STEM Teachers' Practices, Opportunities, and Challenges in the Age of Emerging Technologies: Implications to Education, Administration, and Teacher Training Institutions

Reena R. Ongsotto

National Institute for Science and Mathematics Education Development, University of the Philippines - Diliman, Philippines

DOI: https://dx.doi.org/10.47772/IJRISS.2025.903SEDU0369

Received: 20 June 2025; Accepted: 01 July 2025; Published: 30 July 2025

ABSTRACT

The demands of globalization have ushered in the Age of Emerging Technologies (ETs). Although some educational technologies (ETs) are not new, very few Filipino educators utilize them in their classroom practice, despite their potential to improve the teaching-learning process. The study identified the types of educational technologies (ETs) used by Filipino STEM teachers and how these are being utilized, the reasons for using ETs, the observed or perceived effects on students' learning, the observed or perceived challenges in using ETs, and the enabling mechanisms to support the integration of ETs in STEM classrooms. The study used a case study qualitative research design with participants from Public HS (PHS) and Public Science HS (PSHS) who completed an online questionnaire. The results of the study showed that there was no difference between PHS and PSHS teachers' use and perception of ETs and that most teachers use AI in their teaching practice. The result also showed that teachers use ETs mostly as teaching aids and to promote STEM education and careers. Teachers were also found to have either positive or negative observed and perceived effects of ETs' use on students' learning. The challenges in using ETs were the lack of equipment, training, integration time, teaching resources, and their potential misuse. Enabling mechanisms for ET integration include an investment in infrastructure and human resources, and programs to sustain teachers' motivation to use ETs. The findings of the study have potentially useful implications for STEM Education, School Administration, and Teacher Training Institutions.

Keywords: Emerging Technologies, STEM Education, School Administration, Teacher Training, Teacher Practices and Challenges

INTRODUCTION

The demands of globalization have ushered in the Age of Emerging Technologies, which is characterized by rapid advances that are greatly influencing how we live, work, and learn. Artificial intelligence, 3D Printing, the Internet of Things (IoT), Robotics, 5G, Big Data, Cloud Computing, and Blockchain, among other emerging technologies (ETs), have seeped through people's consciousness due to their applications in every facet of human life. The influence and impact of these ETs as agents of globalization is primarily due to, as stated by Litvinski (2018), their growing role in contemporary society, regardless of geographical locations or socioeconomic status of involved actors. Leavy et al (2023) stated that global society has entered the Fourth Industrial Revolution and that ETs will forever change our way of life.

Not all technologies can be considered ETs. Cukurova and Luckin (2018) defined emerging technologies as those that include but are not limited to virtual reality and augmented reality implementations, mobile learning devices, physical computing tools, Internet of Things hardware with sensors, and technologies that allow collaborative learning at a great scale. Halaweh (2013) further described technology as "emerging" when it causes a radical change in business, industry, or society. Within the context of education, emerging technologies are those that have the potential to change the current state of affairs in education (Cukurova and Luckin, 2018).

As borders blur and cultures converge, education must evolve to prepare students for a globalized society (Nikitina and Ishchenko, 2023). Integrating emerging technologies (ETs) in K to 12 Education, according to

Dubhar (2023), has become increasingly important due to the fast-paced evolution of technology and its impact on modern-day society. Education has been a critical vehicle of economic growth and social progress throughout the modern era (Borner, 2018). The education sector is then expected to prepare the future workforce for future jobs that use these emerging technologies (ETs). According to Leavy et al (2023), technology has played a vital role in STEM Education, particularly offering boundless capabilities and possibilities for creating high-quality learning experiences that foster students' innovation, creativity, communication and collaboration, critical thinking, and problem-solving skills. Therefore, STEM Education would be the prime agent in the development of these future skills through the utilization of emerging technologies.

