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PERSPECTIVE

ICT tools for remote teaching and learning mathematics: A proposal for autonomy and engagements

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Abstract: This paper explores the paradigm shift in using ICT tools while teaching mathematics remotely within the TPACK framework. Remote teaching is not only one of the primary modes of teaching and learning in the present context throughout the world but the transition from paper to the digital world, where mathematics teachers struggle to visualize the content concisely and clearly. This paper focuses on promoting pedagogy and learning and learner empowerment by emphasizing autonomy and engagement rather than technology. The ethos of this paper is all about encouraging the mathematics teachers to promote the students for quality engagement while teaching remotely. However, all the remotely leading ICT tools require some techniques and methodologies, thereby the mathematics teachers' skill, experience, and expertise. Those skills, experiences, and expertise will be developed by excelling in mathematics teachers' ICT tools. This paper shall be one of the guiding principles for mathematics teachers (but not limited to) while dealing with the mathematics content remotely and/or in any other mode.

Keywords: paradigm shift, remote teaching, mathematics

1 Introduction

Now, "Learning and teaching may both benefit from the development of interactive Web 2.0 (or greater) and cloud apps on mobile devices, such as laptop computers, electronic pads, and smartphones." (Barak & Ziv, 2013). The domain of education has taken great leaps by capitalizing on technology and the utilization of modern devices (Katsaris & Vidakis, 2021). COVID-19, a pandemic that the world has not seen in decades, has caused several new obstacles for student learning and education throughout the globe. As a consequence of the worldwide surge of COVID-19 instances, several schools and institutions in almost every region of the globe have closed in 2020 or switched to online or remote learning, which will have a variety of repercussions for student learning. This has led to educators and students spending more time online than ever before, with both groups researching, learning, and familiarizing themselves with information, resources, tools, and frameworks to adapt to online or remote learning (Mohammed, 2022). When it comes to the online and distance mode of education, students get an education without attending face-to-face classes. Therefore, remote teaching and learning practices seem to be the fundamental tenets of mathematics education within the TPACK framework (Njiku et al., 2021; Marbán & Sintema, 2021) to provide a quality education through an online mode of delivery. TPACK is a technology integration framework that identifies three types of knowledge instructors must combine to succeed with tech integration: technological, pedagogical, and content knowledge. The COVID-19 pandemic has also forced us to limit our educational activities to an online mode of learning (Karakose et al., 2021; 2022). Schools were closed, students and teachers remained in their own homes, and teaching and learning started flourishing via zoom, google meet, and other synchronous and asynchronous digital learning platforms (Karakose et al., 2021). In the pandemic period, these platforms helped educators create activities, keep them in the software or online platform, conduct classes, facilitate online discussions and activities, and finally assess students' learning.

Facilitating mathematics teaching and learning was extremely difficult and challenging for mathematics teachers. In education, digital or traditional, the material studied by students is the basis from which they will achieve knowledge. For this reason, schoolbooks have been designed to be scientifically correct and pedagogically sound. With the digitization and growth of education, and the shift to adaptive learning methods, educational content is no longer centrally decided and distributed; instead, many professionals are allowed to create and distribute material within their area of expertise, and educators often develop material

for their classes (Barianos et al., 2022; Tzimopoulos et al., 2021). The abstract nature of this subject, which needs some additional and advanced skills such as typing equations, symbols, fractions, *etc*.; communicating abstract ideas with students; helping students develop procedural and conceptual mathematics skills via visualization, requires more digital tools related to mathematics. However, the availability of various tools seemed to be helpful for mathematics teachers, and students are involved in learning mathematics in a meaningful way. The online and offline tools such as Desmos, GeoGebra, SketchUp, Microsoft Mathematics, MathsPad, *etc*., are/were being meaningful for developing a conceptual understanding of mathematics.

