUGH TPACK?:
AN ACTION RESEARCH OF GEOGEBRA AND MS EXCEL IN GRADE X

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AN ABSTRACT

of the dissertation of *Lokendra Karki* for the degree of *Master of Education in Mathematics Education* was on 23 July 2026 entitled *How Do I Improve My Mathematics Pedagogy Through TPACK?: An Action Research of GeoGebra and MS Excel in Grade X*.

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The study began with my concern that traditional mathematics teaching, mainly based on copy and board work, memorization and repeated practices often made students passive and less interested in learning. There was also a gap between learning mathematical procedures and development real conceptual understanding. So, my research aimed to explore practical ways of integrating technology with appropriate teaching methods and mathematical contents to improve teaching and student's learnings.

This study is situated within the interpretive and critical paradigms, and the research design is qualitative. I applied action research to generate information for my study. I conducted the study in Grade 10 of community school of Kathmandu District through two cycles of teaching and reflection, where 14 students were selected among them 6 were selected purposively. In the first cycle, GeoGebra was used to teach linear programming and helped students understand inequalities, graph, feasible regions and optimization through visual and interactive activities. In the second cycle, Microsoft Excel was used to teach statistics and to support students in understanding statistical calculations and concepts. The continuous process of planning, acting, observing and reflecting was carried out across both cycles. Student reflections, classroom observations, learning activities, and pre and post assessment results were used to understand changes in teaching and learning.

The findings show that Technological Pedagogical and Content Knowledge (TPACK) helped me meaningfully connect technology, pedagogy and mathematical content. GeoGebra made abstract mathematical ideas easier to visualize and understand, while Excel helped students to perform calculations and focus more on mathematical concepts. Technology helped to reduce students' fear and anxiety about mathematics because they explored the concepts through visual and practical activities. Both phases indicated improvement in student's educational achievement and conceptual understanding.

The study brought significant changes in my teaching practice. Previously, I explained solutions on the board and asked students to copy them. I have since shifted from transmitter to facilitator, guiding students to explore and construct knowledge. Students engaged in group and peer work, discussion, problem solving and learning activities. However, I found that technology alone cannot improve learning therefore teacher patience, kindness, empathy, classroom management and safe learning environment were equally important for successful technology integration.

The study concludes that TPACK contributes to improving mathematics pedagogy when strong content knowledge is coupled with purposeful technological knowledge. GeoGebra and Excel can be used not simply to replace traditional teaching but to help students to visualize, explore, discuss and understand mathematics more deeply. The study recommends regular professional development for facilitators on the meaningful technology integration and enhanced access to digital resources in schools.

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23 July 2026

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शोधसार

स्टिम शिक्षामा स्नातकोत्तरको डिग्रीका लागि लोकेन्द्र कार्की को शोध प्रबन्धको शिर्षक “TPACK मार्फत म आफ्नो गणित शिक्षणशास्त्रलाई कसरी सुधार गर्न सक्छु? : कक्षा १० मा GeoGebra र MS Excel को प्रयोगसम्बन्धी एक कार्यमूलक अनुसन्धान” ७ साउन २०८३ मा प्रस्तुत गरिएको थियो ।

.....

उप. प्रा. ईन्द्र मणि श्रेष्ठ

शोध निर्देशक

अध्ययनको प्रारम्भिक चरणमा मेरो सरोकारको प्रमुख विषय परम्परागत गणित शिक्षण पद्धति, जुन मुख्यतया प्रतिलिपि र बोर्ड कार्य, कण्ठस्थता र बारम्बार अभ्यासहरूमा आधारित, विद्यार्थीहरूलाई निष्क्रिय र सिक्नमा कम रुचि भएको थियो । गणितीय प्रक्रियाहरू सिक्ने र वास्तविक अवधारणात्मक बुझाइ विकास गर्ने बीच पनि खाडल थियो । त्यसैले, मेरो अनुसन्धानको उद्देश्य शिक्षण र विद्यार्थीको सिकाइ सुधार गर्न उपयुक्त शिक्षण विधिहरू र गणितीय सामग्रीहरूसँग प्रविधिलाई एकीकृत गर्ने व्यावहारिक तरिकाहरू अन्वेषण गर्नु थियो ।

यो अध्ययन व्याख्यात्मक र आलोचनात्मक प्रतिमानमा आधारित गुणात्मक अनुसन्धानका रूपमा अवस्थित छ । अध्ययनमा ज्ञान तथा अनुभवको गहिरो अन्वेषण गर्न कार्यमूलक अनुसन्धान विधि अवलम्बन गरिएको थियो । अनुसन्धान काठमाडौँ जिल्लास्थित एक सामुदायिक विद्यालयको कक्षा १० मा शिक्षण र प्रतिबिम्बको दुई चक्रहरू मार्फत अध्ययन गरिएको थियो, जहाँ १४ विद्यार्थीहरूलाई छनोट गरिएको थियो जसमध्ये ६ जनालाई उद्देश्यपूर्ण नमूना छनोट विधिबाट गरिएको थियो । प्रत्येक चक्रमा योजना कार्य अवलोकन र प्रतिबिम्बको निरन्तर प्रक्रिया अवलम्बन गर्दै शिक्षण अभ्यासमा आवश्यक सुधार तथा परिमार्जन गरिँदै लगिएको थियो । पहिलो चक्रमा, GeoGebra लाई रेखीय प्रोग्रामिङ सिकाउन प्रयोग गरिएको थियो र विद्यार्थीहरूलाई दृश्य र अन्तरक्रियात्मक गतिविधिहरू मार्फत असमानता, ग्राफ, सम्भाव्य क्षेत्रहरू र अनुकूलन बुझ्न मद्दत गरिएको थियो । दोस्रो चक्रमा, Microsoft Excel लाई तथ्याङ्कीय गणना सिकाउन र विद्यार्थीहरूलाई गणितीय अवधारणाहरूको अर्थ र प्रयोगमा थप ध्यान केन्द्रित गर्न सहयोग गरिएको थियो । योजना, कार्य, अवलोकन र प्रतिबिम्बको निरन्तर प्रक्रिया दुवै चक्रहरूमा गरिएको थियो । विद्यार्थीको विचार, कक्षाकोठा अवलोकन, सिकाइ गतिविधिहरू, र पूर्व र पछिको मूल्याङ्कन परिणामहरू शिक्षण र सिकाइमा परिवर्तनहरू बुझ्न प्रयोग गरिएको थियो ।

अध्ययनका निष्कर्षहरूले प्राविधिक शैक्षिकसामग्री तथा विषयवस्तुगत ज्ञान (Technological Pedagogical and Content Knowledge-TPACK) को प्रभावकारी प्रयोगले प्रविधि, शिक्षाशास्त्र र गणितीय सामग्रीलाई अर्थपूर्ण र सार्थक रूपमा जोड्न मद्दत पुर्याएको देखियो । GeoGebra ले अमूर्त गणितीय

विचारहरूलाई कल्पना गर्न र बुझ्न सजिलो बनायो, जबकि MS Excel ले विद्यार्थीहरूलाई गणना गर्न र गणितीय अवधारणाहरूमा बढी ध्यान केन्द्रित गर्न मद्दत गर्‍यो । प्रविधिले विद्यार्थीहरूको गणितको बारेमा डर र चिन्ता कम गर्न मद्दत गर्‍यो किनभने उनीहरूले दृश्य र व्यावहारिक गतिविधिहरू मार्फत अवधारणाहरू अन्वेषण गर्थे । दुवै चरणहरूले विद्यार्थीको शैक्षिक उपलब्धि र वैचारिक बुझाइमा सुधारलाई संकेत गरे ।

यस अध्ययनले मेरो शिक्षण अभ्यासमा महत्त्वपूर्ण परिवर्तनहरू ल्यायो । पहिले, मैले बोर्डमा समाधानहरू व्याख्या गरेँ र विद्यार्थीहरूलाई तिनीहरूको प्रतिलिपि गर्न लगाएँ । म त्यसबेलादेखि ट्रान्समिटरबाट सहजकर्तामा सरेको छु, जसले विद्यार्थीहरूलाई ज्ञान अन्वेषण र निर्माण गर्न मार्गदर्शन गर्दछ । विद्यार्थीहरू समूह र साथीहरूको काम, छलफल, समस्या समाधान र सिकाइ गतिविधिहरूमा संलग्न छन् । यद्यपि, प्रविधिले मात्र सिकाइ सुधार गर्न सक्दैन त्यसैले शिक्षक धैर्य, दया, सहानुभूति, कक्षाकोठा व्यवस्थापन र सुरक्षित सिकाइ वातावरण सफल प्रविधि एकीकरणको लागि उत्तिकै महत्त्वपूर्ण थिए भन्ने कुरा मैले पाएँ ।

यस अध्ययनले निष्कर्ष निकालेको छ कि जब विषयवस्तुको बलियो ज्ञानलाई उद्देश्यपूर्ण प्राविधिक ज्ञानसँग जोडिन्छ, तब TPACK ले गणित शिक्षण विधिलाई सुधार्न योगदान पुऱ्याउँछ । 'जियोजेब्रा' (GeoGebra) र 'एक्सेल' (MS Excel) को प्रयोग केवल परम्परागत शिक्षण विधिलाई विस्थापित गर्न मात्र होइन, बरु विद्यार्थीहरूलाई गणितको दृश्य चित्रण गर्न, अन्वेषण गर्न, छलफल गर्न र यसलाई अझ गहिराइमा बुझ्न मद्दत गर्नका लागि गर्न सकिन्छ । अध्ययनले विद्यालयहरूमा प्रविधिको अर्थपूर्ण एकीकरणका लागि सहजकर्ताहरूको नियमित व्यावसायिक विकास तथा डिजिटल स्रोतसाधनमा पहुँच अभिवृद्धि गर्न सिफारिस गर्दछ ।

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लोकेन्द्र कार्की
उपाधि उम्मेदवार

७ साउन २०८३

This dissertation, entitled “*How Do I Improve My Mathematics Pedagogy Through TPACK?: An Action Research of GeoGebra and MS Excel in Grade X*” was presented by *Lokendra Karki* on 23 July 2026.

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I understand and agree that my Dissertation will become a part of the permanent collection of the Kathmandu University Library. My signature below authorizes the release of my Dissertation to any reader upon request for scholarly purposes.

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DECLARATION

I hereby declare that this dissertation is my original work, and it has not been submitted for candidature for any other degree at any other university.

.....

23 July 2026

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DEDICATION

This work is dedicated to the cherished memory of my late grandfather Dim Bahadur Karki, my grandmother Kausalya Devi Karki, my father Balram Karki, and my mother Yagya Kumari Karki. My heartfelt gratitude extends to my family members, Indira Acharya, Yasaswi Karki, and Nirvana Karki.

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ABBREVIATIONS

AI	Artificial Intelligence
CDC	Curriculum Development Centre
CK	Content Knowledge
ELT	Experiential Learning Theory
ELT	Experiential Learning Theory
ICT	Information Communication Technology
KUSOED	Kathmandu University School of Education
MLT	Multimedia Learning Theory
MS	Microsoft
NCF	Nepal Curriculum Framework
PCK	Pedagogical Content Knowledge
PDF	Portable Document Format
PK	Pedagogical Knowledge
SEE	Secondary Education Examination
SLC	School Leaving Certificate
TCK	Technological Content Knowledge
TK	Technological Knowledge
TPCK	Technological Pedagogical Content Knowledge
TPACK	Technological Pedagogical and Content Knowledge
US	United States
VR	Virtual Reality

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CHAPTER I

INTRODUCTION

This chapter presents the background study of my study, the statement of the problem, the research purpose, the research questions, the rationale and the significance of the study.

Background of Study

The year 2003 is memorable for me because this is the year when I completed my School Leaving Certificate (SLC) (now Secondary Education Examination [SEE]) level study. At the starting of my teaching career, I was following the new curriculum that has been changed in 2010. One of the topics of mathematics named “maximization and minimization”/ “Linear Optimization” was a bit tough for me as the teacher used to solve the questions on the board by drawing the figures side by side and explaining them. I remember the terms boundary line, solution region, feasible region, objective function, and subjective function which were confusing to me at that moment. By rigorously practicing those algorithmic questions, I was trying my best and being able to solve the problems related to it. These activities boosted my confidence in solving the problems from the topic. At the board examination, I was sure that I could solve all the questions along with the linear optimization as I had memorized the process (way) to solve it. I was shocked by seeing the questions that the answer we used to obtain while solving the problem was the question. Finally, I was able to solve the problem as I practiced question-solving in both ways, I mean to say question to the answer and reverse of it because we (me and my friends, a group of ten students) used to do so much that the solving of the mathematical problems was easier too.

Later, I joined a school in Kathmandu Valley in 2013 as a mathematics teacher. From my side, I worked a lot believing that I’d make an easy way of learning mathematics. I sporadically used to link the contents of mathematics with real-life activities. I used to repeat the process of solutions more times so that my students would know the way/method for solving the problems. I used the same method as my teacher used to teach linear optimization. But here I repeated the description of the solution more times (max. 5 times) and finally students were able to solve it. I taught them a variety of questions related to it. After doing this, more students find it

difficult to solve the problems, but they remember a few steps of the solution and can get a few marks. I continue following this method and students too with their rigorous effort to solve the problems and obtain good marks. I was blissful as my students in the year 2015 obtained 100 out of 100 in mathematics that I used to teach them.

Besides this, in the year 2013, the same happened in teaching “Transformation”. I wrote the formula and solved the questions on the whiteboard. I have repeated the solution at least three times, believing that students knew how to solve the questions related to it. Forcefully, students copied the solution and did as I directed in solving the numerical. I shared “By attempting maximum questions formula was memorized and easy to solve the further problems related to transformation. Students seem less active in learning the contents in the Grade room with forced teaching (asking them to copy the contents that I have written on the whiteboard). One of the students, Bijju Bhai (Pseudonym) in the year 2015 asked me “Sir, is there any other easy way to solve the problems?”. I replied do as I directed, and it would be understood. Like linear optimization teaching style, in 2020, I taught transformation to my students using GeoGebra, and they seemed to be more enthusiastic (Al Rawashdeh et al., 2021) in learning the contents (translation, reflection, rotation, dilation, inversion circle) of transformation. One of my students in the Grade room said to me “Sir! I understand transformation this time properly”.

Likewise in the year 2020, while teaching linear optimization at Grade ten, I asked my students to copy the contents that I was teaching to them. Few students at an instant start copying the solution. But more of them start slowly much more slowly. I repeat to them, please copy fast otherwise I’ll rub it. One student asked me, Sir! Can you click the photo and send it to us so that we understand here and at home too? One student asked me “Can we copy the solution? I replied “of course”. I replied to the student who asked me to take the photos of the solution, why not I’ll do that too, but you need to copy the solution right now. After this, they copied the solution and again I revised the procedure of the solution believing that it would be a quick revision for them so they could understand and solve similar types of problems. At the end of the class, one student, Satyam (Pseudonym) told me, “Can you revise it tomorrow because I didn’t get the contents of linear optimization that you taught us today?” At first, my temper rose sharply but I suddenly stopped it as I can’t do this for my students. The next day I repeated the same even though a few of them were not able to catch the procedure of the solution. Forcefully, I completed the teaching of linear

optimization. The next day I got a proxy class for Grade X instead of Computer, I plan to take them to the Information Communication Technology (ICT) lab and teach mathematics over there. I have a few ideas for using the Desmos and GeoGebra application in linear optimization. I taught linear optimization at the ICT lab using Desmos (TLS & Herman, 2020) and GeoGebra simultaneously. Most of the students were focused on learning and were a bit more active regarding the classroom.

The incident that happened in my teaching experience at MCS (Malpi City School) in Linear programming as well as transformations to Grade X students, made me think seriously about teaching linear programming. Only a few students out of the 31 students were engaged but the maximum seemed to be in dilemma. They nodded their head at my question “Do you understand” and copied the solution that I had solved on the whiteboard. During my school days, I liked to attend more computer classes and even though I was sick I used to go to school because the learning environment was quite interesting as we did the activities that we learned in our class. Now, I remember the integration of ICT in learning was fruitful. I even today remember the activities and learning that we learned in our computer classes. My neighbor's ward got a chance to take the class from me as support. I taught him using the mathematical app GeoGebra in linear programming. He found it easy, and I let him do the problems in that software, and he was able to. Later, he shared with me that it was feasible to learn linear optimization by visualizing the inequalities solution region as well as the feasible regions of the given constraints. These incidents and experiences encouraged me to incorporate ICT with flexible teaching pedagogy in teaching linear optimization at the school level, focusing on the maximum learning of the students.

Similarly, I got a chance to attend the workshop on TI-Nspire Instruments at Kathmandu University School of Education (KUSOED), Hattiban Lalitpur for a six-day session starting from August 4 to August 19, 2023. Over there I learned more about teaching linear optimization by using the CAS calculator (both handheld and software) which was interactive and interesting. From my experience, visual presentation helps a lot in understanding the contents related to linear optimization as well as Transformation. Not only does my past experience of using the ICT tools in teaching and learning lead me to conduct this research. Students were engaged in learning the mathematics content. The change in the pedagogy, incorporation of ICT in teaching-learning makes the class more engaged rather than the lecture method.

Statement of the Problem

I believe technology integration has become vital for enhancing effective teaching methodologies to facilitate better learning prospects. Nevertheless, mathematics education continues to face the challenge that traditional pedagogical approaches appear ineffective in addressing the diverse needs of learners in performing mathematics (Lee & Paul, 2023). In my teaching experience, teachers seem to have quite a hard time using technology in ways that complement both the content and pedagogy. The Technological Pedagogical and Content Knowledge (TPACK) framework (originally TPCK) by Mishra and Koehler (2006) offers a model that embeds technology in pedagogy and subject content, specifically, a model that shows the junction of the domains above. This study looks to explore how I can strengthen my mathematics pedagogy using TPACK within an action research framework. Research has shown that although ICT can provide opportunities for visualization, exploration, representation, and interaction in mathematics learning, the use of technology does not automatically lead to improved learning. Its effectiveness depends on how appropriately it is connected with mathematical content, learning objectives, and instructional strategies. In a mathematics classroom, students may experience difficulties in connecting abstract mathematical concepts with their graphical, symbolic and numerical representations. Such difficulties are particularly relevant in topics such as linear programming and statistics, where learners need to interpret graphs, understand the relationship among variables, and apply mathematical methods meaningfully.