Although some emerging technologies are not new, very few educators, especially in the Philippines, use these in their classroom practice despite their potential to improve the teaching-learning process, among other reported benefits. The current study then aimed to determine whether Filipino STEM teachers use ETs in their teaching practice and classroom instruction, their lived experiences and observation of the effects (positive or negative) of integrating ETs on their student's attitude towards learning, the challenges they have encountered, and the kind of support that their school or institutions have provided to them. Similarly, the study also aimed to determine the perspective of Filipino STEM teachers who are non-ET users. Specifically, the study aimed to determine whether they wish to use ETs, their perceived effects (positive or negative) of using ETs in their teaching practice, their expected roadblocks in integrating ETs, and the kind of support they would need from their school or institutions.

Background of the Study

The study was initially conceptualized as a final requirement for the course, EDFD 331-Educational Sociology in the Philippine Setting. However, the study has relevance to the nature of the researcher's work in an institution that promotes STEM Education and Emerging Technologies in Education. Among the researcher's work in the institute relevant to the current study are the conduct of capacity-building training for teachers and the development of curriculum materials on Science and Emerging Technologies. The researcher has also been a lecturer for the pilot testing of the curriculum on 3D Printing and Artificial Intelligence Literacy developed by the institute. As the lecturer for the pilot implementation of two (2) curricula, 3D Printing and Artificial Intelligence Literacy, the researcher received initial training to acquire the needed knowledge and skills to develop curriculum materials to teach these courses.

The challenges experienced by the researcher in the conduct of the pilot implementation served as one of the motivations for the current study. Although the researcher's pilot classes were stand-alone courses on specific emerging technologies, this was different from regular Public High Schools, even in some Public Science High Schools. Emerging technologies are not usually taught as a course but are utilized as a teaching tool in subjects, particularly in STEM subjects. The researcher would like to determine how emerging technologies are utilized by STEM teachers, if ever. And if they do, what are their reasons for using ETs in their teaching practice? What are the specific challenges or difficulties they encountered? And, what kind of support do they need from their schools or divisions to help them sustain their use of ETs?

Since there would be STEM teachers who have non-ET users, the study would also like to determine the extent of their knowledge of ETs and if they wish to use these in their teaching practice, their reasons for wanting to use ETs, the challenges they think they will encounter, and the kind of support that their school or division can provide for them.

Research Gaps

There are several research studies conducted outside the Philippines on the utilization (or integration) of emerging technologies in STEM Education, but very few in the Philippines. Dublar (2023) conducted a literature review of studies in the Philippines published from 2010-2022 on integrating ETs in Philippine Education. The study only cited twelve (12) published studies in peer-reviewed journals, conference proceedings, or academic books. The research of Dubhar (2023), in particular, focused mainly on identifying the type of ET utilized, its effect on students' knowledge and skill acquisition, the challenges and limitations of its use, and the implications for tech integration in K-12 Philippine education in each research reviewed. None

of the reviewed research presented in the study addressed the reasons for the teacher's use of ETs or how they decide on which ET to use, which the current study has determined.

Although most literature on integrating ETs in Education is not subject-specific, it was hypothesized that perhaps due to the difference in curriculum or resources, there would be significant differences in the perspective between STEM teachers in Public Science High Schools and those in regular Public High Schools. In addition, experience in using ETs might also affect the perspective of STEM teachers (ET users and non-ET users). As such, the current study has compared the perspectives of these groups of teachers to determine similarities or differences in opinion on the integration of ETs in their teaching practice.

Another aspect that the current study explored is the support structure or enabling mechanism that Public Science High Schools are expected to have regarding technology integration, compared to regular Public High Schools. The finding would greatly inform school leaders in regular Public High Schools on supporting their STEM teachers in integrating ETs into their teaching practice.

Lastly, due to the nature of the researcher's work, the current study extended the research to determine the implications of the research findings not just on STEM education and school administration, but also on teacher training and curriculum development institutes like the researcher's place of work. The current study's findings will help the institute ensure the alignment, appropriateness, and relevance of future training or workshops, particularly on the effective integration of ETs in STEM Education.

Research Questions

The current study aims to answer the following research questions:

What emerging technologies have STEM teachers used or would wish to use in their classroom practice? How?

What are the reasons for integrating (or wanting to integrate) emerging technologies in your practice?