It is right to say that this scenario has brought multiple opportunities but brought several challenges for mathematics teachers (Dahal & Dahal, 2015; Cassibba et al., 2021) in integrating ICT tools (Tsoukala, 2021). Regarding opportunities, the mode provides spaces for mathematics teachers to sharpen their knowledge, skills, competencies, training, and leadership (Dahal et al., 2020). However, the discourse on remote teaching mathematics has not got room for discussion in the training, workshops, seminars, and conferences before the pandemic caused by COVID-19 (Kallou & Kikilia, 2021). During the pre-COVID time, contextualized teaching and learning mathematics might not have been the priority of school education in Nepal (Luitel, 2020). So, remote learning might allow mathematics teachers, students, teacher educators, and other stakeholders to explore online teaching tools and resources and introduce locally available materials that can be found at home or around the home to visualize mathematics and make it more contextualized. Thus, this paper paves the path for the discourse and explores remote teaching mathematics in general and in crises such as the COVID pandemic. The conditions resulting from the pandemic in education have plagued educational practice at the universal level. The new practices followed in educational practice in conjunction with disease control and strict measures to alienate citizens had psychological effects and were stressful for the employees in education (Konstantopoulou et al., 2022).

Likewise, there are several unanswered questions, such as how do mathematics teachers use emerging ICT tools to facilitate mathematics teaching and learning through distance and online modes of instruction? Further, how does the present changing scenario assist the mathematics teachers and practitioners in developing new perspectives about using ICT tools, techniques, and methodologies? How do ICT tools, techniques, and methods used in mathematics teaching? Furthermore, what types of ICT tools are needed to function in the day-to-day teaching activities in mathematics? In searching for the answer to the above-unanswered questions and gaps, this paper aims to explore possible ICT tools that will facilitate mathematics teaching remotely for any grade level. Further, in this paper, we address how we promote teaching and learning mathematics lessons remotely using ICT tools?

More so, ICT tools significantly impact the many facets of mathematics education in the TPACK framework. This paper offers the mathematics teachers and teachers educators to conceptualize remote teaching and learning, thereby exhibiting and excelling the tools to visualize and manipulate mathematical concepts. Likewise, tools facilitate mathematics discussion and collaboration, tools for encouraging creativity, and tools that allow the creation of interactive learning quizzes. These tools would enable the creation of online learning content, tools for formative feedback, and tools for receiving the live responses.

2 Remote teaching and learning

The Coronavirus was declared a global pandemic in 2020 (Karakose et al., 2021; 2022), and that has been seen in Nepal since March 2020. Nevertheless, COVID-19 does not only cause health crises all over the world, but it also affects all aspects of life, including the educational field. The sudden transition to distance teaching forced teachers and students to adjust their educational practices using digital platforms and unknown educational approaches (Skaraki & Kolokotronis, 2022).

All schools in several nations throughout the globe were closed as a precautionary measure to protect children and teenagers from contracting the virus (Ferri et al., 2020). The Nepal government has also decided to shut down the academic institutions, markets, and shops from March 2020. One of the suggestions made by Nepal's Ministry of Education is the use of online and distance learning as a method of instructing students. Online conferencing and asynchronous activities made possible by remote teaching allows for simultaneous integration of courses and interactive learning technologies (Camacho, 2020).

Teaching and learning may now take place on various platforms because of the widespread use of technology in education (Poultsakis et al., 2021). However, there is still a challenge to the teacher, teacher educators, parents, children, and other stakeholders to continue the teaching and learning process because of the lack of technological and pedagogical knowledge

in this crisis. In order to facilitate learning through various digital tools, online models of education such as blended learning, flipped classrooms, remote teaching/learning, *etc*., are famous among educators and educational institutions. These methods have become essential to provide education in these challenging times wherein students cannot continue their studies. Remote learning is a platform where students can get an education through a distance mode of delivery. The use of synchronous and asynchronous digital tools and platforms is life saviours in the distance learning education model. Students can get access to learning materials via these platforms. They can participate in discussions and collaborative learning through synchronous types of digital tools such as zoom, google meet, and many others. Via asynchronous platforms such as google classroom, moodle, *etc*., students have tremendous opportunities to participate in forum discussions and communications where every student can get feedback and provide others feedback to improve.

Most of us might be familiar with distance learning and how it has created a space for people to get an education without taking face-to-face classes. Distance learning allows students to be far from the educational institution and cannot participate in regular classes; distance learning allows them to continue their education by attending online classes or doing learning activities per their interests and pace. The digital tools applied in this mode of education are helpful in terms of regulating the learning process, facilitating learning, and assessing the learning of students. In this way, remote learning is similar to the distance learning model of online education. This has flourished in the education system to provide space for quality education without attending face-to-face classes. Moreover, the development of enough and various technological tools and platforms are helping to promote remote learning and students getting an education, reducing the gap between students and teachers and placing both in a place to continue the educational activities.