The persistent problem in mathematics instruction has been determining effective ways to integrate technology without sacrificing content accuracy or instructional quality. Most teachers are reluctant to start using technology or have very limited knowledge of its use (Angeli & Valanides, 2009). Mathematics educators need to identify how to effectively integrate technology into their teaching. In doing so, the necessity for a systematic methodology towards pedagogical advancements-developing models such as TPACK-further amplifies. This action research addresses how TPACK enhances the pedagogy of mathematics. The issue is therefore not merely the lack of technology within mathematics classrooms, but rather the difficulty of using the technology we have in ways that promote conceptual understanding rather than merely replacing the traditional with digital. Research has demonstrated that teachers often find it difficult to develop the knowledge and confidence required

to meaningfully incorporate technology into subject-specific teaching (Angeli & Valanides, 2009). This reflects a gap between access to ICT tools and the effective use of ICT tools for mathematics teaching-learning.

Besides, the TPACK framework encompasses a holistic approach through integrating technological, pedagogical, and content knowledge; it thus allows teachers to adopt a holistic approach to teaching mathematics with the use of technology. However, these components have proved to be challenging to balance for any teacher in real life, and I am no exception. It is, therefore, important to learn practically how to apply TPACK in the mathematics classroom. It attempts to explain how the TPACK framework can be put into effective use in lesson design and teaching strategy to help me build and improve my teaching practice as a math teacher. This challenge is also evident in my own teaching practice where students can sometimes become proficient in following mathematical procedure through repeated practice while having trouble in visualizing, interpreting and explaining the underlying mathematical concepts. For example, learning linear programming requires students to connect inequalities, boundary lines, feasible regions, graphs and optimization, while statistics requires them to move between formulas, numerical calculations, table and graphical representations. Difficulties in making these connections can limit students' conceptual understanding and meaningful engagement with mathematics.

A second and equally important issue is the scarcity of professional development that makes teachers proficient in integrating technology into their teaching (Priyanda et al., 2025). Teachers are very often ill-prepared to train in the use of such technologies in ways that build on mathematical ideas. Unless put within a framework of ongoing learning and reflective practices, such gains in methods of teaching are quite impossible to sustain. I use this action research to develop strategies for continuously improving my TPACK competencies, therefore acting as a model for other educators with similar challenges. Moreover, effective technology integration requires continuous opportunities for teachers to experiment with digital tools, observe students learning responses, reflect on instructional difficulties and modify their teaching practices. Without such practice-based and reflective opportunities, professional development may not sufficiently address the contextual challenges teachers encounter when integrating ICT into mathematical classrooms.

Thus, there is a need for classroom-based inquiry that examines not only whether ICT tools are used, but also how their use influences teaching practices and

students' engagement with mathematical ideas. This creates a practical problem for me as a mathematics teacher/facilitator: how can I integrate appropriate ICT tools with mathematics content and pedagogy in ways that address students learning difficulties and improve instructional practice?

The core problem that this research tries to address is the gap between the availability of ICT tools and their meaningful integration into mathematics teaching and learning. The TPACK framework is used as a conceptual lens rather than as the problem itself, enabling me to examine how technology, pedagogical and content knowledge can be brought together to address the identified challenges in my mathematics classroom.

Research Purpose

The purpose of this study was to explore how mathematics pedagogy can be improved at the secondary level (Grade X) by integrating technology using the TPACK framework to enhance teaching practices and student learning outcomes.

Research Questions

- I. What are the specific strategies for integrating the TPACK framework into pedagogical practices to enhance mathematics instruction?
- II. How does the TPACK framework influence my pedagogical practices and students' learning?

Rationale of the Study

As a mathematics teacher, I observed that many students struggled to understand mathematical concepts and to engage in class activities. I used to teach mostly by traditional methods which gave students few opportunities to actively construct understanding, explore mathematical topics and visualize ideas. This situation made me think critically about my teaching styles and consider other ways I could improve students' educational experiences. This action research was undertaken in an effort to gain better understanding of how the inclusion of TPACK could improve my mathematics pedagogy and help students to learn. The study was essential in helping me become a better professional as a reflective mathematics teacher, as well as solving the current problems in the teaching-Learning of mathematics classroom.

Significance of the Study

The significance of this study is the investigation of the integration of technology, pedagogy and mathematical content using the TPACK framework to

improve the teaching of mathematics and students' learning at the secondary level. It tackles the issues students face while learning mathematical concepts using conventional, teacher-centered, and procedure-based methods. The study emphasizes the ability of ICT tools such as GeoGebra in making mathematics more visual, interactive, meaningful and engaging. It may help mathematics teachers develop effective technology-integrated pedagogical practices and reflectively improve their teaching. The study also adds to the professional development of the researcher in terms of opportunities to investigate and improve teaching practices through action research. It may also provide some useful insights for schools, teacher educators and future researchers interested in TPACK, ICT integration, action research and technology supported mathematics education.

Chapter Summary

In summary, this chapter explains a journey from traditional, rote-based math teaching to a method that uses TPACK framework. I remembered earlier difficulties in teaching linear programming and transformations. I identified a substantial gap in how technology, pedagogy and content knowledge are connected in practice. The study employed the TPACK framework within an action research design to formulate targeted strategies that integrate technological tools with content delivery, thereby improving instructional practices and student learning outcomes.

CHAPTER II

LITERATURE REVIEW

In this chapter, I have organized the literature review into five key sections: thematic review, empirical review, policy review, theoretical review, and research gap.

Thematic Review

The TPACK framework is a blend of technological, pedagogical, and content expertise for the effective integration of technology in teaching mathematics. It enables teachers to use the most appropriate digital resources to visualize and explore mathematical ideas and fosters problem solving, critical thinking, collaboration and student engagement. TPACK also enhances teachers' technological and pedagogical capabilities through professional development that ultimately results in better mathematics teaching methods and students' learning outcomes.

TPACK in Mathematics Education

TPACK stands for Technological Pedagogical and Content Knowledge and is a framework developed to support the integration of technology into teaching practice (Mishra & Koehler, 2006). It involves three basic forms, technological knowledge, pedagogical knowledge, and content knowledge. Koehler et al. (2013) state that "Technological Knowledge (TK) includes knowledge about various tools, digital devices, software, and digital platforms that might be used when teaching". This pedagogical knowledge involves knowledge of teaching methods, strategies, and approaches in which one should engage and facilitate effective learning among students. Content knowledge or CK refers to teachers' expertise or mastery in certain knowledge within a particular subject area, including the depth and breadth of understanding within that discipline.

Koehler and Mishra (2009) theorize TPACK as the assimilation of technological, pedagogical and content knowledge, Koehler et al. (2013) provide more importance on the specific knowledge required to use technology efficiently within the teaching environment. These views are complementary because technological knowledge alone does not lead to effective teaching, rather, its educational value depends on how it interacts with content and pedagogical knowledge. In contrast to viewing technology as an independent skill, the TPACK

perspective positions technology as interconnected with what teachers teach and how they teach it. This distinction is particularly important in mathematics education, where the same technological tool may support different learning outcomes depending on the mathematical content and pedagogical strategy employed.

The selection of the appropriate technology aligned with the mathematical learning contents is a must. Graphing calculators, dynamic geometry software, and interactive simulation tools facilitate students with hands-on experience which enhances their understanding of the contents of learning (Niess, 2015). Pedagogy fosters students' critical thinking, problem-solving, and collaborative learning as well as allowing them to explore mathematical concepts/ideas using technology in a meaningful way. Teachers should regularly refresh both content and technological knowledge in response to new pedagogical demands. For this reason, professional development opportunities should be related both to technology integration and to pedagogy to help teachers develop the necessary skills required to balance the domains of TPACK (Koehler et al., 2013). The technology-content relationship identified by Niess (2015) is further supported by Koehler et al. (2013), who focus on professional development. While appropriate technological tools can create new possibilities for mathematical exploration, teachers require opportunities to develop the knowledge needed to connect those possibilities with instructional purposes. Therefore, professional development should not focus solely on learning how to operate digital tools but should also address how those tools can transform mathematical teaching and learning.

Niess (2015) expands upon this view, highlighting the alignment of technology and mathematics content, arguing that technology's utility depends on its appropriateness for the mathematics concepts being conveyed. This complements the TPACK perspective but also shifts attention from simply knowing technological tools to knowing why, when, and how a particular tool can support mathematical learning. For example, dynamic mathematics software may provide opportunities to explore graphical relationships that are difficult to demonstrate through static representations alone. Taken together, these perspectives suggest that the strength of TPACK lies not in any one of its single domains but in the dynamic relationships among them. However, scholars differ in their emphasis: some focus more strongly on defining the knowledge domains, while others emphasize the contextual and subject-specific integration of technology. This difference is meaningful for mathematics education

because effective ICT integration requires teachers to consider the characteristics of mathematical knowledge, the affordance and limitations of particular technologies and the pedagogical approaches needed to support students learning. However, such technological affordance does not automatically produce conceptual understanding; teachers still need appropriate pedagogical strategies to guide students in interpreting, discussing and reflecting on what they observe.

The literature indicates that TPACK should not be understood merely as a framework for adding technology to mathematics lessons; rather, it provides a way of thinking about the reciprocal relationship among mathematical content, pedagogy, and technology. For the present study, this perspective is particularly relevant because GeoGebra and Excel are not introduced simply as digital alternatives to traditional tools but as technologies whose value depends on how they are pedagogically and mathematically integrated into teaching of linear programming and statistics. This position is consistent with Dahal et al. (2022), who argue that ICT tools support mathematics learning only when teachers deliberately align them with content and pedagogy within the TPACK framework.

Application of TPACK Framework in Mathematics

In the context of mathematics education, TPACK is one of the strongest conceptual frameworks for educators to effectively integrate technology, pedagogy, and content knowledge in ways that develop and enhance students' mathematical learning experiences (Koh et al., 2014). In mathematics, TPACK has enabled teachers to engage students with complex mathematical ideas with conceptual as well as procedural understandings of the contents.

Technological Knowledge (TK) in TPACK mathematics focuses on the use of digital tools like graphing calculators, mathematical software, and online simulations. On the other hand, Pedagogical Knowledge (PK) is concerned with the adoption of different teaching strategies making students explore, solve problems, and think critically about mathematics. Similarly, Content Knowledge (CK) is concerned with the deep understanding or mastery of concepts, procedures, and their applications in mathematics.

TPACK framework is about the process of enhancing mathematics teaching with technology in a way to create an opportunity to visualize and explore abstract mathematical ideas dynamically. For instance, graphing software allowed a teacher to demonstrate functions, graphs, and geometric shapes so that students saw

relationships in mathematics and, instead, better understand abstract conceptions. Moreover, through online collaborative platforms or educational apps, teachers were able to let their students work through interactive problem-solving activities and create an environment of collaborative learning where students discuss mathematics and explore different problem-solving strategies.

According to Hernawati (2019), teachers learn to incorporate innovation into teaching while simultaneously encouraging increased student engagement in learning. Furthermore, Hernawati points out that the TPACK framework illustrates how technology, pedagogy, and content knowledge interrelate in education and that it guides technology integration in teaching. Aligning material features with suitable instructional tools and technology in Mathematics Mobile Learning can enhance both learner achievement and motivation. The researcher concludes that ICTs can be used as epistemic tools, metacognitive tools, and cognitive tools to support critical and creative thinking, and authentic and inventive problem solving, as usual elements learning in the twenty-first century. TPACK framework in mathematics teaching-learning encourages active participation from students, creating learning and teaching opportunities that align with evolving trends, particularly within the realm of Mathematics studies.

Components of the TPACK Framework

The Technological Pedagogical Content Knowledge (TPACK) framework consists of seven interconnected components: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006). Technological Knowledge is the knowledge and capacity of teachers to use technological tools and digital resources for teaching and learning. Pedagogical Knowledge is the knowledge that teachers have about instructional strategies, classroom management, assessment, learning processes, and supporting diverse learners. Content Knowledge is the knowledge teachers have of the subject matter they will be teaching. PCK is the integration of content and pedagogy. This allows teachers to find the most effective way to represent and describe specific content. TCK is about understanding the ways in which technology can represent, explore and transform particular content. TPK is about understanding how technology can support, modify and enhance pedagogical practices. At the intersection of these

domains is TPACK, the combined knowledge required to successfully integrate technology, pedagogy and content within a particular teaching context.

The components of TPACK are not isolated but they interact dynamically to facilitate meaningful technology integration. Effective technology integration requires that teachers know how to use a technology tool, but more importantly, when and why to use it for a specific content and for a specific group of learners. For example, in teaching mathematics, a teacher might use GeoGebra to visualize graphs, inequalities, and geometric relationships or Microsoft Excel to organize data, perform statistical calculations, and make graphical representations. When the teacher understands the relation between the technological affordances and the mathematical content, then this use is TCK. When technology is incorporated through appropriate pedagogical strategies such as inquiry, collaboration, exploration, or formative assessment, then this use is TPK. In addition, PCK allows the teacher to anticipate students' mathematical difficulties and to choose appropriate explanations, representations and learning activities. TPACK is not just the addition of technology to traditional teaching practices, it is the integrated application of knowledge about technology, pedagogy and content.

Thus, developing TPACK can foster teachers' ability to create and facilitate meaningful technology-enhanced learning experiences. Chai et al. (2013) reported that the development of teachers' TPACK was related to their ability to integrate technology in the classroom with implications for student engagement and learning outcomes. Koh et al. (2015) likewise suggested that the TPACK framework provides a strong basis for educators in planning and implementing technology-enhanced learning activities. TPACK in mathematics education can assist teachers to move from a technology-centric use of digital resources to a pedagogically and content-specific integration of technology. It allows teachers to choose technologies according to learning goals, mathematical concepts, instructional methods, students' prior knowledge and classroom contexts. Thus, TPACK provides an appropriate conceptual framework to explore how teachers can change their mathematics pedagogy through the purposeful use of technologies such as GeoGebra and Microsoft Excel to enhance students' conceptual understanding, engagement, and learning.

Exploring Teachers Pedagogical Reasoning in Mathematics Education

Priyanda et al. (2025) is based on Shulman's (1987) idea of pedagogical reasoning, which is the mental process by which teachers convert content knowledge

into pedagogically powerful forms, further developed by the TPACK framework. The authors locate their review cognitively within the updated, process-oriented perspective on TPACK provided by Petko et al. (2025), which moves the framework from a static, tripartite knowledge construct to a dynamic, context-dependent system dependent on contextual knowledge and adaptive expertise. In this architecture, pedagogical reasoning in mathematics is conceived as a cycle of six iterative stages: comprehension, transformation, instruction, evaluation, reflection and new comprehension. The digital resources mediate the abstract mathematical concepts (e.g., dynamic geometry software for spatial relationships or graphing software for function behaviour) into interactive scaffolded learning experiences.

When comparing the operationalization of this framework in research with traditional instructional models, a stark contrast exists between static delivery of content and adaptive, technology-mediated reasoning. In non-TPACK or conventional paradigms, technology often functions as an easy substitute or demonstration tool without transforming underlying pedagogical structures. The review, in contrast, aggregates evidence that teachers, infused with TPACK driven pedagogical reasoning, move away from procedural exercises to active, inquiry-based exploration and collaborative mathematical communication. Methodologically, the synthesis contrasts the widespread use of self-report surveys capturing teachers' subjective confidence with observational case studies and mixed methods approaches, and shows that self-reports often overestimate actual enacted classroom practices. Moreover, although TPACK integration substantially improves instructional planning, student engagement, and conceptual understanding, its systematic implementation varies markedly across school settings, owing to resource limitations and a widespread lack of subject-specific professional development.

The interpretation of these theoretical and empirical synthesis points suggests that technology is not an auxiliary novelty but a critical cognitive scaffold in mathematics education. The review's main finding is that technology alone will not improve mathematical understanding unless it is actively mediated by a teacher's reflective pedagogical reasoning. By framing TPACK enactment as a situated and responsive practice, the paper demonstrates that the development of adaptive expertise among teachers, supported by subject-specific professional development and equal access to digital infrastructure, is key to moving beyond superficial tool use to meaningful, sustained conceptual development among digital age learners.

Policy Review

The policy review for the integration of technological tools into the curriculum for the subject Optional Mathematics of Grades 9 to 10, issued by the Curriculum Development Centre (CDC, 2025) under the Ministry of Education and Science Technology (MoEST), highlights the use of digital tools, including Excel, in the teaching and learning of graphs, linear optimization and Statistics. The National Curriculum Framework (NCF) 2019 (CDC, 2022) includes making timely improvements in classroom teaching and curriculum structure based on national needs and international standards and establishing a foundation to ensure the use of technology in school education. The NCF states that the curriculum was framed around current national needs (CDC, 2022).

However, there is an observed gap in the real scenario despite being mentioned in the curriculum. The demand of the current situation is the integration of TPACK framework in teaching-learning, but it is not in the implementation stage, and the framework does not explain in detail how teachers should integrate technological knowledge with pedagogical and mathematical content knowledge.

Theoretical Review

The theoretical review is based on Experiential Learning Theory (ELT) and Multimedia Learning Theory (MLT). ELT views learning as a continuous process of concrete experience, reflective observation, abstract conceptualization and active experimentation, and it promotes the continuous improvement of technology-integrated teaching. MLT is grounded on learning through the visual and auditory channels supported by multimedia resources like videos, animations, and interactive simulations. These theories jointly inform the design of interactive, reflective, student-centered and cognitively manageable experiences in mathematics learning.