What are the perceived or observed effects on students' learning when emerging technologies are integrated into science instruction?

What are the perceived or observed challenges Science teachers encounter in integrating emerging technologies into their classroom practice and instruction?

What mechanisms/structures should be in place to enable or support Science teachers in integrating emerging technologies into their classroom practice and instruction?

REVIEW OF RELATED LITERATURE

The summary of the related literature presented in this section focused on literature that discussed or presented findings on the following topics: Types of ETs, Integration of ETs in (STEM) Education, Challenges or Issues in Integrating ETs in (STEM) Education, and Implications of Integrating ETs in (STEM) Education.

Types of Emerging Technologies

Van Mechelen (2022) commented that despite the increase in children's use of and exposure to emerging technologies in recent years, the full impact of these technologies on children's lives is yet to be realized. ETs differ in their complexity and their prevalence in children's lives. Yet despite the characteristics and potential impacts that make ETs challenging and ambiguous to integrate into learning processes for coming generations (Van Mechelson, 2022), Nikitina and Ishchenko (2023) stated that the use of smart technologies to support STEM education can radically change the traditional teaching system. Swargiray (2024) called this a convergence of ETs with traditional pedagogies that would revolutionize the educational landscape.

Presented in Table 1 are some of the types of ETs and their descriptions, which were included in the papers of Van Mechelen (2022) and Nikitina and Ishchenko (2023). Both papers conducted a literature review of studies integrating ETs in Education.

Table 1: Types of Emerging Technologies

Type of ETs	Description	
	(Van Mechelen, 2022)	**(Nikitina and Ishchenko, 2023)**
Augmented Reality	Augmented reality (AR) is an interactive experience of a real-world environment where objects are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities. Unlike VR, which creates its computer-generated environment, AR adds to the existing world as it is.	Technologies that immerse users in virtual environments through simulating real-world scenarios and experiments.
Virtual Reality	Virtual reality (VR) is a computer-generated environment with scenes and objects that)t appear to be real, making the user feel they are immersed in their surroundings. This environment is typically perceived through a device known as a VR headset or helmet.	
3D Printing		Enables the creation of physical objects from digital models, revolutionizing prototyping and hands-on learning in engineering and design.
Artificial Intelligence	Artificial intelligence (AI) is intelligence demonstrated or simulated by technological means, as opposed to natural intelligence. It allows computers and robots to do tasks that are usually done by humans because they require human intelligence and discernment	These technologies enable computers to perform tasks that typically require human intelligence, allowing for data analysis, pattern recognition, and problem-solving.
	Machine learning (ML) is a type of AI that allows software applications to become more accurate at predicting outcomes without being explicitly programmed to do so. ML algorithms use historical data as input to detect patterns and predict new output values.	
Internet of Things (IoT)	The Internet of Things (IoT) describes physical objects or 'things' that are embedded with sensors, processing ability, software, and other technologies that connect and exchange data with other devices and systems over the Internet or other communications networks.	Connects everyday objects to the internet, allowing for data collection and automation, leading to innovations in fields like smart homes and automation.
Blockchain		Provides secure and transparent record-keeping, with applications in secure transactions, data integrity, and cryptography.
Genetic Engineering and Biotechnology		Involves the design, construction, and programming of robots, enabling automation in various industries and fields.
Nanotechnology		Focuses on manipulating materials at the atomic or molecular scale, leading to breakthroughs in materials science and electronics.

The types of ETs considered by Van Mechelen (2022) were subject matter independent, while those considered by Nikitina and Ischenko (2023) focused on ETs utilized in STEM education. Conversely, Leavy et

al (2023) conducted a literature review of studies on the use of emerging technologies in STEAM Education. Specifically, the study identified the classification of ETs used in STEAM education. The findings reveal four (4) classifications, namely: 1. Augmented Reality/ Virtual Reality/ Mixed Reality; 2. Programming and Robotics; 3. Maker Movement; 4. Other Technological Applications. Based on this classification of ETs utilized in STEAM Education, some of the STEM-specific ETs selected by Nikitina and Ishchenko (2024) would fall as follows: 3D Printing under Maker Movement, Genetic Engineering and Biotechnology, and Nanotechnology under Other Technological Applications.