3 Tools for visualization of mathematics

The tools for visualizing mathematical concepts on the web and in the form of apps that shall be helpful in teaching mathematics are available in various search engines. Mathematics instructors may utilize various internet resources, both free and commercial, in their courses for their students. However, since the quality of the information might vary, we must thoroughly examine any web-based tools or programs before recommending them to learners. Among the tools available on the web and in the application that we have been integrating with our teaching are DesmosCalculator, Chrome Canvas, IDroo, Google Jam board, Mathspad, Microsoft Mathematics, GeoGebra, and Microsoft Whiteboard. These tools are standard for some mathematics teachers and shall be new for others in Nepal while visualizing mathematical concepts remotely.

Amongst others, Desmos is a graphic calculator that plots graphs together. It can solve simultaneous equations and others with variables. Chrome Canvas is a sketching program that includes a colour palette and a simple toolbar with pencil, pen, marker, chalk, and eraser tools. The features are pretty simple to use in mathematics teaching and learning. IDroo is an online whiteboard for teaching mathematics. Its feature is fascinating for instant real-time without the hassle of collaboration in the browser with students. Google Jamboard is an interactive digital collaborative whiteboard that allows for remote or in-person sharing in a shared space while teaching or learning mathematics. Learners can contribute ideas, problem-solve or draw collaboratively while teaching or learning mathematics. MathPad is a geometry tool that includes a ruler, dividers, protractor, set square, and compass for instructors to use. When teaching geometric construction, MathPad comes in handy. With thorough step-by-step explanations and interactive graphs, Microsoft Math quickly detects the issue and assists learners in solving it. Designed for use by students and teachers of mathematics and science at all levels, from elementary school to university, GeoGebra is an interactive geometry, algebra, statistics, and calculus tool. Microsoft Whiteboard is a digital canvas where mathematics teachers and students come together remotely using their own devices for solving the mathematics algorithm problem collaboratively. In the end, these tools, in some cases, support the mathematics teachers to visualize the mathematical contents.

4 Tools that manipulate mathematical concepts

Manipulation in mathematics helps students learn mathematics through concrete objects, and these objects allow the students to explore ideas engagingly and/or in hands-on activities. With this ethos in mind, while teaching mathematics remotely, some ICT tools to manipulate

mathematical ideas in the classrooms are Tengram, Geoboard, Fraction-strips, Dice, Number Line, and Mathigon for geometry and numbers fractions, algebra, and probability.

Tengram employs seven geometrical shapes that provide learners with several opportunities to rotate and investigate the relationships between them. Geoboard provides an opportunity for the learners to arrange different sizes of the same shape and help recognize the geometry shapes of triangles, namely, scalene, isosceles, and right triangles. Fraction strips help to manipulate the concepts of fractions while teaching fractions. In general, fraction strips help to show different fractional parts virtually. Virtual dice are placed in multiple positions and used for generating random numbers. The virtual number line, which may be stretched in any direction indefinitely, is commonly shown horizontally. Mathigon is an interactive textbook. It is also a virtual personal tutor. It integrates cutting-edge technology and an innovative mathematics curriculum that shall be useful for all mathematics teachers. In the end, these online manipulatives offer the teachers and students conceptualized mathematical ideas remotely. These are for promoting conceptual understanding of mathematics, which focuses on concepts or figuring out the answer to the questions of how and why a particular knowledge works (Manandhar, 2018). Visual representation "draws students' attention and helps identify misconceptions and facilitate deeper conceptual understanding" (Ge et al., 2015).

5 Tools that facilitate mathematics discussion and collaboration

Verbal communication while teaching and learning mathematics with sharing facilities allows learners to share their ideas, knowledge, and skills in face-to-face, online, or remote teaching contexts (Dahal & Pangeni, 2019). This is one of the crucial 21st-century skills that need to be developed by people to foster their life and continuously grow. A student needs support from the teacher and their peers or friends to perform various learning tasks and develop knowledge and skills in the learning process. The interactions and collaboration among students are essential as far as social constructivism learning theory (Vygotsky, 1978) and practical human interest (Habermas, 1972) are concerned. When it is face-to-face educational activities, students can have group discussions and complete tasks and presentations. However, how is it possible in a remote learning or teaching scenario? Are there any effective ways or ICT tools or techniques for facilitating students through group discussions and collaboration? If they are available, how do they help teachers and students?