Experiential Learning Theory

I adhere to the basics of the ELT developed by David Kolb (1984; 2014) in my action research. The theory emphasizes that learning occurs due to experiences and as a result of reflections. The four-stage cycle of the ELT in concretizing experience, through reflective observation, abstract conceptualization, and active experimentation-guides the process (Kolb & Kolb, 2018). Through the classroom experiences where I integrated technology, pedagogy, and content, I reflected on what happened as a result and identified areas for further work. I then relate these reflections to ELT, from which I learn about the development of new approaches.

These new strategies are then attempted in subsequent lessons, thus completing the cycle of continuous improvement. This iterative process was a strategy to fine-tune my teaching and design increasingly more effective, interactive, and student-centered mathematics learning by keeping the TPACK framework as the core framework. This continuous loop of action and reflection illustrates how I achieve professional mastery in real-time workplace setting by systematically transforming raw classroom experience into actionable data, grounding their reflections and actively experimenting with refined strategies to achieve the sustained pedagogical growth.

Multimedia Learning Theory

My action research is based on the theory of Multimedia Learning by Mayer (1997, 2002, 2014). This theory emphasizes the effectiveness of conveying the information to learners in two forms, visual and auditory. The theory of multimedia learning provides the principles of dual-channel processing, limited capacity, and active learning, which determines my strategy of using technology in mathematics teaching. I would like to try using multimedia resources, such as videos, animations, and interactive simulations, which better capture the students' visual and audio attention, but at the same time are presented in manageable chunks to avoid cognitive overload. Also, I designed activities where students were interactive with mathematics content to take an active role in their learning for enhanced understanding and remembrance. I was then able to integrate these principles into the development of an improved technological application that best suits the processing and learning of mathematics by the students. This principle helped me to consider the balance of visual representation, verbal explanation and students' active involvement in mathematical concepts in my action research. I found that technology could be more meaningful when multimedia resources were directly connected with the learning objectives and presented in a way that supported students' understanding, rather than simply adding more information. Therefore, the theory guided my thoughts about how multimedia could be created with the goal to promote students' conceptual understanding, reduce extraneous cognitive load, and support more active involvement in mathematics learning.

Empirical Review

Literature illustrates various ways of conceptualizing how technology influences teaching and learning. Hill and Uribe-Florez (2020) examined the TPACK framework of secondary math teachers in a rural part of the U.S., focusing on

technology integration. Teachers reported high confidence in PK but lower confidence in TK, with a mean TPACK score of 3.91. Technology was mainly used to enhance conceptual understanding while limiting resources and time were the major issues in integration. The authors conclude that more professional development is needed to improve TK and support effective technology use in mathematics classrooms. In consideration of limitations, this also therefore forms a valued exploration of the role of TPACK framework in shaping classroom technology practices.

Mudzimiri (2012) study describes the development of TPACK in pre-service secondary mathematics teachers. This article studies how a method course, a mathematical modeling course, and a practicum together contribute to the development of TPACK framework. The study followed five pre-service teachers over 15 weeks and found that their prior technology experiences and mathematical background impacted the development of their TPACK framework. Although this study showed the developments in terms of integrating technology into teaching, it did not really reflect the true assessment of TPACK framework. The research supports a holistic approach to teacher training in content, pedagogy and technology in an effort to allow for universally effective instruction.

Thapa et al. (2022) examined the use of GeoGebra in teaching the concept of the circle within the Grade 10 mathematics curriculum of Nepal. The research was developed with 18 students from the teaching experiment methodology based on social constructivism. The study revealed that GeoGebra improved students' ability to visualize and understand abstract geometrical concepts on chords, diameters and cyclic quadrilaterals. The software promoted active involvement by means of group work and allowed meaningful learner-centered instruction. The research ended with GeoGebra enhancing students' motivation and conceptual learning and supporting innovative interactive approaches to teaching mathematics.

Dahal et al. (2022) used GeoGebra to teach geometric transformations to ninth-grade students in Kathmandu, Nepal. In the qualitative teaching experiment, 20 students were involved in the concepts of reflection, rotation, translation, and dilation through dynamic mathematics software. It was observed that GeoGebra is easy to handle and supports deep learning in fostering discovery and collaborative learning. It visualizes abstract ideas in mathematics and therefore helps learners retain the knowledge better. Besides, GeoGebra helped to make the transition from teacher-

centered instruction to student-centered instruction to students who would become active creators and independent explorers of mathematical ideas.

Priyanda et al. (2025) performed a systematic review on the impact of the TPACK framework on the pedagogical reasoning of mathematics educators in instructional preparation. The authors examined teachers' decisions to incorporate digital materials into their instruction. The summary indicated that TPACK helped teachers to create interactive simulations, dynamic visualizations and scaffolded assignments to support inquiry-based learning and enhance students' conceptual understanding. However, the review also revealed persistent structural problems such as variable teacher competency, resource limitations and lack of specialized training. Finally, the authors underlined that digital integration must be supported by continual professional development, fair distribution of resources and institutional support to enable teachers to adequately alter their teaching practices. Closer to the present context, Pant et al. (2024) analyzed the narratives of four Nepali secondary mathematics teachers who integrated GeoGebra and reported that conceptual understanding improved only where teachers redesigned tasks rather than merely projecting them, while Simkhada et al. (2025) show that professional anxiety among Nepali mathematics teachers is itself a barrier to pedagogical change. Dahal et al. (2023) further demonstrate that the practicality of technology-supported course design in Nepali depends on validated materials and sustained institutional support.

Siregar (2025) studied the pedagogical potential of GeoGebra as a dynamic tool in teaching learning of mathematics. Siregar describes how GeoGebra integrates abstract algebraic, geometry and calculus concepts into dynamically linked, real-time graphic representations, using classroom observations, document analysis and literature reviews. The use of GeoGebra enhances interactive and inquiry learning, improves intellectual memory, and influences students by converting fixed abstract problems into energetic investigations. It also allows teachers to develop flexible, visual instructional materials and support the formative assessment in real time. However, Siregar points to practical problems, such as a lack of online literacy among teachers and the absence of technology infrastructure in some institutions. The review, overall, reaffirms the need for continuous professional development and institutional support of technology for the full utilization of GeoGebra in today's mathematics teaching.

Research Gap

The literature I have reviewed shows how technology is influential in teaching and learning through various frameworks, for example, the TPACK framework and dynamic tools such as GeoGebra. However, an important gap lies in the measures used to date to assess TPACK development. For instance, Mudzimiri (2012) reported changes in pre-service teachers' TPACK framework. However, reliance upon self-reported data limits insight into whether real changes in instructional practices have occurred. Future research needs to try to establish clear measures of the TPACK framework as a way of better capturing its effect on teaching efficacy.

Findings also depend on specific contexts, such as rural U.S. settings and the schools in Nepal, which limits the transferability of the outcomes. Extending such research to varied cultural and educational settings would broaden understanding of technology integration. While the studies by Thapa et al. (2022) and Dahal et al. (2022) are helpful in terms of discussing the use and advantages of GeoGebra, there remains a need to examine multiple-tool integration to understand how these will complement each other in enhancing TPACK framework. Therefore, future research should seek to connect integration and improvements in student performance using quantifiable measures as a sound basis to inform the effective use of technology in mathematics education.

Chapter Summary

This chapter has set out a theoretical and empirical foundation for integrating the TPACK framework into mathematics education. I have employed Experiential Learning Theory and Multimedia Learning Theory to support dynamic, student-centered instruction. The policy review indicates growing institutional support for digital tools, although a gap remains in practical classroom implementation. The empirical evidence focuses on the effectiveness of tools like GeoGebra, and MS Excel, yet underscores a need for longitudinal research to assess long-term pedagogical impacts.

CHAPTER III

METHODOLOGY

This chapter presents the philosophical considerations of the study-ontology, epistemology and axiology- followed by the research paradigms, the action research design, the site and participants, the action research plan, information collection, meaning making, quality standards and ethical considerations.

Philosophical Considerations of the Study

Philosophical implications underpin this study's concept of reality, knowledge, and values. This portion gives my own perspective on the study's ontological, epistemological, and axiological fundamentals and how they mark the research procedure.

Ontology

Ontology is dedicated to philosophy concerned with questions or queries about existence, being, and reality (VandenBos, 2007), it involves basic issues regarding what there is, and the nature of existence, such as what entities exist, how they might be grouped, and how they might be related to each other. Ontologically, my study assumed multiple and contextual realities. According to Smith (2012), ontology is a branch of philosophy that studies the nature of existence and examines the various types and structures of objects, properties, events, processes, and relationships across all aspects of reality. It deals with the nature and structure of reality (Guarino et al., 2009). In my study, GeoGebra and Microsoft Excel were used in teaching and learning of linear programming and statistics, and students constructed understanding differently from one another.

Epistemology

It is concerned with the theory of knowledge, including attempts to understand nature, source, and limits of knowledge. It answers questions like, what is knowledge? How is it acquired? What are the limits of knowledge? It studies the conditions under which a belief would be appropriately considered true, the sources or causes that give rise to knowledge, and how beliefs are justified. It also deals with the connection between knowledge and truth, as well as belief, while dealing with uncertainty, certainty, and the reliability of different sorts of knowledge (Steup & Neta, 2005). Epistemologically, my study assumed subjective and collaborative ways of knowing.

Axiology

It is the aspect of philosophy concerned with the study of values, not only moral values on what is good and just but also aesthetic values on what is beautiful and pleasing. It looks at types of values that exist, how they are formed, and on what basis actions, outcomes, and objects should be judged. Axiology seeks to find out what possesses value and why, it, therefore, addresses the subjects of ethics, aesthetics, as well as religious philosophy (Hart, 1971). Axiologically, this study integrated the subjective values of the researcher and participants. Thus, it is believed that contextual and subjective values informed the research.

Research Paradigms

Paradigm simply means the world view. It is a lens through which the researcher sees reality, knowledge, experiences and findings (Kivunja & Kuyini, 2017). I have used two research paradigms, interpretive paradigm and critical paradigm, in my study.

Interpretive Paradigm

My research fits into the interpretive paradigm. According to Creswell and Poth (2016), the interpretive paradigm emphasizes understanding the subjective meanings and experiences of individuals. According to Taylor and Medina (2011) focusing on constructing inter-subjective knowledge through participant observation, informal interviews allow the researcher to deeply immerse in the research. This provides rich insights into the lived experience of teachers and students within classrooms, schools and communities. As an interpretive researcher, my role is centered around elaborating knowledge and meaning by processing interpretation. I reflect on the interactive environment and extract meanings from the context surrounding me.

In the study, I emphasize on practical knowledge application to overcome real-life problems and bring about positive change. The theory and practice are not separate entities but intertwined in action research, they emphatically state that the practitioner must also be a contributor to knowledge itself through their action research, contributing to the general reservoir of educational theory yet essentially solving issues within a context (McNiff, 2009). Using the action research, I have collaborated with the students in an educational setting by conducting the two cycles which are carried on the outcomes of each cycle. Adopting, this method allows the addressing of learning challenges collaboratively and results in contributing to a

deeper understanding of integrating technology into mathematics education (Mudzimiri, 2010).

Critical Paradigm

My research is also located in the critical paradigm that focuses on critical reflection, interrogation of existing practices and meaningful change. The critical paradigm is interested in understanding educational practices and also in examining the assumptions, inequalities and limitations that exist in them (Taylor & Medina, 2013). My research includes a critical reflection on my current practices of teaching mathematics and the identification of the challenges students experience when learning abstract mathematical concepts. I do not take traditional teaching for granted, I ask the question “what works?” and look for ways to make learning mathematics more meaningful, interactive, and accessible.

Furthermore, reflection and improvement are an essential part of my action research. I always reflect on my teaching practice, students’ responses, learning difficulties and the results of each action cycle. This reflection helps me to see what worked, what didn’t work and what needs to be improved in the next cycle. In the process, I critically discuss how ICT tools such as GeoGebra and Excel can challenge traditional teacher-centered teaching and learning practices and support more active and student-centered learning of mathematics. Thus, my research does not simply produce knowledge, but through critical reflection, changes teaching practices and enhances students’ experiences of learning. I hope to make a positive difference in my mathematics class with this model of planning, acting, observing, reflecting, and improving.

Action Research as a Research Design

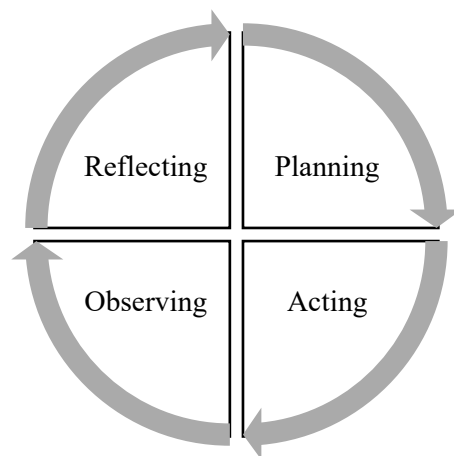
The systematic process of identifying the problem, taking action to address it, observing the outcomes and reflecting on the action to improve the practice is action research. According to Lewin (1946), action research is a systematic and participatory approach to address practical problems through cycles of plan, action, observation, and reflection. It is an invaluable guide for novice and experienced researchers from a range of disciplines, backgrounds and levels of study to understand how action research works in real life contexts (Stringer & Aragón, 2020).

I applied action research in my study. According to McNiff (2013), it is a reflective, participatory, and iterative process undertaken by individuals or groups to investigate and improve their practices, generate knowledge, and bring about positive

changes in their personal and professional contexts. Based on Hult and Lennung (1980), action research helps to solve real world problems, to advance scientific knowledge and to improve the skills of the people involved. It involves collaborative efforts in real-time situations, utilizing feedback to create a cyclical process as shown in the following diagram.

Figure 1

Components of Action Research



Its goal is a deeper comprehension of a social scenario, especially focused on changes within social systems. Action research operates within an agreed-upon ethical framework, primarily suitable for comprehending and facilitating change processes within social systems. TPACK framework aims to encapsulate the fundamental aspects of knowledge necessary for teachers when integrating technology into their instructional practices (Koehler & Mishra, 2009). In both the classroom and ICT room environments, action research offers chances for both educators and students to reflect and enhance their methods, acting as a space to test and refine their teaching and learning activities/approaches. Action research is a cyclic process of planning, acting, observing and reflecting. The methodology aims to produce iterative improvements and to produce practical knowledge in a specific teaching content of mathematics.

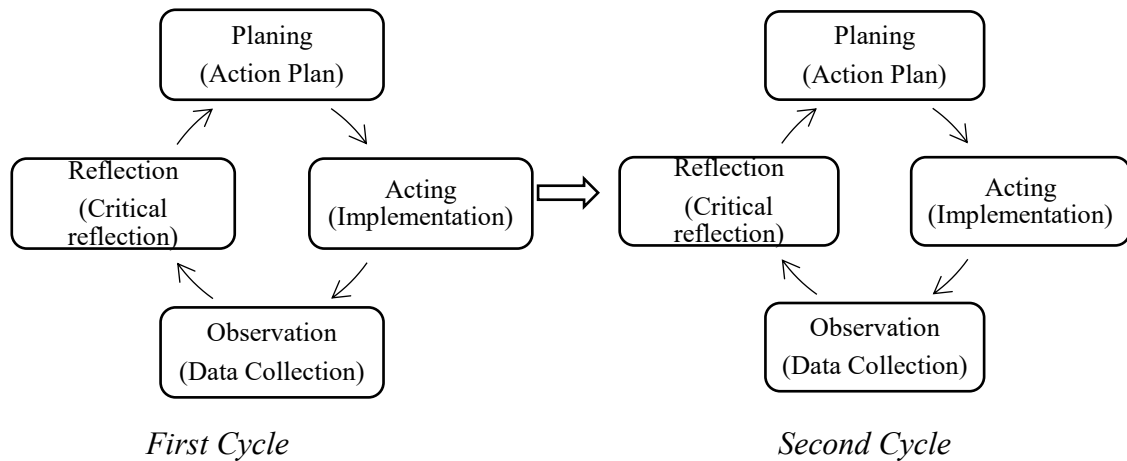
Cyclic Plan of My Action Research

Action research is a cyclical process of planning, acting, observing, and reflecting. Each cycle is a chance to gather data, analyze it, reflect on it, and improve what we do next. Each cycle involves many interested groups. This research involves two cycles of iterative process and then needs assessment. This approach allows for ongoing learning, modification, and improvement.

My action research followed the cycles as shown in Figure 2:

Figure 2

Cycles of Action Research



Action research involves numerous cycles of planning, acting, observing, and reflecting. However, I followed the two cycles for the study because of time constraints. It permits data gathering, analysis, reflection, and intervention refinement for future cycles. In each cycle, different interest groups participate. The iterative procedure of this research incorporates two cycles followed by needs assessment, allowing for continual learning, adaptation, and improvement. I followed Kemmis and McTaggart et al. (1988), involving various interest groups and stakeholders in the sequential movement of planning, acting, observing, and reflecting.

Research Site and Participants

For my research, I have chosen one of the community educational institution of the Kathmandu district. My research participants were Grade 10 students aged 14 to 17 years, who are taking mathematics as an optional subject with a total of 14 students, comprising 5 boys and 9 girls. I focused the study on class as well as ICT room to enhance the learning procedure of students using technology so that they can skill up their learnings based on the learning achievement prescribed by Curriculum Development Centre Nepal. The intervention ran for 19 instructional days across the two cycles. Six students (3 boys & 3 girls) were selected purposively because action research emphasizes in-depth understanding and improvement of practice within specific context rather than statistical generalization. Information reached saturation with the selected participants.

My Role as Researcher

This research is grounded in democratic values that treat participants' contributions as equally valuable. Because I was simultaneously the students' teacher and the researcher, I was careful that my teacher authority did not dominate the safe and friendly space for communication, and I invited students to disagree with my interpretations of their reflections.