Integrating Emerging Technologies in (STEM) Education

The article by Nikitina and Ishchenko (2023) determined the aspects of globalized education, one of which is the utilization of technology for educational access.

Leavy et al (2023) investigated the pedagogical motivation of researchers in using STEAM education interventions using ETs. The findings of the study revealed four (4) themes from the literature review. There are:

Using STEAM challenges to respond to interdisciplinary real-world issues

A focus on the development of 21st-century skills

The promotion of equity and access for all students

Developing positive attitudes and dispositions towards STEAM

Nikitina and Ishchenko (2023) stressed that access to resources like online courses, educational websites, open-source platforms and communities, STEM education kits, maker spaces, and Fab Labs can help educators provide students with rich learning experiences that ignite their curiosity and passion for learning. Aside from this, the article presented the positive effects of using these technologies, such as allowing students to interact with educational materials, develop both their hard and soft skills, and cultivate a deep understanding of STEM concepts. Among the skills that would be developed by engaging in technologies are practical skills, critical thinking and problem-solving abilities, and collaborative skills.

Similarly, Swargiary et al (2023) presented the following positive impacts of ETs in education:

Student engagement and motivation

Personalized learning

Inclusive education

Teacher empowerment

Lifelong learning and Continuous upskilling

Fulton et al (2002) also identified several opportunities made possible through technology. The following opportunities were selected based on their relevance to the current study:

Technologies make it possible to collect more information on students in real time, on a continuing basis.

Today’s virtual communities of practice extend the opportunities for face-to-face learning and support.

Powerful lessons, modules, or units of curriculum are being created and tested in schools to use the power of technology to help students apply and better understand complex scientific concepts or other intellectual stumbling blocks in various curricular areas.

Children are using technologies to create new cultures of communication and learning that are developing entirely outside of school.

The almost universal agreement in this country that education should be at the top of the political agenda provides an opportunity for leveraging new resources with technology.

The current teacher quality crisis is defined as an issue of quantity as well as quality.

In the local setting, Dublar (2023) conducted a literature review of existing research on technology integration in the Philippine Education System, particularly focusing on the K to 12 Curriculum. The study considered the following types of emerging technologies in the literature review: educational software, virtual and augmented reality, mobile learning, and online learning platforms. It also identified the following advantages of effective integration of technology:

Improved student engagement;

Increased access to educational resources;

Enhanced collaborative learning;

Improved student performance; and

Enhanced teacher professional development

Challenges or Issues in Integrating Emerging Technologies in (STEM) Education

Rotolo et al (2015) presented an operationalized definition of emerging technologies, which identified five (5) of its key characteristics, namely: radical novelty, relatively fast growth, coherence, prominent impact, and uncertainty and ambiguity. As a consequence, the characteristics of ETs and their potential impacts make them so challenging and ambiguous to integrate into learning processes for the coming generations (Van Mechelson, 2022). The most apparent issue in integrating ETs into Education would be with regard to resources and funding. This was stressed in the paper of Leavy et al (2023), who argued that since most of the ETs require technology-heavy resources, their integration or utilization in Education would pose issues in resources, cost, and expertise.

Conversely, Atabek (2019) conducted research to identify the obstacles to the integration of technology into education using a questionnaire administered to professionals in the Turkish Ministry of National Education. The study categorized obstacles to technology integration into: Undersupply, Insufficiency of Resources, Insufficiency of Infrastructure, Negative Psychological State, and Difficulty of Newer Technology. The study found that undersupply was the leading category of obstacle, while insufficiency of infrastructure was intermediate, and difficulty of newer technology was the least significant obstacle to technology integration.