The virtual and remote learning environments need various technology-based platforms to elicit discussion and collaboration among teachers and students. While taking virtual classes, teachers may use these tools to form groups, provide topics for discussion, have students discuss in their respective groups, help students come to conclusions, and present the findings. These tools seem to become a life-saver for both teachers and students since they can collaborate and generate knowledge by discussing the topic or issues provided. Unlike face-to-face mode group discussions and collaborations, the remote learning and teaching platform use various ICT tools for the same tasks; regarding this, some tools can be helpful for these tasks. These synchronous and asynchronous mediums are supportive of the functions. Some of the tools are Zoom (for breakout sessions), Google Meet, Flipgrid, Padlet, and Educreations, Google Drive and cloud-based storage and sharing, Google Jamboard, Google Site, and Google Docs. Evernote, MOODLE, Virtual Whiteboards (Microsoft whiteboard and others), Blogs and Microblogs, Google and other chat services, *etc*. These tools can be convenient and helpful, with low and no-cost features while teaching remotely.

The tools, as mentioned earlier, are great resources for mathematics teachers to use while giving the tasks for collaboration, communication, and conducting discussions. Students can put their ideas, thoughts, and queries in their groups during the teaching and learning process and have group discussions with the motto of constructing knowledge and generating ideas. Most of these tools have the facility of keeping records of the activities students do so that teachers can use these materials in the future too. Alternatively, teachers can develop videos and publish them on YouTube. Some of these tools also have the facility to present themselves virtually (showing the face). These handy tools work well when there is a good internet connection. This allows teachers and students to work without getting interruptions. This also makes the learning worthwhile by promoting the value of collaborative learning and social interaction. Even teachers and peers can applaud their students and partners when necessary. With the help of these ICT tools, as virtual encouragement as possible, students will become motivated to learn and actively participate in the learning process in mathematics.

6 Tools for encouraging creativity

Creativity can be visible when students innovate ideas and create something different from the available resources (Songkram et al., 2021). Sometimes, creativity can be imaginative thoughts and ideas. However, the power of thinking something different and creating interesting hands-on products can be considered creativity. It is an ability of a person to challenge the past and ongoing system or things being used (a material). Creativity in learning refers to developing innovative ideas to solve real-world problems when it comes to education. The ability to solve real-world problems needs an exceptional quality of a person to deal with the issues and figure out the solutions. Also, thinking out of the box is necessary when solving complex problems (not only textbook-oriented problems). The higher-order thinking skills (HOTs), such as analyzing, evaluating, and creating (Husain, 2021; Dahal & Pangeni, 2019), should be at the centre to elicit creativity and problem-solving. Several progressive educational methods are effective in stimulating students' creative thinking.

As far as remote teaching is concerned, it does not seem easy to address students' creativity while doing tasks and activities in a virtual medium of instruction. Teachers may feel challenged to orient their students in doing activities, think creatively, and perform activities. Moreover, the virtual way of instructions might be challenging for doing online-based assignments and projects that elicit their ability to create something innovative. However, it is the teachers' job to use various online and ICT-based platforms to focus on students' creative activities. In this context, there are some tools for this. Tools such as MovieMaker, audacity, iMovie, PowerPoint online, Snagit (to name) for audio and video creation; Storybird, Bitmoji, and emojis, *etc*., for digital storytelling, likewise, SketchUp, Pixabay.com, Unsplash.com, canva.com, *etc*., for image creation; PowerPoint, Prezi, Knovio, Zoho presenter, *etc*., for Presentations; Camtasia, Screencastify, *etc*. for screencasting. These are some of the tools for helping students to develop their creativity.

7 Tools that allow creating interactive learning quizzes

These resources assist students in having fun while studying mathematics. They are excellent methods to get distant students to participate in real-time on questions/challenges posed by teachers. Students may also use them to construct mini evaluations that they can share with the rest of the class. Some tools that allow creating interactive learning quizzes and games are Kahoot, Socrative, and Quizizz.

Kahoot is a platform for game-based learning. It has been utilized in schools and other educational organizations as a teaching tool. It is used to create real-time multiple-choice quizzes that can be viewed using a web browser. Socrative is a web-based student response system. It offers mathematics teachers to create simple quizzes and assess them in real-time during the online class. Quizizz is a student engagement tool that enables teachers to engage their students in interactive courses and quizzes. These are some tools that will enable interactive learning quizzes for the learners.