My Action Plan

The action plan for Cycle I and Cycle II in the form of plan, act, observe and reflect is mentioned below.

Cycle I

Plan

Identify students' difficulties in understanding Linear Programming, particularly graphical representation of inequalities and optimization. Prepare a pre-test to check the students' prior knowledge. Prepare lesson plans and GeoGebra activities to represent inequalities, identify feasible regions and maximum and minimum values.

Act

Day 1: Perform a pre-test to the students to know their prior understanding and learning difficulties.

Day 2: Introduction of constraints, equality, inequality, feasible region, objective function of linear programming.

Day 3: Graphical representation of linear inequality (Both paper graph and GeoGebra)

Day 4: Instruct students to graphically show the linear inequalities with the use of graph papers.

Day 5: Instruct students to graphically show the linear inequalities with the use of GeoGebra and students will find out the solution part by the help of shaded regions.

Day 6: Facilitate the students to find the maximum and minimum values of the objective function by the help of Graph Papers.

Day 7: Facilitate the students to find the maximum and minimum values of the objective function by the help of GeoGebra.

Day 8: Conduct a written test (post-test) to find out the learning of the students after the intervention.

Observe

Monitor student participation and interest, confidence and ability to use GeoGebra. Students have trouble entering equations, interpreting graphs, identifying feasible regions and determining optimal values. Compare the students' performance on the pre-test and the post-test. Witness the changes in student motivation, involvement and comprehension of graphical concepts.

Reflect

Evaluate the pre-test and post-test scores. Consider whether GeoGebra supported students' understanding of the graphical representation and optimization of the inequalities. Identify students who made substantial progress and those who still struggled with the content. Consider whether the interactive visualization improved students' engagement and conceptual understanding. Use the results to improve the teaching strategy on the next cycle.

Cycle II**Plan**

Identify students' difficulties in calculating Quartile Deviation, Mean Deviation, Standard Deviation, and their coefficients. Prepare a pre-test to determine students' existing knowledge and computational ability. Design the lessons using the formulae and MS Excel so that students can compare both approaches. Prepare worksheets and statistical problems for practice.

Act

Day 1: Conduct a written pre-test.

Day 2: Teach the computing Quartile Deviation and its Coefficient using formula.

Day 3: Teach the computing Quartile Deviation and its Coefficient using MS Excel.

Day 4: Solution of numerical related to Quartile Deviation and its Coefficient using both formula and MS Excel.

Day 5: Teach Mean Deviation and Standard Deviation and their coefficients using conventional formulae.

Day 6: Teach Mean Deviation and Standard Deviation and their coefficients using MS Excel.

Day 7: Teach Mean Deviation and Standard Deviation and their coefficients using formulae and MS Excel.

Day 8: Problems solution by MS Excel (Quartile Deviation, Mean deviation and Standard Deviation).

Day 9: Practical problems solution by MS Excel (Quartile Deviation, Mean deviation and Standard Deviation).

Day 10: Written post-test.

Day 11: Conduct reflection activities with the six selected students to register their experiences, perceptions, difficulties and opinions about the use of formula and Excel.

Observe

Observe students' ability to understand statistical formulae and carry out calculations correctly. See how they use Excel, how confident they are. Record errors in manual calculations and errors in data and formulae entries in Excel. See whether Excel can save students time, check calculations and help them understand statistical concepts. Gather students' feedback during the reflection session and compare pre-test and post-test performance.

Reflect

Review students' pre- and post-test results to assess the effectiveness of the intervention. Consider whether Excel helped students become more accurate, faster, more confident and more interested in learning statistics. Examine the six students' reflections to find common advantages and problems. Determine whether students prefer calculations based on formulas or based on Excel or a combination of both. Use the results to enhance future statistics lessons and pedagogy involving ICT.

Information Collection Procedure

The research is based on action research where students were fully involved in the learning activities as well as me, as the plans included the teaching phenomena or procedure that has to be prepared by the teacher and need to be more crucial and attentive while performing the activities that has been included in the action research. The activities are performed in class as well as in the ICT room. The preliminary test is conducted before the implementation of the action research. Students worked collaboratively in learning and solving problems related to linear programming and statistics. Reflection from the students is another source of data. The class assignment and examination records also support the data. At the end of the cycle, an evaluation-based examination is conducted to find out whether the action research can provide adequate support in the learning process of the students and also their ability to apply the learnings to real-world problems. The cycle was repeated twice.

Meaning Making and Interpretation

Interpretation stands as the pivotal challenge in qualitative research; it is imperative for deriving meaning from our data, without which understanding the information becomes unattainable (Willig, 2014). Information was analyzed thematically from classroom observation notes, students' written reflections and classroom assignments, supported by pre- and post-test scores in each cycle by providing them with the questions along with their classroom activities like attention towards the teachers teaching, obeying the instruction provided by teacher, distraction with the outdoor surroundings, collaborative learning, helping in learning of friends. Similarly, the grade room class assignment and reflection are also analyzed.

Quality Standards

As Action researchers, we need to maintain certain standards to ensure the strength and dependability of the findings. To make the research acceptable the data needs to be analyzed and interpreted (Willig, 2014). To maintain this level of quality, I explicitly outline the research design, encompassing specifics about data collection methods, analysis protocols, and ethical considerations. Action research supports the active engagement of both the researcher and learners throughout the research process. I triangulated evaluation marks, classroom observation notes and students' written reflections, and I shared my interpretations with participants for confirmation. The words of researcher and learners are valued (Taylor & Medina, 2011). Rubrics are created for the evaluation of the students in the collaborative, classroom as well as the ICT room while learning linear optimization. I am transparent with the data collected from the research. I applied the TPACK framework in mathematics learning through action research so that the students could apply their learnings to real-world problems.

Ethical Considerations

I strictly followed the ethical guidance propounded by my University, Kathmandu University School of Education. Students were made aware of the research process and activities, and assent was obtained from students in addition to parental consent (Zeni, 1998). Pseudo-names are used to indicate the students. Consent was obtained from parents and the school administration for the videos and photographs that support the evidence of the research and identifying features were removed before reporting. The learners were treated respectfully (British Educational Research Association [BERA], 2011). Moreover, I evaluate both the possible

advantages and drawbacks connected with the research. My goal is to make sure that the benefits derived from the research are greater than any potential negative consequences or harm that might arise.

Chapter Summary

This chapter has set out a qualitative action research design grounded in the interpretive paradigm and critical paradigms. It explores multiple and contextual realities through ontological and subjective epistemological lenses. I used two-cycles iterative process of planning, acting, observing, and reflecting. The study integrates ICT tools like GeoGebra and Excel to teach linear programming and statistics of mathematics. I followed the ethical guidelines prescribed by Kathmandu University, maintaining participant anonymity and informed consent.

CHAPTER IV

THE ACTION RESEARCH JOURNEY: IMPLEMENTING TPACK IN THE CLASSROOM

I have tried to describe my firsthand experience of bringing the TPACK framework into Grade 10 mathematics classroom. Based on my action plan and fieldwork, I have presented in this section the daily events, observations, and student reactions gathered during my teaching. It provides a detailed, clear account of how theory was applied across two cycles of research.

In this chapter, I have narrated the story of what actually happened: the sequence of events, the changes in classroom behavior, the digital tools introduced and the changes in student engagement with mathematics. This chapter provides raw evidence by carefully documenting the planning, acting, observing and reflecting phases of each cycle. The evidence presented here is the foundation for the subsequent deep thematic analysis and meaning-making process for the next chapters.

Cycle I: Visualizing Linear Programming with GeoGebra (Days 1-8)

The first cycle took eight instructional days. The content I selected was Linear Programming, with emphasis on finding maximum and minimum values of the objective function; this constituted the content knowledge of my action research. The technological tool (Technological Knowledge) was GeoGebra, software selected to allow students to visualize the relationship between written equations and graphs.

Planning and Baseline Assessment (Day 1)

On the first day, to understand where my students were starting from, I gave them a written pre-test. All 14 enrolled students were present. The scores were out of a total of 20 marks and showed a wide range of understanding:

Table 1*Cycle I Pre-Test Scores*

Student	Pre Test (20)
1	10
2	7
3	11
4	8
5	10
6	8
7	9
8	10
9	13
10	11
11	14
12	7
13	5
14	10

As per my planning, I was able to meet the requirements that I had set (Overall nature of teaching, learning, activities, and evaluation). Students seem uneasy while taking the test, as they were unaccustomed to this type of activity. They seem happy as I share with them the entire cycle 1.

Acting and Observing: The Classroom Experience (Days 2 - 7)

Day 2: Setting the Foundation

On this day, I was on time, and the students were also on time. I recall the activities I performed yesterday so it will be easy for them to connect. I shared their marks that they have obtained in the previous day's test. There seemed to be hope in the students that they could definitely perform better in the topic linear optimization. I started teaching them how to solve inequality along with the property of trichotomy, by providing the basic concepts of inequality. This is made clear in their understanding of the foundations of inequality and equality. After that, I introduced the basics of graphs and shared the basic rules that were to be used in graph plotting. After solving it manually, I also showed its visualization in GeoGebra. Before this, I directed students on how to use GeoGebra with its fundamentals by providing them

with two questions. I provided them with three questions and asked them to solve them using a graph and a pictorial presentation in GeoGebra, and they solved them accordingly.

Students find different ways of teaching mathematical content. In today's class the main contents were the difference between greater than ($>$) or smaller than ($<$) and greater than or equal to ($\geq$) and smaller than or equal to ($\leq$) and with its representation in brackets and graphically with its bounded values too.

One student explained, "Does study go like this?" In return, one explained, "Have a read first, and we will discuss it afterward". One girl student stopped them by saying, "Come on, guys, why are you like this? He is our teacher, and we can learn through different new techniques. It makes me easy as the students guide their friends in the learning process. I also added on, "The study needs to be gone like this because the method I'm following keeps student at the center of learning.

Day 3: Building Skills and Teamwork

This morning (same day), I discussed my class with our school's vice principal. He told me just now that the exams of the students are approaching and asked me to be very careful so that the students are well prepared. I shared with him my lesson plan, schedule and told him I would go according to plan, covering subjects as necessary. I began the class quickly summarizing what we had covered the day before. To encourage active engagement, I asked Hem (Pseudonym) to describe to me what we did the previous day. This approach not only made it possible for the revision of previous concepts but also prompted the students to participate in the learning process. Upon attending, I noticed that four new students joined the class while Sita (Pseudonym) was absent. After inquiring about her friends, I noticed that she was unable to attend due to health concerns. I noticed she wasn't there and made a note to ensure she received the material for today's lesson later.

Today's class covered the two-variable equations and inequalities as a follow-up to single-variable equations that they have studied before. To allow for a smooth transition, I began by providing questions based on single-variable equations and asked the students to solve them in their notebooks with graph representations. Regular students were largely confident about solving these problems. Among the new students, one grasped the concepts quickly and three required additional attention. To facilitate learning, I allowed the regular students to help some of their peers solve problems and sketch the corresponding graphs. This interactive method

enhanced peer learning and empowered new students to gain understanding and confidence in solving mathematical questions/problems.

The new students were visibly surprised to see their peers using GeoGebra to create graphical solutions. It enhanced their understanding of equations and inequalities, but also increased their interest in using technology as a learning tool. Lastly, I gave them two practice problems on two variable equations so they can practice using their skills independently. The practice questions helped to strengthen problem-solving methods (procedures) and provided students with the opportunity to practice visualization of solutions efficiently. The questions are:

1. Draw the graph of given inequalities: $x + y \leq 3$, $x \geq 0$ and $y \geq 0$.
2. Draw the graph of given inequalities: $x + 2y \leq 8$, $x - y \leq 1$, $x \leq 7$, $x \geq 0$ and $y \geq 0$.

The session overall was productive, positive and participatory. The session integrated traditional teaching methods with technology to enhance conceptual understanding and engagement. The use of a collaborative approach to learning, and the use of GeoGebra, helped students to develop skills of visualization and problem solving and to adequately prepare for future exams, while at the same time creating a positive and engaging learning environment.

Figure 3

Students Engagement in Learning the Basics of GeoGebra in Pairs



Day 4 Overcoming Math Fear

Today's class focused on graphs, and it helped to find inequality. Students seem astonished, as they have not learned this type of question. I connected the lesson to their previous learning of coordinate geometry. The slope of the line joining the two points, the equation of a straight line passing through a single point, and the equation of a straight line passing through two points. Students solve the problem that I have given them. After that, I solved one of the related problems. Now they seem happy, and I asked them to check the inequality they obtained in GeoGebra. They did it and answered that the graph obtained in GeoGebra is the same as in the given question. I provide them with three questions as an assignment, and the class ends for today.

While moving around the class, I heard from one of the students Hem (Pseudonym), "My friend, I'm irritate with this topic," he shared with Gita (Pseudonym). When I reached him, he stopped talking with his friend. I gently asked him what was troubling him. He was reluctant at first and then shared that in Grade 8 a teacher had punished him for being unable to identify the greater-than and less-than signs.

From my perspective as a researcher, this classroom experience revealed that students' difficulties in mathematics may sometimes be connected to their previous negative learning experiences. The use of prior knowledge, collaborative problem solving and GeoGebra helped students develop confidence in understanding graphical inequalities. Hem's (Pseudonym) response made me reflect on the emotional impact of punishment in learning. I realized that a caring and child protective classroom environment is necessary for overcoming mathematics anxiety and inspiring the students to take part openly and confidently in the learning process of mathematical contents.

Day 5 - 7: Managing the Digital Classroom

I solved the problems using linear optimization and presented them in GeoGebra as well. Students were excited by the fusion of these two, i.e. manually solving the problems and presenting it digitally by the use of ICT tools.

Students seem excited and happy in the classroom. The students were more open up towards me. In between, they asked me why this and not the next? To check whether they were attentive in the grade room, I wrote incorrect information. i.e. 6 instead of 3. Three girl students asked me to correct the necessary one. I asked the

students to open GeoGebra so they could check or visualize the graphical/pictorial presentation of the problems. The student followed my instructions and solved the problem I gave them, using GeoGebra. Today, all students were busy with GeoGebra. I gave them three questions on linear optimization as homework. The class is over.

One of the students, Srimon (Pseudonym) seems to smile while I was solving the problems; I think that his nature is just like that. Later, four other students joined him, and they used to look towards me and see the desktop and smile again. I was sure that they might be busy with something else, not in their studies. I found that they were watching a cartoon on YouTube. I ask Srimon (Pseudonym) to stop watching the video, copy the solution, and concentrate on the GeoGebra output. Again, the process was repeated, and I asked him with a sweet smile; he then copied the solution.

Figure 4

Students' Engagement in Learning Linear Programming



From my perspective, this experience demonstrated both the opportunities and challenges of integrating digital technology into the mathematics classroom. The combination of manual problem solving and GeoGebra increased students' excitement, participation and ability to verify their answer visually. Their identification of my intentional error also indicated active attention and critical thinking. However, the incident in which students watched off-task videos underlined the importance of effective digital classroom management. I reflected that technology integration requires not only technical skills but also clear outcomes, monitoring and helpful guidance to maintain students focus and fruitful engagement.

Day 8: Reflecting Cycle I Outcomes

On Day 8, I administered the post-test. With respect to the pre-test, this time, students have obtained better marks after using TPACK in my teaching pedagogy.

Table 2*Cycle I Pre-Test and Post-Test Comparison*

Student 1	Pre Test (20)	Post Test (20)
1	10	13
2	7	10
3	11	12
4	8	10
5	10	11
6	8	8
7	9	10
8	10	8
9	13	14
10	11	13
11	14	17
12	7	10
13	5	8
14	10	13

Class scenario: When I asked the students for feedback, they were very positive. Besides one student, all were happy after the post-test. One student Rima (Pseudonym) shared, *“We want this type of way in teaching.”* I questioned, *“Why?”* Kabita (Pseudonym) replied, *“Tech and Tech skills enhanced our mathematics learning, also the teaching way is different from what we have.”*

After this conversation, Sachit (Pseudonym) *“Sir, my exam didn’t go well. I am unable to do the revision at home due to a lack of a proper device. I do have a phone, but I have a keypad one. Also, I have no time to use the school lab in my free time because of the homework I do free time.”* I replied, *“Don’t worry, you do your best in the upcoming one and manage your time.”* Sachit (Pseudonym) *“Ok, Sir!”* This reminded me that the "digital divide" is a real barrier to using technology in education. Lack of access to a digital device affected this students’ ability to revise at home and also created difficulties in completing technology-based assignments. In response, I shifted more of the digital work into supervised school time.

The cycle I outcomes indicated that the integration of TPACK had a positive influence on students mathematical learning, as most students demonstrated improved

post-test performance. But few lacks, due to the lack of time of revision and device at home as they were home helper, by which they need to focus more in home works rather than study. Their feedback also suggested that the combination of technology and innovative pedagogy increased their interest and engagement. However, Sachit's experience made me reflect critically on the digital divide as usual access to device and learning opportunities can affect students' performance. I realized that effective technology integration must therefore consider equity, accessibility and student's individual circumstances.

Cycle II: Making Statistics Simple via MS Excel (Days 9–19)

By Cycle I, I had successfully established trust and basic computer skills, and I was confident in moving ahead with Cycle II. This cycle was on Statistics (Quartile Deviation, Mean Deviation, Standard Deviation), and the technological tool was Microsoft Excel.

Day 9: Planning and Baseline Assessment

I begin this session with a pre-test on quartiles and their deviations, mean deviation, and standard deviation and its coefficient.

Nine of the fourteen students were present on this day; the remaining five sat the pre-test in their return, so that Table 2 reports all 14. The primary objective of the class was to explore students' prior understanding of the concepts of central tendency and dispersion and to identify their learning gaps before covering the content.

A significant issue I identified was that students had memorized the formula without understanding what they meant. And they had trouble with simple scientific calculators, having to rely on their friends to do simple addition and division.