The first category, Undersupply, refers to the lack of technology solutions (habitat of information technologies rather than a piece of hardware) for teachers' use and content support (materials that include strategies, methods, and techniques of instruction) for teachers. The second-ranked obstacle, Insufficiency of Resources, refers to the required technology education provided in teacher training institutions. This also includes knowledge acquired through education, the time needed for using and developing materials with information technologies, and rewards or incentive systems for using information technologies. The intermediate category, Insufficiency of Infrastructure, refers to the insufficiency of physical and technological infrastructure of

educational institutions, and the lack of content to use on or with that infrastructure. The last two (2) categories of obstacles, Negative Psychological State and Difficulty of Newer Technology. The former refers to the negative attitude of educators towards information technologies, while the latter refers to the lack of competency of educators regarding those technologies.

The study found that hardware or its novelty is not an obstacle to technology integration (Atabek, 2019). Major perceived obstacles to technology integration include insufficient in-service and pre-service training, content support, incentive systems, and inadequacy of physical and technological infrastructure. The study also found no correlations between sex, age, level of education, job position, and year of experience with any of the categories of perceived obstacles. Lastly, Atabek (2019) concluded that rather than a series of gadgets on the teacher's desk, technology should be conceptualized as a "solution" to the system of instruction. Moreover, Atabek (2019) added that an effective working system comprising infrastructure, content, pre-service and in-service training, incentives, and harmony between technology and curriculum may bring investment in educational technology to a successful conclusion.

In terms of the Philippines, Dublar (2023) reported the following challenges or limitations identified in the literature reviewed in the study:

Inadequacy of infrastructure;

Lack of funding;

Limited access to technology in remote areas; and

Need for ongoing technical support and maintenance

Implications of Integrating Emerging Technologies in (STEM) Education

The integration of technology in education has led to a transformative shift in the way knowledge is acquired, disseminated, and applied (Swargiary et al, 2023). Its profound impact on education has, as Swargiary et al (2023) stated, revolutionized the traditional classroom setting by blurring the boundaries of physical learning spaces and creating a dynamic interconnected educational ecosystem.

According to Leavy et al (2023), the lack of theoretical frameworks, practitioner knowledge, and empirical evidence limits our ability to capture or critique how ETs transform and impact learning. The study also reported the common themes in the recommendations in their literature review, namely:

Professional development related to developing content and pedagogical content expertise in using ETs to improve educators' confidence levels and proficiency; guidance to assist teachers and schools to integrate ETs into day-to-day STEAM instruction seamlessly, and the Creation of complete, ready-to-use modules using ETs.

In the paper published by Fulton et al (2002), they stated that because of the rapid technological innovation and development, what is believed to be the most effective way to use technology to improve teaching and learning today may be significantly different five years from now. As a consequence, education practitioners, policy-makers, researchers, and other stakeholders need a better understanding of the larger technology trends in our society and how those trends might influence our educational system. This will allow them to identify which emerging developments are worth investing in due to their likely significant effects.

In the paper, Fulton et al (2002) presented three (3) models of computing which have impacted education, the key themes to consider in integrating technology in education, the opportunities made possible through technology, and the key areas that leadership organizations should focus on to address the core challenges of integrating technology in education. According to Fulton et al (2002), knowing the three (3) models of

computing (the desktop model, the ubiquitous model, and the immersive model) will help better understand the trajectory of technology and the underlying social and human infrastructures they raise with their use in education.

Although each of these models has different trajectories and implications for education, any technology under consideration for education, regardless of the model or device, must be anchored on a series of key themes. Of interest to the current study are the following themes identified by Fulton et al (2002):

The environment students enter after schooling demands that we rethink the purposes and goals of education.

Real change at the classroom level is driven most effectively by teachers, but it cannot thrive unless it is supported by school structures.

Technology, in many ways, is forcing the issue; it is a means to an end, not a goal in and of itself.

Lastly, Fulton et al (2002) identified three (3) key areas that leadership organizations should focus on as starting points for change. These are:

It should be made clear to leaders that change is a process of continuous improvement, not a series of "reforms" (Fulton et al, 2002). Strategic planning should involve building a vision beyond today's crisis, setting long-term goals, and identifying strategies to achieve them.

Focus on the teacher quality issue.