8 Tools that allow creating online learning contents

Among the available tools on the web or in the form of applications, Adobe Spark, PlayPosit, EdPuzzle, Quizlet, and Canva are the tools that help create bespoke learning activities based on existing content. Because creating more complicated activities takes time, it is best to include them in an existing website or learning management system. Encouraging students to design their own is much more beneficial.

Adobe Spark is a mobile and web-based integrated suite of media production apps created by Adobe Systems. PlayPosit is an online and chrome-based application that allows instructors to create and modify interactive video assessments using streamed or uploaded material. To make an interactive movie or bulb, teachers submit an audio clip or a video from popular sites like YouTube and Vimeo. Edpuzzle is a simple platform that enables math teachers to engage each student with a single video. *Quizlet* is a simple learning tool that lets learners study anything. It helps create flashcards, games, and learning tools, assessing the learners' understanding of the mathematical contents.

9 Tools for formative feedback

Yacapaca, Learning by Questions, Nearpod, Seesaw, and Google Classroom are some of the tools in mathematics that offer mathematics teachers platforms to provide formative feedback.

These tools let you choose from a list of pre-made questions and create online assessment projects. Even math teachers can keep track of their students' development and highlight areas where they need additional help.

Yacapaca's is a unique peer feedback tool offered immediately to the student who answers a question. Mathematics teachers can use it to create, execute, grade, and share assessments for students. It can design tests, quizzes, and surveys for learners. Learning by questions is a teaching method that works well with online math instruction and learning. Nearpod is a web-based application in the mathematics classroom that encourages active learning and student participation. As an interactive PowerPoint or Google Slides alternative, this is a helpful tool. Nearpod allows uploading PowerPoint effortlessly, or Google Slides presentations, including various interactive exercises for teaching math remotely. Seesaw is a simple tool that allows instructors and students to record and share classroom activities. Students may use it to record their learning, be creative, and learn how to use technology using Seesaw. Each kid receives their journal and will fill it with items such as photographs, movies, drawings, and comments. Google Classroom is a free online service for schools created by Google. The goal is to make creating, sharing, and grading assignments as simple as possible. The primary goal of Google Classroom is to make it easier for instructors and students to share files in any type of mathematical instruction, including but not limited to mathematics.

10 Tools for receiving the live responses

These technologies enable math teachers to keep track of student progress while delivering online classes for rapid input, collect feedback, and keep track of the interaction. Some online tools are Crowdsignal, Poll Everywhere, Mentimeter, and Google Forms.

Crowdsignal is a mobile app that allows gathering survey data and taking quizzes without connecting to the internet. This program enables math instructors to gather data from students by syncing surveys and quizzes produced on https://crowdsignal.com. Poll Everywhere allows hesitant or timid pupils to reply alongside their friends openly, and students respond simultaneously from their devices. Mentimeter is web-based tool and an easy-to-use for receiving online responses. With Mentimeter, mathematics teachers can create fun and interactive presentations. Google Form is a web-based questionnaire and survey solution that allows for real-time collaboration and comprehensive customization features for a survey and/or online questions.

11 Conclusions

ICT tools significantly impact the many facets of mathematics education. ICT tools bridge the various modes of teaching and learning mathematics by encouraging the mathematics teachers to promote the students for quality engagement while teaching mathematics remotely. In this paper, we explore some possible ICT tools within in TPACK framework that shall facilitate mathematics teaching remotely for any grade level by addressing how we promote teaching and learning mathematics lessons remotely using ICT tools? Likewise, it is all about the transition from paper to digital teaching and learning mathematics, where mathematics teachers struggle to visualize the mathematics contents concisely and clearly (Dahal et al., 2020). This paper offers various possibilities for mathematics teachers while remotely delivering the mathematics contents. For that, we discussed some of the ICT tools to explore and exhibit mathematical ideas and concepts are visualizing mathematical concepts, manipulating mathematical concepts, facilitating mathematics discussion and collaboration, likewise for encouraging creativity, creating interactive learning quizzes, offering online learning content, assessing formative feedback, and receiving the live responses of the students. However, mathematics teachers must be given the freedom to choose the ICT resources that best fit their teaching and learning methods. Teachers must also alter their perspectives about ICT's role in math instruction if they are to make effective use of already existing and yet-to-be-released technologies. Various ICT tools facilitate continuous professional development on ICT use in mathematics education to promote pedagogy and learning and learners' empowerment: emphasize autonomy and engagement rather than technology.

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