This was what I based my plan on. So, I therefore decided to offload the heavy arithmetic to MS Excel. If the computer did the math, students could put their mental energy into understanding the concepts. I realized that I also needed to build students' fluency with the scientific calculator alongside their statistical learning.

The baseline assessment revealed an important gap between student's procedural learning and conceptual understanding. Although they could recall statistical formulas, many students struggled to explain their meaning and apply them independently. Their difficulties with scientific calculators also affected their confidence and efficiency in problem solving. Their confidence and efficiency in problem solving were also affected by their difficulties in using scientific calculators. This discovery helped me plan my instruction and so I integrated MS Excel to cut

down on the heavy lifting of long calculations and focus more on conceptual understanding. I also realized the importance of building up students basic technological and computational skills along with statistical learning.

Days 10 - 14: Acting and Observing: The Classroom Experience

On Day 10, I taught them how to calculate quartile deviations by hand, and then on Day 11, I taught them how to use Excel formulas step by step.

I was about 20 minutes late for class. I met with one student Namika (Pseudonym) on the way. I stopped and asked her why she was not in class. She replied that she was not feeling well (with a fever and a weak body). I came to know she is staying in another's home, and under their guidance, she was there. I started the class by explaining quartile deviation with examples, beginning with individual, discrete, and finally continuous series. I provided the examples so that they could understand the quartile along with the deviation. I have solved one problem and asked them to solve the next one. They were able to solve it (collaboratively). One student, Angel (Pseudonym) said, *“Wow, Sir! This is how the lesson should be taught. I understood everything so”*. In return, I asked him, *“Why?”* He replied, *“You have added to the use of learning contents in our daily life, so.”*

I smiled and assigned three questions as home assignments. Also, I shared a plan for tomorrow, and students were eager to use Excel to solve problems related to quartile deviation.

Figure 5

Students Engagement in Learning Statistics Using Technology



Interesting day today. As our classroom is in an ICT lab, there are no worries about the ICT physical tools. The fully furnished lab at the community school has made me more comfortable teaching and learning mathematical content (Optimization and Statistics). First, the commands and instructions were provided to the students so that they wouldn't lag in using Excel. I used the data as the questions in the book (CDC) and the practice book (*Readmore Publication*). Students seem jolly in today's classroom as they learn statistics using Excel. Students asked me, "Can something like this really happen?" First, it was a bit difficult, but with my guidance and collaborative support, they were able to perform the activity. A student, Samika (Pseudonym) shared her experience, "*Wow, this is exactly so easy and can be done quickly. You just need to right prompt only.*" After the first activity, students practice three more questions. They compared yesterday's and today's classes and shared that "It would be so nice if we could always learn like this, ICT with contents in learning really influences us in learning mathematics contents in an interactive way." Today, a student, Krishna (Pseudonym) was absent. He is one of the students who grabs the contents easily. Likewise, student Hari (Pseudonym) grabs content today easily despite being a slow learner, but he is laborious. Lastly, I ask Hari (Pseudonym) to share his experience today. According to him, "*The class taught using ICT was very beneficial for me. I understood everything well.*"

These five days demonstrated how combining hands-on mathematical procedure with ICT can strengthen students' conceptual understanding and engagement. Teaching deviation manually first provided a foundation, while Excel subsequently made calculations faster and more meaningful. Students' reflection indicated increased confidence, enjoyment and recognition of mathematics in practical contexts. I also observed that collaborative support benefited students with different learning abilities. The experience reinforced my understanding that TPACK based teaching can create an interactive learning environment where technology complements mathematical content and supports diverse learners.

Days 15 - 16: Total Focus

Day 15 provided me the most striking observation of the whole study. Students are back at their regular desks doing math by hand. Local musicians (Dhime baja) passed by the school, playing loud music. Students Angel, Rima and Kriti (Pseudonym) immediately stopped working and ran to the window to look.

I learned that students shared their learning experiences in statistics with their friends. Angel came to me and asked me to revise shortly because he had learned in yesterday's classroom. I started my class by introducing mean deviation, standard deviation, their coefficients, and their applications. The formula details are explained, and problems involving group data are solved. I provide them with three questions as home assignments.

The questions are,

1. Write the use of mean deviation, standard deviation in statistics.
2. Write formula to calculate mean deviation, standard deviations and their co-efficient.
3. Calculate mean deviation and standard deviation given data.

C.I	5 – 15	15 - 25	25 - 35	35 - 45
f	8	7	20	15

I met Rima (Pseudonym) on the way to school. She was not attending today's class because she needed to visit her relatives to borrow money for her monthly expenses. She is living with her village friends and elder sister at Bohoratar, Kathmandu. She told me:

Sir, Today I need to pay the house rent to the house owner where I rented. I have to collect the money from a relative first and then give it to the house owner, so I won't be able to attend class today.

Similarly, the students asked me, “*Sir, could you align ICT with learning contents?*” I smiled. This reflects that the students are eager to learn the contents using TPACK.

The ethnic (*Dhime baja*) musician was passing by, playing music. Students Rima, Sam, Kriti, and Meg (Pseudonym) jumped out of their desks, moved to the nearby window, and started watching the event. One student asked the others not to do so. I was momentarily lost for words. One student shared with me that “*It was provided by the ward office to conserve their traditions and culture.*” I asked them, “*Do these activities happen regularly?*” Sam (Pseudonym) replied, “*Sometimes, sir, when we were busy with our writing work.*”

On day 16 of my action research. I was about 5 minutes late. Firstly, I met with the vice-principal to discuss ongoing classes and students' responses. According

to him, “*Students shared that they were enjoying the class that blends with the technological tools of mathematics*”. After that, I reached the classroom, and students were busy solving problems on the computer. I found that Gita (Pseudonym) was taking the lead and reaching out to help each of her friends. This makes me so happy. Students were happy to be using Excel to solve the problems. After that, a short prompt was shared, and questions(data) were taken from their textbook. Interactively, they solved five different problems involving mean, deviation, standard deviation, and their coefficients. I asked them to Google the real-world applications of standard deviation. They came to know that it was widely used. Rita (Pseudonym), who used to be quiet told me, “*Math is amazing. I’m realizing it now.*” I simply smiled at her, as it was the first time she had been open with me. I ask them to solve three problems related to standard deviation.

The group of ethnic musicians was passing by the school; definitely, this was disturbing the classroom. This time, none of the students were distracted by it. They were busy solving the problems with the computer. I saw the students' dedication to their studies. After a few minutes had passed, I asked students Angel, Rima and Kriti (Pseudonym), *why they had not watched the incident? Before they were busy doing so.* With a smiley face, Rima (Pseudonym) replied, “*Sir, I find it quite interesting to solve standard deviation problems using MS Excel. So, I didn’t watch it.*” Others also nodded in support of her. This proved to me that when teaching is truly engaging, students become so focused that external distractions disappear.

The observations clearly demonstrated the importance of meaningful engagement in sustaining student attention. On Day 15, while working with pen and paper, students were easily distracted by external event. On Day 16, the same distraction had little effect while students were actively using Excel to solve mathematical problems. This contrast made me note that when technology is deliberately integrated with content and pedagogy, it can lead to deep concentration and motivation. I also saw a rise in collaboration, confidence and participation indicating that engaging TPACK based instruction can minimize distractions and promote sustained learning.

Day 17: Teaching by Students to Complete the Learning Cycle

According to my plan, today students need to work in groups to perform the practical work (solving statistics problems) using MS Excel. Before starting the session, I divide them into pairs. After that, I provide them with three different

questions for seven groups. After receiving the question, all of them started solving the problems manually, and right after each manual solution, they used MS Excel to validate their work. They collaborate to solve the problems. Today, based on their understanding, I asked them to create five questions for each group and cross-check their understanding by asking questions of other groups. Finally, I asked the questions that I had prepared for them. At last, during the reflection, Srimon (Pseudonym) said:

Sir, the method you involve us in group work is amazing, we got to know more as our friend has created and asked the questions which make us attentive in our classroom. Not only that, but at the end, when you pose the questions, it provides a better understanding of deviation and its use in the real world, too.

Similarly, Hari (Pseudonym) said, "*The use of ICT tools motivates me in learning statistics.*" What I was expecting was that the class would be disturbed as students are involved in writing as well as practical, too, but the class was a progressive classroom, I mean, student-centric, collaboration with their friends. They are busy learning and solving problems both manually and with ICT blended too.

This classroom experience demonstrated the value of shifting responsibility for learning from the teacher to the students. By creating questions, solving problems collaboratively and cross-checking each other understanding, students became more active, attentive and responsible for their own learning. The combination of manual calculations and MS Excel also enabled them to verify their answers and strengthen conceptual understanding. I was particularly encouraged to observe that the anticipated classroom became more student centered, collaborative, interactive and focused on meaningful mathematical learning.

Day 18: Reflecting: Cycle II Outcomes

I have conducted a post-test with questions from the pre-test for comparison. A practical session was also conducted along with the post-test. Students welcome me to their respective desks to show their outcomes via MS-Excel. Similarly, verbal questions were asked, along with feedback on their use of the ICT tools in learning the content.

Figure 6*Students' Engagement in Post-Test*

The post-test of the Cycle II was informative. Students did not become passive users of Excel; rather, their conceptual understanding and their scores both improved, although two students scored lower than in the pre-test.

Table 3*Cycle II Pre-Test and Post-Test Comparison*

Student	Pre Test (20)	Post Test (20)
1	15	16
2	10	10
3	12	13
4	9	14
5	10	12
6	10	8
7	8	12
8	11	8
9	14	14
10	13	14
11	16	19
12	8	10
13	6	9
14	9	13

Day 19: Voices from the Classroom: What the Students Said

In my understanding, action research is about collaboration. To ensure this study accurately represents the students' experiences, I asked them to write down their honest thoughts on the last day. Their reflections show a significant shift in their views of school and mathematics. All students were present that day. I collected written and conversational reflections from the six purposively selected students. The school principal, the vice-principal, the accountant, and the computer teacher were also present. The principal praised my work (TPACK in Teaching Mathematics).

A student shared that *"We first heard about this class from our school teacher"*. We were informed that it would cover two topics: optimization and statistics. At first, we assumed, it would be similar to the normal (as usual) lessons we usually studied in school. But, the class was completely diverse from what we thought it would be. Instead of learning these topics only in textbooks, we learned to learn with computers. Initially we knew very little about the use of digital technology or communication tools. We didn't know what to do, or how to use them right. But our teacher was like our own teacher, and he took care of us step by step patiently. This type of class was new to us, but it was not very difficult because our teacher explained everything very clearly and progressively until we understood very well.

During the course we learnt how to use digital tools of communication, what they can be used for and how to use them effectively. At the start we were a bit unwilling and unmotivated because we weren't used to this style of learning. But as the classes wore on, they turned out to be fun, interesting, and a lot easier than we had anticipated. Our teacher's kindness, encouragement and support made us enjoy the learning process even more. We really were happy to be able to learn new skills in such a caring environment. I think that if every teacher taught students with the same patience, dedication and affection, very few students would fail in school. We did not have the opportunity to attend many classes like this, but we really hope that the younger students coming after us will have even more opportunities to learn through such interactive and meaningful classes.

Similarly, a second student, Hi! I am currently in grade 10 at this school. Today I want to tell my story. I am from a family of five. Father, mother, elder sister, younger brother and me. My mother's name is Maya (Pseudonym) & my father's name is Thir (Pseudonym). I have been cheerful and energetic since my childhood. My sister and I learned at a School when I was young. We had good studies and our

parents loved us and encouraged us for our good academic performance. Life was good until the COVID-19 pandemic struck and Kathmandu went into lockdown. So, the entire family had to go back to our village.

Since the lockdown lasted for a long time, we continued our studies in the village. We did study well there initially, even there, but as time passed, our education started to suffer. Our family life began to fall apart at the same time. The student then described a period of serious family difficulty and instability at home, following which the family moved to the village. My sister, my younger brother, and I continued studying there for some time. Later, my mother returned to Kathmandu for work with my younger brother with her. She worked hard, and almost all of what she earned was spent on my brother's education.

After my sister completed her SEE examination, she also moved to Kathmandu. I was left alone in the village and living on my own led to many negative thoughts. A few months after my sister left, I also returned to the city. Even after coming back to the city, life was not easy for my sister and me. The student attributed much of the family's hardship to the absence of parental support for education and daily living expenses. Maybe I would have been able to pay my tuition fees on time. But I have learned that we should be grateful for what we have and keep moving ahead.

When I joined this class for the first time, I thought that we would be studying mainly Mathematics, especially Optional Mathematics and improving our mathematical skills. But the class was better than I thought. One of its greatest strengths was that in a short time we learned many new things through simple, practical methods. If I have one suggestion, it is that these classes should have started a few months earlier so we could have benefited even more. At the beginning I thought the teaching style was a little slow because the teacher explained everything in detail and spoke slowly. But gradually as the classes passed I started liking the teaching method more and more. It was fun, motivating and enjoyable. The later sessions were much more interesting than the first day, as we learned through new and interactive approaches. I really liked the experience overall. I think if we would've had the opportunity to attend these classes earlier, I could've gotten better even more. I am grateful for all that I learned and for all the encouragement I received throughout the course.

For example, the next student told the Grade 10 students that a teacher would come to teach Optional Mathematics using ICT tools etc. Initially, we thought the classes would disrupt our regular classes as there was not much time left for the preparation of SEE. But our presumption proved to be false. But the classes actually made it much easier and effective to learn. To be honest, I didn't have high expectations at first. The first two days I wasn't too interested in the classes. But as the sessions went on, I saw how useful and engaging the sessions were. I even thought that it would have been better if the teacher could have continued to take more classes. In general, it is better than I expected. I have no grumbles about the classes. And, I think they were done well. One of the biggest strengths of these classes was the, use of different digital ICT tools. These tools helped us to distinguish between correct and wrong solutions more clearly. Also, develop a more realistic understanding of mathematical concepts with respect to our regular classroom teaching-learning activities. My only worry is that the more dependent on technology may affect the habit of independent learning habit/behavior of the students. The benefits of using these ICT tools, however, far outweigh the potential disadvantages. The teacher's teaching methodology was great. He treated all students equally and didn't concentrate only on those who already understood/grasped the lessons. Instead, he saw the strengths and weaknesses of each individual student and taught us patiently in a fun and engaging manner. His method was to invite all to participate and learn with confidence. As I said before, I wish these classes had started a few months earlier so we could have learned even more. Now, I can easily solve linear optimization problems using GeoGebra. Similarly, I have learned to solve statistical problems more easily using Microsoft Excel. Overall, I strongly believe that if technology is integrated into teaching and learning, students like us will not only find mathematics easier to understand but will also develop a deeper interest in learning many mathematical concepts.

Further, the next student, A new way of learning began toward the end of our Grade 10 classes when a friendly and inspiring teacher came to our school. His teaching method was excellent. He introduced us the innovative ways of learning and made difficult mathematical concepts simple and simple to understand. This helped me plenty in preparing for my board examination.

He was a much better teacher than I thought he would be. He obviously knew a lot, and how to express ideas. We had always studied Mathematics, especially

Optional Mathematics in the traditional way but this learning experience was totally different. Never did we think that we could learn and solve Optional Mathematics on computers before attending these classes. For us, it was a new experience to learn with digital tools. The classroom teaching was motivating, engaging, and enjoyable. If there were more teachers that taught this way, learning math would be a lot easier, and students would never get bored in class. We learned how to use computers and various software to solve mathematical problems. This made the lessons more interactive and practical.” This method improved our understanding of mathematics as well as helping us to develop useful digital skills. The teacher was nice and friendly to all students. He would take each of the learners one by one, listen to our questions, talk about our difficulties and patiently clear all our doubts. His positive attitude made us feel confident and inspired to learn.

I would like to thank him for spending with us and introducing us to such creative way of learning. He taught us not only mathematical concepts but how mathematics can be used in our lives. I am so thankful for this great learning experience.

Moreover, the next students, when a new teacher was added to our school, we were a little nervous because everything was new to us. We always learned math in a simple traditional way, so we didn’t know many new ways. In the beginning, it was difficult for us when the new teacher began to teach using computers. We struggled to adapt to this new method of learning. But gradually it became easier and more fun. At first, we didn't care and were feeling lazy, but as we went on learning, we started liking it a lot. We didn't know we could even practice exercises on a computer because we had never done so before. We are very happy that the new teacher introduced us to new ideas and new ways of learning. We hope that the students in the lower grades will also get the opportunity to learn these methods from the beginning. Since our classes started later, we could not cover everything, but whatever we learned was very useful, practical, and skill oriented.

“We are now confident we can pass on what we learned to our younger brothers, sisters and others back home.” We think that all students should have the chance to learn on computers. Our teacher was very good at teaching us with new teaching methods and we were happy to learn new things. We wanted to know more but unfortunately the classes were over. We felt sad. We want to give our deepest thanks to our teacher for teaching us so effectively. We had only a short time for our

classes, but we learned many valuable things. We hope the students who come after us will have the chance to learn even more than we did.

We appreciate the valuable courses that have been provided for us within such a short period of time. We learned how to solve mathematical problems with the help of technology, and we understood that it makes learning mathematics more effective. Learning mathematics using visual methods made the concepts easier to understand and more interesting. We were particularly delighted to learn this way. Finally, the reflection of the next student, my name is *Seema* (Pseudonym), and I am currently studying in Grade 10. As far as I can remember, I have been able to learn and understand many things since Grade 1. During my early school years, I gained knowledge in many subjects. I studied in my village until Grade 3. Since my academic performance was not so good, my family decided to send me to Dhangadhi for a good education at the age of seven years old. I went there and stayed with my uncle.

According to Seema, when she moved to Dhangadhi, she joined Rainbow Boarding School (Pseudonym) in Mahendranagar in Grade 3. She found the new household demanding at first, but the guidance she received helped her studies improve considerably. In her first year she passed the examinations, and in the year after she was first in my class. Her teachers were pleased with her academic performance and kept studying hard. Until 6th grade, she was the best student in her school. But she had to return back to her birth place (village) due to the reason of COVID-19 pandemic. But when She returned home it was difficult to leave her family and village again. So, she could not go back to the school. She continued her studies in her village. But she could see that her studies were increasingly being affected. She was more into hanging out and playing than school. She was not doing well in school when she was in Grade 8.

Later, she came to Kathmandu Valley to continue her studies. One day, her head teacher informed us that a new teacher would conduct classes to teach us using ICT in mathematics. When she first heard this, she thought it would increase her study burden and that it might affect her examination results. Therefore, she was not very interested in attending those classes.

However, the classes turned out to be much better and more effective than she had expected. She knew a lot of learning contents/things, and the classes were fun, fascinating, and effective too. In the classes she along with her friends learnt about

computers and many other modern technologies. The teacher executed practical activities that helped to understand the concepts more easily and effectively. According to her, the classes conducted by the sir were near to our examination period, which made it a little difficult to manage her exam preparation, but the learning of linear optimization along with Statistics was extremely valuable and effective. She add on that the teacher taught the contents in well-mannered by the integration of ICT tools. He was friendly, and taught in a motivational, interactive, and positive manner. He taught with student-centric teaching methodology which made the learning experience more meaningful. We all really liked the classes. The teacher explained the learning contents in a simple and understandable way. He used technological tools to teach mathematics, especially topics such as linear optimization (maximization and minimization) and Statistics, in a totally different way from the conventional methods that we used to have before. His classes were student-centered, and I was introduced for the first time to the use of technology to learn math.

Thank you for this opportunity to my school and our teacher. The teacher did the assessment and said that my performance improved a lot. The score I got after the classes was much higher than the score I got before the classes. Finally, I discovered that learning mathematics with TPACK method made the subject easier to understand and the concepts were clear and meaningful.

Chapter Summary

This chapter has presented a story of my action research. By explaining two teaching cycles using GeoGebra and MS Excel, the observations show a clear journey of teaching and learning using the TPACK approach. Students began with confusion and apprehension about technology; guided by a patient and supportive teaching style, they became highly focused, collaborative learners who reported enjoying the process. The test scores indicate improvement for most students, while the classroom observations and student reflections point to increased confidence and engagement.

CHAPTER V

DATA ANALYSIS AND INTERPRETATION

The primary goal of qualitative action research is not merely to report what happened in the classroom, but to deeply understand *why* it happened and what it means for pedagogical transformation. In the previous chapter, I presented the raw narrative of my fieldwork across two action research cycles using GeoGebra and Microsoft Excel. In this chapter, I followed Data, Discussion, Literature and Experience (DDLE) structure to analyze that data to answer my core research questions regarding the impact of the TPACK framework on mathematics instruction.

Coding my classroom observations, notes, students' written reflections and the pre- and post-test records yielded three major themes. Coding was inductive and iterative: I read the corpus repeatedly, generated initial codes, clustered them into candidate themes and revisited the raw material to confirm or discard each theme.

Making the Abstract Visible to Minimize Cognitive Load

The first major theme is how the strategic use of technology moved my students from rote memorization of math procedures to a real understanding of abstract concepts.

For instance, students in Cycle I only had a superficial understanding of linear programming of mathematics in the baseline assessment. Students knew the formulas but could not apply them in solving the numerical problems (Mahmudi, 2021). However, with GeoGebra students could see the shaded regions of inequalities immediately (Days 2-5). Day 4 was a pivotal moment with Hem (Pseudonym). He was very frustrated and told me a story about a teacher punishing him for not knowing the greater than ($>$) and less than ($<$) signs. He could manipulate these symbols dynamically on the screen with GeoGebra and see the graph change immediately which enabled him to overcome the fear. Hem (Pseudonym) wrote in his final reflection that the tools gave the class a clearer sense of correct and incorrect answers and a more realistic understanding of mathematical concepts, a pattern also reported by Siregar (2025). Post-test scores improved for most students, although two students scored lower than in the pre-test, which cautions against reading the gain as uniform.

Before this intervention, my students functioned largely as human calculators. They had been taught that mathematics is a sequence of rules and procedures to be

followed and copied from the whiteboard. The data reveal that technology, when used correctly, does not do the learning for the students; rather, it acts as a visual bridge. For Hem (Pseudonym), the abstract inequality symbols had become a source of anxiety. GeoGebra gave him a concrete, visual anchor that eased his anxiety because he could visualize the symbols ($<$, $>$, $\geq$ and $\leq$). The software could do the manual graphing work, leaving students with the mental bandwidth to ask “why?” instead of “how?”

This theme aligns with Mayer’s Cognitive Theory of Multimedia Learning (Mayer, 1997, 2002, 2014). Mayer argues that the human brain has a limited processing capacity. Students experience “cognitive overload” when they are required to perform complex manual calculations and draw complex graphs simultaneously. Using the Technological Knowledge (TK) of the TPACK framework to introduce GeoGebra helped me reduce this extraneous cognitive load. Dynamic graphs engaged the visual channel, freeing working memory to grasp the core content knowledge (CK). Also, this result is consistent with the findings of Dahal et al. (2022) and Thapa et al. (2022) who found that dynamic software like GeoGebra helps learners visualize abstract mathematical concepts and moves the classroom from rote learning to deep understanding. Pant et al., (2024) report the same pattern in Nepali secondary classrooms, but add that the shift occurs only where teachers redesign tasks around the total rather than using it for demonstration.

When I was teaching in 2013 and 2020, I would write a solution on the board, explain it five times, and get frustrated when the students didn't get it. I thought good teaching was just being louder and repeating myself. This cycle has completely changed my epistemological view of teaching. Seeing my students light up as they manipulated graphs in GeoGebra taught me that my job is not to force them to copy my work. My job is to provide the right pedagogical tools so they can construct mathematical reality for themselves.

This theme demonstrates that the strategic integration of GeoGebra transformed student’s learning from rote memorization to meaningful conceptual understanding. By making abstract mathematical ideas visible and dynamically manipulable, the technology reduced extraneous cognitive load and allowed students to focus on understanding mathematical relationships rather than merely following procedures. More importantly, this experience transformed my own teaching philosophy helping me realize that effective mathematics teaching is not about

repeatedly transmitting procedures but about creating meaningful opportunities for students to explore, visualize, and construct mathematical understanding independently.

Immersive Engagement and Student Agency

The most powerful observation of student engagement occurred during Cycle II (Statistics) on Days 15 and 16, involving a group of local ethnic musicians (*Dhime baja*). On Day 15, while the students were doing math manually at their desks, the loud music easily distracted them, few students ran to the window. However, on Day 16, while the students were using MS Excel to calculate standard deviations, the musicians passed by again. This time, all of the students were looking at the screen. I questioned why? Rima (Pseudonym) smiled and stated, "*She found it exciting to solve standard deviation problems in MS Excel. Well, I didn't noticed the musician passing by.*"

Additionally, on Day 17, I paired up the students and asked them to write their own math questions, solve them by hand, and check them out in Excel. "Srimon (Pseudonym) said that *the group work was valuable because his friends created and posed the questions, which kept the class attentive.*

Traditional mathematics classrooms tend to be silent, individualistic, and teacher centered. The Dhime Baja incident offers qualitative evidence of flow (Csikszentmihalyi, 1990) sustained intrinsic motivation and concentration-although a single classroom episode cannot establish this on its own. The technology captured their attention, but the collaborative pedagogy sustained it. By asking students to create their own questions and verify them in Excel, I transferred the agency of learning from the teacher to the student. They were no longer just receiving knowledge; they were actively creating and testing it with their peers.

This theme is a living classroom example of David Kolb's Experiential Learning Theory (Kolb, 1984; Kolb, 2015). According to Kolb, authentic learning is a process of Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation. My students went through the whole experiential learning cycle in their interaction with Excel (Concrete Experience), made mistakes and reflected on them (Reflective Observation) what mistake/errors they have made, learned the statistical formulas (Abstract Conceptualization), and came up with new questions for their peers (Active Experimentation). This is in line with the results of

Chai et al. (2013) that teachers who were skillful in integrating TPACK domains enhanced student engagement and collaborative learning naturally.

I was moved to see Gita (Pseudonym) moving around the ICT lab, helping her peer fix their Excel formulas. In that moment, I stepped back and realized the classroom was running itself. I felt an immense sense of pride. I learned that an expert teacher using TPACK does not try to be the center of attention. Instead, the goal of effective teaching is to eliminate the need for the teacher by equipping students with the tools and confidence to find the answers jointly.

This theme highlights how interactive digital tools combined with collaborative work transformed a passive classroom into an active one. Through Microsoft Excel and peer problem creation, students sustained deep focus on the mathematical content despite external distractions. Aligned with Kolb's Experiential Learning Theory (Kolb, 1984, 2015) and TPACK integration, this shift decentralized authority, empowering students to systematically test ideas, support one another and take complete ownership of their mathematics learning.

Empathy as an Anchor in Technology Integration

At first, students were frightened by the advent of computers. As Sachit (Pseudonym) and Srimon (Pseudonym) reflected, they felt nervous, as everything was new and they expected the technology to be an additional burden. In Cycle I, I saw two students watching a cartoon on YouTube instead of working. In addition, the qualitative reflections showed profound personal struggles outside the classroom. *“One student's written reflection described sustained family difficulty and stress outside school; the details are withheld here to protect the participant”*. After a test, Sachit (Pseudonym) came up to me looking worried because he only had an old keypad phone at home and couldn't practice the digital methods outside of school hours.

The data clearly indicate that just placing computers in a classroom does not immediately enhance learning; indeed, it can initially provoke technological anxiety and reveal the “digital divide”. For students without suitable device at home, such as Sachit (Pseudonym), or those carrying serious difficulties outside school, technology can become one more barrier. This action research was successful not because of the software itself but because of the empathic environment in which it was introduced. When I saw students watching cartoons, I did not reprimand them, I redirected them with a smile. I patiently guided students when they were confused. As, Srimon

(Pseudonym) wrote, " *He was encouraging and supportive, which gave us confidence and motivation to learn.*" The technology only succeeded because the students felt psychologically safe.

This theme illustrates the critical importance of Pedagogical Knowledge (PK) within the TPACK framework (Mishra & Koehler, 2006). While much attention is given to the "T" (Technology) and the "C" (Content), the "P" (Pedagogy) involves classroom management, empathy, and the creation of a supportive learning environment. As Niess (2015) claims, the transformation of a teacher's knowledge depends on a delicate balance between these domains. My findings argue that pedagogical knowledge must serve as an emotional anchor. Without a highly empathetic and patient pedagogical approach, Technological Knowledge would have only caused cognitive overload and classroom alienation.

This theme represents my biggest growth as an educator personally. In Chapter I, I told a story from the year 2020 when the "mercury of my temper" rose quickly at the request of a student to repeat the lesson. I relied on forced compliance and authority. In this action research I took a different road deliberately. Handling the YouTube distraction with a smile instead of punishment and creating a safe space for students like Sam (Pseudonym) taught me a profound lesson. I learned that an extraordinary teacher does not command fear; an extraordinary teacher commands trust.

Epistemological Transition from Knowledge Transmission to Co-Construction

This theme highlights a fundamental shift in instructional identity and classroom dynamics from a traditional, authoritative model of teaching to a student-centered, reflective facilitation model. IN earlier teaching practices, mathematics was delivered as a fixed set of procedure where students were expected to passively listen, copy whiteboard solution, and reproduce algorithmic steps through repetition. Integrating the TPACK framework disrupted this traditional paradigm, prompting a transition toward as epistemology stance where mathematical knowledge is dynamically constricted by the learners themselves (Mishra & Koehler, 2006; Petko et al., 2025).

By stepping back and allowing digital tools like GeoGebra and MS Excel to handle repetitive procedural mechanics and static representations, the teacher's role evolved into that of a learning catalyst and guide. As a captured in the chapter IV qualatitative log, when students were given the autonomy to manipulate inequalities,

alter graph parameters, or build their own dataset in Excel, authority in the classroom shifted away from teacher command toward shared inquiry. Classroom interactions moved from silent, individual copying to active peer discussions, students-led problem generation, and collaborative verification, illustrating a practical shift away from transmission toward knowledge co-construction (Niess, 2015).

Furthermore, this shift redefined how mathematical truth and accuracy were established during instruction. Rather than looking solely to the teachers or answer key for validation, students began utilizing feedback loops provided by software interfaces to verify their hypothesis. Chapter IV interview extracts reinforce this transition: multiple participants noted that dynamic visual software allowed them to see why a solution worked immediately rather than relying on teacher confirmation. Consequently, the fundamental nature of mathematical errors evolved; mistakes were no longer viewed as personal failures requiring immediate teacher correction, but rather as valuable, actionable data points for further investigation. The classroom environment transformed into active sense-making where discourse was grounded in shared visual representations. As students verbalized their reasoning while manipulating digital objects on screen, they learned to defend their mathematical logic using empirical evidence gathered directly from the software. The dynamic environment made abstract concepts tangible, enabling students to construct personal mental models of mathematical relationships rather than memorizing external definitions.

Ultimately, this transformation demonstrates that effective TPACK implementation require more than simple technical mastery on the part of the educator, it demands a deep epistemological re-orientation (Mishra & Koehler, 2006; Petko et al., 2025). By trusting students' innate capacity to explore, question, and co-construct mathematical meaning, the instructor succeeds in shifting the center of gravity in the classroom from passive reception to active, lifelong intellectual agency.

Experiential Learning Cycles and the Emergence of Student Agency

This theme captures how the deliberate pairing of hands-on digital experimentation with peer-led problem-solving drives self-directed learning and sustained cognitive engagement. Grounded in Kolb's Experiential Learning Theory (1984), the instructional process systematically guided students through four distinct stages: engaging with concrete digital task, identifying computational or conceptual

errors, understanding underlying statistical or spatial formulas and formulating new mathematical questions for their peers to solve.

A clear indication of increased student agency emerged when students moved beyond assigned exercise to create, test, and cross-check their own statistics problems using Excel. Chapter IV survey data and student reflections showed increased confidence in independently navigating digital tasks. By taking ownership of the learning process, students demonstrated deep focus and intrinsic motivation, often described as flow (Csikszentmihalyi, 1990) where classroom distractions became less influential. Constructing Excel and developing formulas also strengthened their understanding of mathematical concepts, consistent with perspectives on self-efficacy and agenda (Bandura, 1993; Saadah & Indrawatiningsih, 2024).

Continuous experimentation transformed students' problem solving approaches. Rather than immediately seeking teacher assistance, students increasingly used systematic trial, observation, and adjustment. This self-correcting behavior strengthened cognitive resilience and enabled them to break complex mathematical problems into manageable, testable components using technology.

Peer Collaboration further expanded student agency. Students who discovered software features, shortcut, or mathematical patterns naturally shared their knowledge and assumed teaching roles. Focus group data indicated that collaborative digital work helped students take charge of their own learning, without relying on step-by-step teacher guidance. This transformed the classroom into a community of practice with distributed leadership.

Overall, the findings suggest that digital tools integrated through collaborative, inquiry-driven learning can strengthen student agency. Students moved from passive recipients of mathematical rules to active investigators, developing confidence, independence, and resilient problem-solving dispositions (Kolb, 1984; Saadah & Indrawatiningsih, 2024).

Chapter Summary

This chapter use the Data, Discussion, Literature and Experience format to analyze the fieldwork information generated during my action research. Thematic analysis showed that the TPACK framework for enhancing mathematics pedagogy is a multi-faceted process. First, technology needs to be used strategically to visualize abstract mathematics in a way that reduces students' cognitive load as supported by Mayer's Multimedia Learning Theory. Second, when digital tools are embedded into

collaborative tasks, students are in a state of highly focused experiential learning that corresponds to Kolb's learning cycle. And, most importantly, this analysis shows that technology cannot succeed in a vacuum. For this to happen, it needs to be built on a strong foundation of empathetic patient Pedagogical Knowledge (PK) that can break through historical math anxieties, digital distractions and create a safe space for all students to thrive.

CHAPTER VI

FINDINGS, CONCLUSION AND IMPLICATIONS

The starting point of this action research was profound pedagogical dissatisfaction. Looking back on my early years as a mathematics teacher, especially in linear programming and statistics, I always found a gap between rote memorization and true conceptual understanding. The traditional board-and-marker approach did not engage my students, leaving a classroom of passive copying rather than active learning. This study examined the incorporation of the TPACK framework (Mishra & Koehler, 2006) into my Grade 10 mathematics classroom, motivated by the intention to change my teaching practice.

I employed a qualitative action research approach and worked within an interpretive and critical paradigm in two iterative cycles of teaching. In Cycle I, I used GeoGebra to visualize linear programming, and in Cycle II, I used Microsoft Excel to contextualize statistics. The study sought to address how TPACK strategies can be specifically implemented and what the impacts are on both pedagogical practice and student learning through deeply analyzing qualitative field notes, student reflections, and pre- and post-test records through the lens of Experiential Learning Theory (Kolb, 1984) and Multimedia Learning Theory (Mayer, 1997).

Key Findings

The thematic analysis conducted in Chapter V yielded findings that directly address the main research questions of this study.

Research Question 1: Strategies for TPACK Incorporation

Visualization to Minimize Cognitive Load (TK + CK)

Technology was best applied as a dynamic visualization tool, not as a digital textbook. Using GeoGebra to graph inequalities instantly and Excel to manage tedious statistical arithmetic greatly reduced the extraneous cognitive load on students. This strategy reduced the burden on working memory, allowing students to focus on the mathematical concepts underlying the procedure (content knowledge) rather than on procedural mechanics. The key result to emerge from this theme is that technology works best when it is used as a cognitive aid and for visualization purposes, rather than just as a digital substitute for textbooks. Technology reduces unnecessary procedural and computational load, enabling students' working memory to

concentrate on deeper comprehension of underlying mathematical concepts and of Content Knowledge.

Enhancing Collaborative and Experiential Learning (TK + PK)

Technology integration was more effective in conjunction with collaborative pedagogical strategies. The classroom became a dynamic laboratory by moving away from teacher-centered lectures, and having students work in pairs to solve problems manually and check their solutions digitally (e.g., in Cycle II using Excel). This strategy successfully guided students through Kolb's (1984) full cycle of experiential learning.

The general conclusion of this topic is that the integration of technology is more meaningful and successful when combined with collaborative student-centered education. Technology could support the whole experiential learning cycle and change the classroom from a passive to an active and dynamic learning environment, by exposing the students to practical problem solving, peer collaboration and digital verification.

The use of technology also enabled students to take more responsibility for their own learning, while I was able to move from being a transmitter of knowledge to being a facilitator of learning. In pair and group activities students could talk through mathematical procedures, compare answers, find mistakes and check reasoning with digital resources. This process strengthened the connection between technological knowledge and pedagogical knowledge as it showed that technology was best utilized when embedded in purposeful interaction, collaboration, reflection and problem solving activities. In this way, the students' interaction with digital resources did not represent a separate technological activity, but was part of their experiential learning process.

Attaching Technology in Pedagogical Empathy (PK as Anchor)

A significant finding of this research was that Technological Knowledge (TK) could not flourish without deep Pedagogical Knowledge (PK), namely empathy and patience. Redirecting rather than punishing students for digital distractions (e.g., the YouTube incident) and creating a psychologically safe space for students with math anxiety (e.g., Hem's (Pseudonym) fear of inequality signs) proved to be an essential strategy for successful TPACK integration. The new insight from this intervention is that success of technology integration is not determined by technological skills alone, but is critically dependent on pedagogical empathy and patience. The finding suggests

that PK is an anchor to TPACK that helps teachers manage digital distractions, alleviate mathematics anxiety and develop a psychologically safe learning environment for students to use technology more confidently and meaningfully.

Addressing Research Question 2: Effects on Practice and Learning Epistemological Transition in Teaching Practice

The action research process had a profound effect on my own pedagogy. I transitioned from an authoritative transmitter of knowledge who had students copy solutions from a whiteboard at a fast pace, to a facilitator of learning. The TPACK framework led me to relinquish control and to trust students' ability to build knowledge together. The main finding of this theme is that meaningful TPACK integration can promote an epistemological shift in teaching, shifting the role of the teacher from an authoritative transmitter of knowledge to a facilitator of student-centered knowledge construction. The new insight is that a belief in students' capacity to explore, collaborate and construct knowledge is crucial to the transformation of both teaching practice and the nature of classroom learning.

Overcoming Mathematical Anxiety

The qualitative findings showed that the dynamic representations of the digital instruments helped to overcome the long-standing fear of mathematics. Abstract symbols became objects that could be manipulated. Student confidence increased dramatically and reluctance to learn decreased. The main result of this theme is that dynamic digital representations can change students' emotional and cognitive engagement with mathematics by making abstract mathematical concepts visible, interactive and manipulable. The new insight is that technology is a cognitive instrument for comprehending mathematics and an effective tool for reducing mathematical anxiety, increasing confidence and fostering active engagement with learning.

Enhanced Engagement and "Flow"

The TPACK embedding fostered a very high level of intrinsic motivation. The Dhime Baja incident is a case in point. When pedagogical strategies match appropriate technological tools, students enter a state of deep focus (or "flow") that renders them impervious to external distractions in the classroom. The main outcome of this theme is that successful TPACK integration can promote students' deep engagement and intrinsic motivation by establishing a strong connection between pedagogy, technology and learning activities. The new insight is that when

appropriate technology is embedded within meaningful pedagogical strategies, students can experience a state of “flow” characterized by sustained attention, deep involvement, and reduced susceptibility to classroom distractions.

Educational Advancements

This study was primarily qualitative; the pre- and post-test records served as supporting rather than primary evidence. Both cycles showed improvement for most students, which is consistent with, but does not by itself establish, a link between TPACK integration and conceptual mastery. The major finding from this theme is that TPACK integration can contribute to the improvement of students’ academic achievement by strengthening conceptual understanding rather than only improving procedural performance. The new understanding is that qualitative evidence, supported by pre- and post-intervention observations and assessment records, can indicate meaningful educational progress within this classroom, through no casual or generalizable claim is made.

Conclusion

The findings of this action research bring us to a conclusive point, the integration of technology in mathematics education is not a panacea; its effectiveness depends on how it is embedded within the pedagogical and content domains.

The TPACK framework makes a change in my classroom teaching-learning from teacher-centric to student-centric along with the student wellbeing’s. Traditional barriers to mathematical understanding were reduced in my classroom by delivering abstract mathematics (CK) through an empathetic, student-centered and collaborative teaching approach (PK), using tools such as GeoGebra and Excel (TK) to dynamically visualize mathematics. This research finds that the integration of TPACK shifts the locus of learning from the teacher to the learner. It turns the math class from a place of rote learning and fear into an exciting, interactive environment where students can explore, verify, and understand the mathematical principles that shape the world around them. It also demands a deep professional evolution on the part of the educator, where authoritarian instruction is substituted by patient facilitation.

Implications

I have drawn the conclusions from this study that carry significant implications for various stakeholders in the educational sector.

Implications for Teachers and Practitioners

Mathematics teachers must move beyond viewing technology merely as a substitute for the whiteboard (e.g., projecting static PDF). Teachers need to adopt the TPACK framework to critically select digital tools that actively modify and enhance how mathematical content is represented. Furthermore, educators need to understand that the introduction of technology can create anxiety in students and, therefore, emphasize the need to develop deep pedagogical empathy and classroom management skills suited to digital environments.

Implications for School Administrators and Policy-Makers

Policies such as the National Curriculum Framework (CDC, 2022) require integration of ICT but the study reveals a serious gap in its implementation mainly due to “digital divide”. Sachit (Pseudonym) reported that the absence of a suitable device at home was a persistent barrier to learning. School administrators and policymakers need to rectify this disparity by ensuring adequate access to ICT labs, high-quality Wi-Fi, and perhaps setting up device-loaning programs. Moreover, schools should invest in continuous, subject-specific professional development that prepares teachers not just on how to use a software (TK) but on how to integrate pedagogically (TPACK).

Implications for Curriculum Developers

Curriculum developers at institutions like the Curriculum Development Centre (CDC) should explicitly embed TPACK-based activities into textbooks and teacher guides. Rather than simply suggesting the use of technology as an add-on, the curriculum should design specific learning modules that *require* dynamic software (like GeoGebra or Desmos) for conceptual exploration, moving assessment away from sheer arithmetic capability toward analytical and interpretative skills.

Directions for Future Research

Based on the limitations and findings of this study, several avenues of future research are recommended:

Longitudinal Studies

This action research was conducted in two cycles spanning 14 action plan days. Future research should employ longitudinal designs to examine whether the

positive effects of TPACK-based technology integration are sustained over a longer period. Since the present action research was conducted in two cycles of 14 action plan days. It could not adequately determine students long term retention of mathematical concepts or the persistence of changes in their attitude and confidence toward mathematics. Studies conducted over an entire academic year or across multiple academic levels could investigate whether technology-supported conceptual understanding is retained over time and whether sustained TPACK integration influences students' motivation, achievement, digital competence and in STEAM related fields.

Broadening Technological Skills

For this study, I focused on the use of GeoGebra and MS Excel, but future research should consider the pedagogical implications of emerging technologies such as artificial intelligence (AI) tutoring systems, virtual reality (VR) for spatial geometry (Maroukakis et al., 2023) and gamified learning platforms within the TPACK framework.

Exploring the Digital Divide

Future research should investigate the experiences of students who have unequal access to digital devices, reliable internet and technology supported learning opportunities, particularly those from lower socioeconomic backgrounds. Qualitative studies could explore how differences in access to technology at home influence student's participation, confidence, learning opportunities and achievement when ICT integrated teaching is implemented in schools. Research should also identify practical strategies such as school-based digital access, device sharing programs, offline learning resources and community support to reduce technology related educational inequalities.

Expanding to Other Settings

This study was carried out in a selected community school of Kathmandu. Further repetition or replication of this action research in different settings, such as other rural schools in Nepal or schools with different cultural demographics would provide further insight into how contextual factors affect the effectiveness of the TPACK framework. A limitation of the present study should also be acknowledged: as the teacher, researcher and assessor of the same 14 students over a short intervention, my dual role may have shaped both students' responses and my reading of them.

Final Reflection

Writing this dissertation has been the most challenging and rewarding endeavor of my academic and professional career. The action research has been a life-changing journey for me, both personally and professionally. When I first started this research, I was disturbed with the gap between students' memorization of mathematical procedures and their real conceptual understanding. My previous practice was traditional; I would explain mathematical procedures, demonstrate the solution on the board, and expect students to follow and practice. However, through this research I have learned that good mathematics teaching is not simply about clearly explaining the content, but rather about providing meaningful opportunities for students to explore, visualize, question, collaborate and construct their own understanding. The incorporation of TPACK into my mathematics teaching helped me rethink my role as a mathematics teacher/facilitator and encouraged me to become more reflective, flexible and student-centered in my teaching profession.

The integration of technology into my teaching was a huge change in my professional practice. Prior to conducting this action research, I perceived technology as an additional resource that could support classroom teaching. From the two cycles, I learnt that technology is powerful when it is appropriately connected to content and pedagogy. I was able to visualize and make abstract ideas in linear programming easier to understand using GeoGebra, and MS Excel offered students the opportunity to explore statistical ideas without being overwhelmed by lengthy calculations. I learnt that technology should not replace mathematical thinking, but rather, it should offer students opportunities to focus on understanding, reasoning, visualization and interpretation. This experience has developed my Technological Knowledge, Content Knowledge and Pedagogical Knowledge and most importantly, it has helped me to see how these domains need to work together through TPACK.

This action research also changed my understanding of my relationship with students. I learned that patience, empathy, encouragement, and trust are as important as technological skills in creating an effective learning environment. During the research, I encountered students who were anxious about mathematics, students who were initially resistant to technology, students who became distracted, and students who had difficulty accessing digital devices outside school. I tried more and more to understand the reasons for their behavior and to provide appropriate support, rather than to answer with authority or punishment. This helped me to recognize that each

learner comes to the classroom with different experiences, abilities, challenges, and learning needs. I learned to listen more carefully, to observe students more closely, and to respond to their needs with greater sensitivity. This was perhaps one of the most significant changes in my professional identity because I moved from trying to control students toward building trust with them.

The research further developed my capacity as a reflective practitioner. The action research cycle of planning, acting, observing, and reflecting encouraged me to continuously examine my own teaching rather than assuming that a particular teaching method would work for every learner. I learned from students' responses, classroom observations, assessment results, and their written and verbal reflections. I also realized that students become active partners in the teaching learning process when they are given responsibility and opportunities for collaboration. I was impressed by students solving problems manually, verifying solutions through technology, creating questions, supporting peers and taking leadership of group activities, which changed my perception of what a successful mathematics classroom can look like. The increase in students' engagement and academic performance gave me confidence that thoughtful technology integration along with appropriate pedagogy can make mathematics more meaningful and accessible.

Finally, this action research has increased my professional commitment to lifelong learning and development. I now see myself not only as a math teacher, but also as a reflective practitioner and researcher who can identify problems in my own classroom, investigate them systematically, make changes and learn from the outcomes. The research has inspired me to continue exploring novel approaches, digital resources, collaborative learning strategies and student-centered pedagogies. At the same time, it has taught me to be aware of challenges such as the digital divide and over-dependence on technology. Most importantly, I have learnt that effective technology integration is not about using more technology; it is about using the right technology, at the right time, for the right pedagogical purpose, while keeping students' needs at the center. This experience has thus affected not only my pedagogy for teaching mathematics, but also my view of myself as a teacher. I am more reflective, empathetic, technologically conscious, and dedicated to creating a classroom in which students are able to learn mathematics with confidence, curiosity, collaboration, and meaning.

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APPENDICES

Parent's Consent Form

Student's Name: _____

Research Title: HOW DO I IMPROVE MY MATHEMATICS PEDAGOGY
THROUGH TPACK?: AN ACTION RESEARCH

Researcher: Lokendra Karki

Purpose of the Study: The purpose of this Action Research in community school of Kathmandu, Nepal is to implement TPACK in secondary level classes and find out how it empowers students to apply their skills in their learning of mathematical contents.

Parental Role: As a parent, your permission is needed for your child, who is under 18 years old, to take part in action research activities. This participation might also include fieldwork, which requires them to go outside the school area and possibly to different places. Because of your child's age, your open consent is required for them to involve in any fieldwork associated with the research work.

Confidentiality: Your child's (Ward's) identity will be kept confidential in the study reports.

Voluntary Participation: Your child's participation is completely volunteer. You can pull out your consent at any time without any consequence.

Consent: I, (..... Parent's /Guardian's Name.....), as the parent/guardian of (Student's/Ward's Name.....), give consent for their participation in this research.

Signature: _____

Date: _____

School Consent Form

I/We, on behalf of _____ School, understand that the above action research is being conducted as part of the academic requirements of Kathmandu University School of Education.

The school permits the researcher to conduct the study within the school during agreed learning sessions. The research may include classroom observations, mathematics activities, use of digital tools, assessments, students' work, and discussions/reflections. The researcher will minimize disruption to regular teaching and learning and maintain the confidentiality and privacy of the school, teachers, and students. Information collected will be used only for academic and research purposes.

By signing below, I/we provide permission for the researcher to conduct this action research, subject to school policies and applicable ethical requirements.

Head Teacher: _____

Signature: _____

Date: _____

School Stamp: _____

19-Day Action Research Plan for Teaching Linear Programming and Statistics Using ICT

Objective

To explore the effectiveness of using ICT tools such as GeoGebra in teaching Linear Programming, and Excel in teaching Statistics.

Timeline and Focus Areas

Cycle 1: Teaching Linear Programming Using GeoGebra (8 Days)

Cycle 2: Teaching Statistics Using Formulae, and Excel (11 Days)

Day wise Timeline and Focus Areas

Cycle 1: Teaching Linear Programming Using GeoGebra (8 Days)

Table 1

First Cycle of *Action Research*

Day	Activities
1	Pre-Test (Written Examination)
2	Introduction to Linear Programming
3	Graphical Representation of Linear Inequalities
4	Finding Inequalities from Graphs
5	Finding Inequalities using GeoGebra
6	Optimizing Objectives (Finding Maximum and Minimum Values) from graph paper
7	Optimizing Objectives (Finding Maximum and Minimum Values) from GeoGebra
8	Assessment Day (Post-Test)

Cycle 2: Teaching Statistics Using Formulae, and Excel (11 Days)

Table 2

Second Cycle of *Action Research*

Day	Activities
1	Pre-Test (Written Examination)
2	Calculation of Quartile Deviation and its coefficients using formulae
3	Calculation of Quartile Deviation and its coefficients using Excel

-
- | | |
|----|--|
| 4 | Solving Numerical related to Quartile Deviation and its co-efficient using both formula and MS Excel |
| 5 | Calculation of Mean Deviation, Standard Deviation and its coefficients using formulae |
| 6 | Calculation of Mean Deviation, Standard Deviation and its coefficients using Excel |
| 7 | Solving Numerical related to Mean Deviation, Standard Deviation and its coefficients using formulae and MS Excel |
| 8 | Problems solving on MS Excel (Quartile Deviation, Mean Deviation and Standard Deviation) |
| 9 | Practical problems solving on MS Excel (Quartile Deviation, Mean Deviation and Standard Deviation) |
| 10 | Post-Test (Written Examination) |
| 11 | Reflection of 6 Students |
-

Ethical Guidelines for Ethical Approval

(Kathmandu University, School of Education)

Office Use Only

Received on:

Approved on:

Returned for revision on:

Ethical approval number:

Kathmandu University School of Education (Research Committee)

Application for Ethical Approval

Section 1: About research project and student/faculty

1.1 Title of the research project:

.....

1.2 Duration of the research project

Research activities start:

.....

Scheduled Completion date:

.....

1.3 About applicant/s:

Applicant's name and title:

.....

Department/Unit:

Email:

Phone:

Role in the research:

1.4 Student project (to be filled up the student if it is undertaken for his/her studies)

If the project is to be undertaken by a research student as part of their studies, please indicate below.

Section 7 must also be completed.

Admitted year:

Level of study:

Department:

1.5 Faculty research

Names of all researchers:

.....

Area of Expertise:

1.6 Has this project been submitted for ethical approval before? If so, when?

Section 2: About the research project

2.1 Introduce your research project (100 words):

.....

2.2 State research questions.

.....

2.3 Methods of study

Describe how the study will be undertaken and explain what interactions will occur between researchers and participants (100 words)

.....

2.4 Location/s of the research (site/s where the research will be carried out)

.....

2.5 Are you familiar with the local culture/context/professionals? If not, what do you do to adjust with the local culture/people/professions?

.....

Section 3: Participants

3.1 Who will be the participants in this project?

.....

3.2 What is the number of participants?

.....

3.3 What is the age range of participants?

.....

.....

.....

3.4 If this research involves children under 18 years of age, describe how do you comply with the study?

.....

.....

.....

3.5 What is the participant selection and exclusion criteria?

.....

.....

.....

3.6 Will any personal information including names, contact details, email addresses of participants etc. be accessed for purposes of report writing?

.....

.....

3.7 Do you provide the information of the participants to the other person/organization? Explain

.....

.....

Section 4: About ethical considerations

4.1 Describe the likely burden/s of participation and any risks to participants during this the research. If so, how will you minimize the risks?

.....

.....

.....

4.2 Are you providing any reimbursement or pocket expenses to the participants? If so, justify.

.....

.....

4.3 Will you disclose about you and research process to the participants?
 How?

.....

.....

4.4 What risks can be there in the field? If so, how do you mitigate?

.....

.....

4.5 Please confirm by putting tick (✓) that you have ensured the following:

	Yes	No
Security of respondents during the research process		
Security of researchers during the research process		
Protection health hazards because of the research		
Avoidance of environmental hazards because of the research		
Maintaining where applicable the gender and other inclusion		
Avoidance of sexist and stereotypical language		

If explanations are needed in case of above points, please write here.

.....

Section 5: About confidentiality issue

5.1 How do you protect the privacy and confidentiality of participant data and samples during the collection?

.....

5.2 How do you protect the privacy and confidentiality of participant data and samples during the analysis and report writing?

.....

5.3 Are you using photographs or recordings of participants using audio tape, film/video, or other electronic medium and how are these to be used? Will you take consent from the participants?

.....

5.4 When the project is completed, for all the records and materials (written or electronic) used or collected during the project, outline how will the records be stored?

.....

Section 6: Declaration of the researcher (s)

I/we, the researcher(s) agree to:

- conduct the project in accordance with ethical guidelines.
- start this research project only after obtaining final approval from the Research Committee
- submit final report to the Research Committee and get its approval before it is submitted to KUSOED or another agency.

- accept responsibility for the conduct of this research project remaining in ethical principles.

Name and signature of applicant/s.		
Applicant's signature:	Name:	Date:
Researcher's signature:	Name:	Date:
Researcher's signature:	Name:	Date:

HoD/Program Coordinator's signature for submitting
this application to the Research Committee for ethical
approval.....

Date:

Pre-Test Questions of Cycle I

1. Write the name of any four applications that can be used in learning mathematical contents? [2]
2. What is meant by maximization and minimization in linear programming? [2]
3. Write your understanding on “feasible region”. [2]
4. A factory produces two products a and b. The profit earned from each unit of a is Rs. 20 and from each unit of b is Rs 10.
 - a. Write the objective function representing the total profit. [2]
 - b. State whether this condition involves maximization or minimization. [2]
5. Draw the graph of given inequalities: $x + y \leq 6$, $x \leq 4$, $y \leq 3$, $x \geq 0$ and $y \geq 0$. [5]
6. Maximize or minimize for the $P = 3x + 2y$ subject to $x + y \leq 4$, $x \leq 3$, $y \leq 2$, and $x, y \geq 0$. [5]

Marking Scheme of Pre-Test Question of Cycle I

Question 1:

Step	Scheme	Marks
1	Name of one appropriate mathematical leaning app	0.5
2	Name of second app	0.5
3	Name of third app	0.5
4	Name of fourth app	0.5
	Total	2

Question 2:

Step	Scheme	Marks
1	Explain maximization as finding the greatest/maximum value of an objective function	1
2	Explains minimization as finding the smallest/minimum value of an objective function	1
	Total	2

Question 3:

Step	Scheme	Marks
1	Identifies the feasible region as the region satisfying the given constraints/inequalities.	1
2	Explains that every point in this region represents a possible/feasible solution.	1
	Total	2

Question 4a:

Step	Scheme	Marks
1	Define variables, eg. x = no.of unts of product a, y = no. of units of product b	0.5
2	Identifies profit from a as $20x$	0.5
3	Identifies profit from b as $10y$	0.5
4	Forms the objective function: $P = 20x + 10y$	0.5
	Total	2

Question 4b:

Step	Scheme	Marks
1	Identifies that the objective is related to profit	1
2	Correctly states maximization because the aim is to obtain maximum profit.	1
	Total	2

Question 5:

Step	Scheme	Marks
1	Converts the first inequality into an appropriate equation for the boundary line.	0.5
2	Finds two appropriate points/intercepts for the first boundary line.	0.5
3	Draw the first boundary line correctly.	0.5
4	Identifies and shades the correct region for the inequality.	1
5	Converts the second inequality into its boundary equation and identifies appropriate points/intercepts.	0.5
6	Draws the second boundary line correctly	0.5
7	Identifies and shades the correct region for the second inequality.	0.5
8	Correctly identifies the common /feasible region.	1
	Total	5

Question 6:

Step	Scheme	Marks
1	Represents the given constraints as boundary equations/lines.	0.5
2	Draws the boundary lines correctly.	0.5
3	Identifies the correct feasible region.	1
4	Correctly identifies the correct/vertices of the feasible region.	1
5	Substitute the co-ordinates of the corner points into $P = 3x + 2y$	1
6	Compares the obtained values and correctly identifies the maximum/minimum value with corresponding (x,y).	1
	Total	5

Post-Test Questions of Cycle I

1. Write the name of four digital tools used in learning linear optimization.[2]
2. Explain the use of maximization and minimization in real life. [2]
3. Explain the feasible region in your own words.[2]
4. A factory produces two products x and y. The loss earned from each unit of x is Rs. 30 and from each unit of y is Rs 20.
 - a. Write the objective function representing the total loss. [2]
 - b. State whether this condition involves maximization or minimization. [2]
5. Draw the graph of the following inequalities, $2x + y \leq 6$, $y \leq 5$, $x \geq 0$ and $y \geq 0$. [5]
6. Optimize for the objective function, $S = 3x - 2y$ subject to $x + y \leq 4$, $x \leq 4$, $y \leq 5$, and $x, y \geq 0$. [5]

Marking Scheme of Post-Test Question of Cycle I

Question 1:

Step	Scheme	Marks
1	Name of one appropriate mathematical leaning app	0.5
2	Name of second app	0.5
3	Name of third app	0.5
4	Name of fourth app	0.5
	Total	2

Question 2:

Step	Scheme	Marks
1	Correctly explains maximization as finding the greatest possible value.	0.5
2	Gives an appropriate real-life example of maximization, such as maximizing profit, production, income, or output.	0.5
3	Correctly explains minimization as finding the smallest possible value/cost/resource.	0.5
4	Gives an appropriate real-life example of minimization, such as minimizing cost, transportation time etc.	0.5
	Total	2

Question 3:

Step	Scheme	Marks
1	Explains that the feasible region is the region containing solutions that satisfy the given constraints/inequalities.	1
2	Explains that points within the region represent possible/feasible solutions to the problem.	1
	Total	2

Question 4a:

Step	Scheme	Marks
1	Identifies x and y as the quantities/number of units of the two products.	0.5
2	Represents loss from product x as $30x$	0.5
3	Represents loss from product y as $20y$	0.5
4	Correctly forms objective function: $L = 30x + 20y$.	0.5
	Total	2

Question 4b:

Step	Scheme	Marks
1	Recognizes that the objective function represents loss	1
2	Correctly states that the objective should be minimized because the aim is to reduce loss.	1
	Total	2

Question 5:

Step	Scheme	Marks
1	Converts the first inequality into its corresponding boundary equation.	0.5
2	Finds appropriate points/intercepts for the first boundary line.	0.5
3	Draws the first boundary line correctly.	0.5
4	Identifies/shades the correct solution region for the first inequality.	1
5	Converts the second inequality into its corresponding boundary equation and identifies appropriate points/intercepts.	0.5
6	Draws the second boundary line correctly	0.5
7	Identifies/shades the correct solution region for the second inequality.	0.5
8	Correctly identifies the common/feasible region	1
	Total	5

Question 6:

Step	Scheme	Marks
1	Converts the given constraints into boundary equations/lines.	0.5
2	Correctly draws the boundary lines.	0.5
3	Identifies the correct feasible region.	1
4	Identifies the corner/vertex points of the feasible region.	1
5	Substitutes each relevant corner point into $S = 3x - 2y$ and calculates the corresponding values.	1
6	Compares the values and correctly identifies the optimum value and corresponding (x,y).	1
	Total	5

Pre-Test Questions of Cycle II

1. Write the name of any two applications used in solving statistics? [2]
2. What is data and its types? [2]
3. Write the names of partition values. [2]
4. Write the formula to calculate quartile deviation and its co-efficient, standard deviation, mean deviation and their co-efficient. [2]
5. Calculate the quartile deviation and its co-efficient of given data. (Formula and Excel) [6]

C.I	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50
f	8	12	10	5	15

6. Calculate the standard deviation and its co-efficient of given data. .(Formula and Excel) [6]

C.I	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50
f	5	10	20	10	5

Marking Scheme of Pre-Test Question of Cycle II

Question 1:

Step	Scheme	Marks
1	Name of one appropriate application/software used for statistics.	1
2	Name another application/software used for statistics.	1
	Total	2

Question 2:

Step	Scheme	Marks
1	Correctly defines data as collected facts, figures, observations, or information used for analysis.	1
2	Correctly identifies the two types: primary data and secondary data.	1
	Total	2

Question 3:

Step	Scheme	Marks
1	Identifies/writes quartiles and/or correctly names Q_1 , Q_2 and Q_3 .	1
2	Identifies/writes deciles and percentiles.	1
	Total	2

Question 4:

Step	Scheme	Marks
1	Write the formulas of Quartile Deviation and its co-efficient.	0.5 + 0.5
2	Write the formulas of Standard Deviation and Mean Deciation.	0.5 + 0.5
	Total	2

Question 5: (Using Both formula and Excel)

Step	Scheme	Marks
1	Correctly calculates $N = 50$, Q_1 and Q_3 .	0.5
2	Correctly identifies the Q_1 and Q_3 class using cumulative frequency.	0.5
3	Correctly applies the grouped data formula and calculate Q_1 and Q_3 .	1
4	Correctly calculate $Q.D = (Q_3 - Q_1)/2$	0.5
5	Correctly calculates co-efficient of $Q.D = (Q_3 - Q_1)/(Q_3 + Q_1)$	0.5
6	Correctly uses/verifies the calculation through MS Excel and reports the final co-efficient.	3
	Total	6

Question 6:

Step	Scheme	Marks
1	Finds the midpoint/class mark x of each class interval and calculate N .	0.5
2	Correctly calculates the mean and/or required intermediate values.	0.5
3	Correctly calculates $\sum(f(x - \bar{x}))^2$ and applies the standard deviation formula.	0.5
4	Correctly obtains the standard deviation.	1
5	Correctly calculates the co-efficient of Standard Deviation using formula.	0.5
6	Correctly uses/verifies the calculation through MS Excel and reports the final co-efficient.	3
	Total	6

Post Test Question of Cycle II

1. Write the name of any two applications that can be used for statistical calculation and data analysis. [2]
2. Define data. Classify data into major types and give one example of each. [2]
3. What is the role of quartiles in statistics? [2]
4. Write the formula to calculate mean deviation from mean and median. [2]
5. Calculate the co-efficient of quartile deviation of given data. (Formula and Excel) [6]

C.I	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50
f	6	14	18	10	7

6. Calculate the co-efficient of standard deviation of given data. (Formula and Excel) [6]

C.I	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50
f	4	10	17	10	8

Marking Scheme of Post-Test Question of Cycle II

Question 1:

Step	Scheme	Marks
1	Name of one appropriate application.	1
2	Name of another appropriate application.	1
	Total	2

Question 2:

Step	Scheme	Marks
1	Correctly defines data as facts, figures, observations, or information collected for analysis.	1
2	Correctly identifies the major types: Primary and Secondary data and write appropriate example.	1
	Total	2

Question 3:

Step	Scheme	Marks
1	Explains that quartiles divide an ordered data set into four equal parts and identifies Q_1 , Q_2 and Q_3 appropriately.	1
2	Explains their use in describing the distribution, position, spread, or variability of data, including their use in finding Q.D.	1
	Total	2

Question 4:

Step	Scheme	Marks
1	Correct formula of Mean Deviation from mean.	1
2	Correct formula for Mean Deviation from median	1
	Total	2

Question 5:

Step	Scheme	Marks
1	Calculate $N = 55$ and determines the position $N/4$ and $3N/4$.	0.5
2	Construct/uses cumulative frequency and correctly identifies the Q_1 and Q_3 classes.	0.5
3	Correctly calculates Q_1 and Q_3 using the grouped data quartile formula.	1
4	Calculate $Q.D = (Q_3 - Q_1)/2$	0.5
5	Calculate the co-efficient of quartile deviation using $(Q_3 - Q_1)/(Q_3 + Q_1)$	0.5
6	Correctly uses/verifies the calculation through MS Excel and reports the final co-efficient.	3
	Total	6

Question 6:

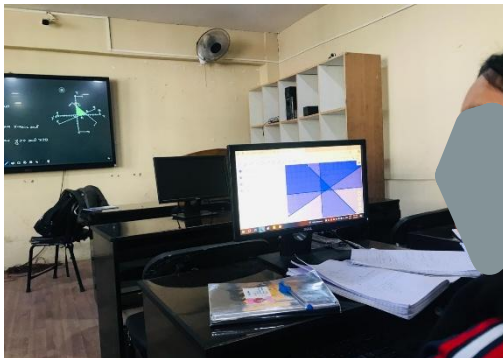
Step	Scheme	Marks
1	Calculate the class marks x and total frequency N .	0.5
2	Calculate $\sum fx$ and determine $\bar{x}$.	0.5
3	Calculate the required deviations and $\sum(f(x - \bar{x}))^2$	0.5
4	Correctly applies the standard deviation formula and obtain standard deviation (σ).	1
5	Calculates the co-efficient of standard deviation	0.5
6	Correctly uses/verifies the calculation through MS Excel and reports the final co-efficient.	3
	Total	6

Photographs

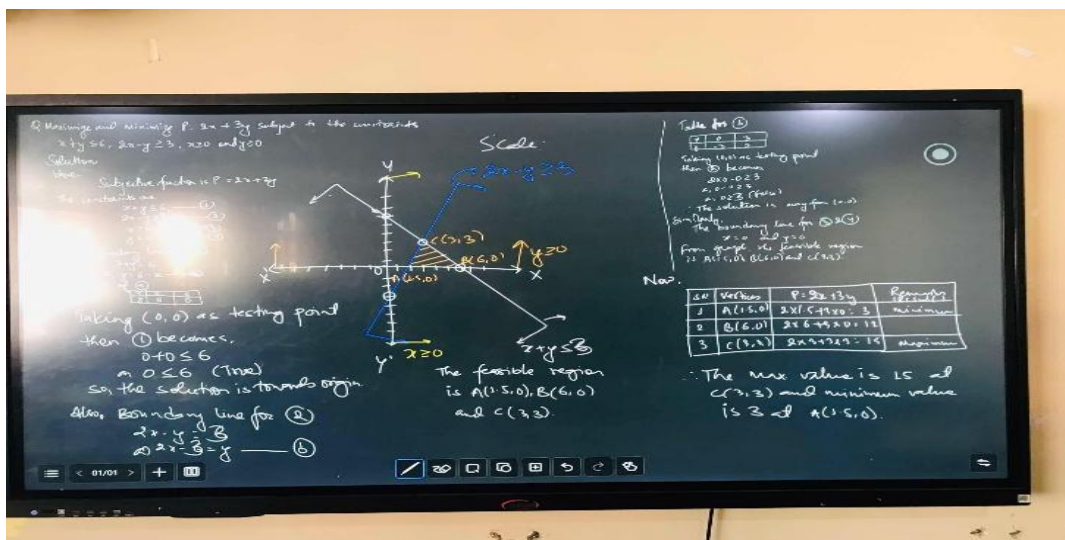
Beginning of the Project



Students enjoy finding the solution region of the inequalities



Question and solution of Inequality



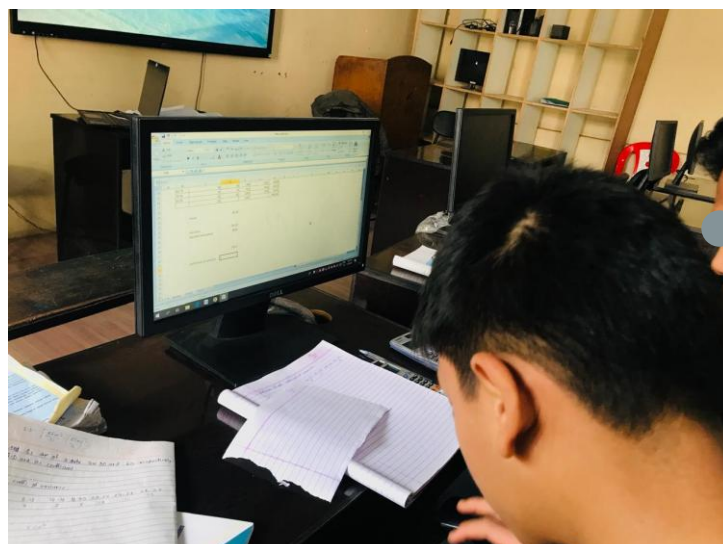
Students in Optimization Class



Students in post-examination of optimization



Students learning statistics using MS Excel

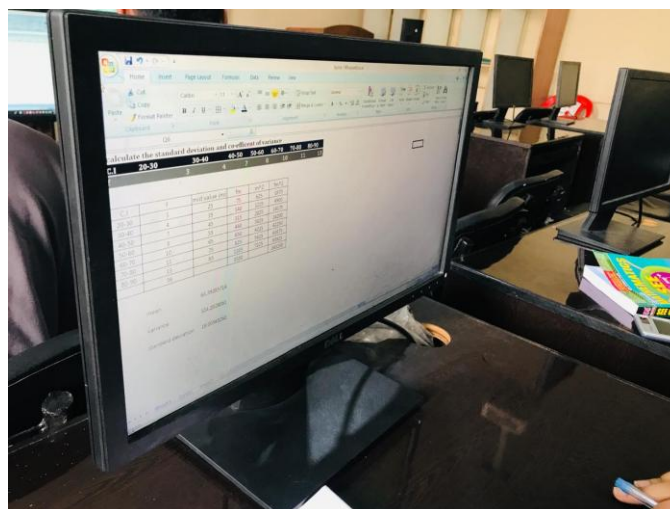




Revision Classes of Optimization and Statistics



Summative Assessment of Statistics



Post assessment of Statistics