There should be a focus on developing necessary skills, specifically digital-age literacy, inventive thinking, effective communication, and high productivity, built upon foundational skills such as reading, writing, and computational skills.

Lastly, Dublar (2019) summarized the recommendations from the reviewed literature into the following:

Continuance and strengthening of the Philippine government's policies and initiatives to integrate technology into the educational system; Increase access to technology; and Provision for teacher training to enhance technological competency

In summary, different types of ETs are being used in Education for varied purposes, all of which are intended to prepare future global citizens by equipping them with the relevant skills they will need to thrive and survive using ETs. The conceptual framework of the current study, presented in the succeeding section, shows the factors that will be explored in the current study, the subjects (data sources) that will be focused on, and the implications derived from the findings.

Theoretical/Conceptual Framework

The prevalence of ETs and their rapid integration into human life necessitates an evaluation of the practices of STEM. Teachers who have used ETs in their instruction to study their successes and challenges, to provide them with the support to sustain their use. On the other hand, the perspective of teachers who wish to use ETs in their instruction would also shed invaluable information on the kind of support that they will require in order to facilitate their use. As such, the current study will investigate the perspective and experiences of STEM teachers (ET users and non-ET users) from both regular Public High Schools and Public Science High Schools.

Figure 1 below shows the conceptual framework of the current study. The observed or perceived practices and experiences of STEM teachers on their teaching practice in integrating ETs, reasons for using ETs in their teaching practice, effect on student's learning, challenges or issues encountered in integrating ETs in their

teaching practice, and the structures or mechanisms that would support or enable their use of ETs in their teaching practice. The information that will be obtained from the STEM teachers will have corresponding implications for STEM Education, School Administration, Curriculum Development, and Teacher Training Institutions.

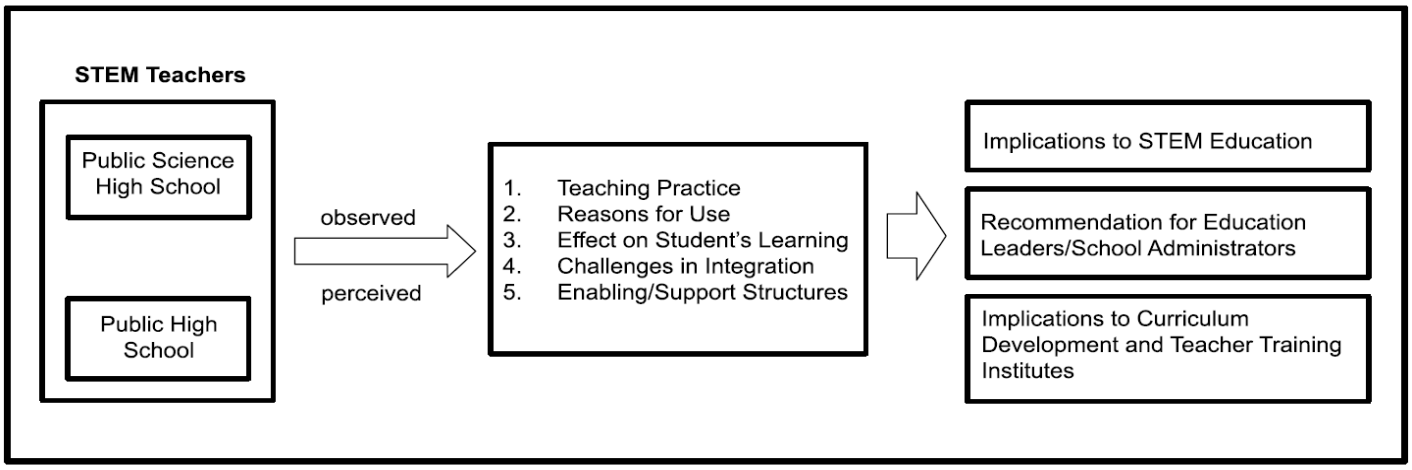

Figure 1: Conceptual Framework of the study

In most cases, despite studies investigating teachers' classroom practices, a top-down system is used in drafting policies and creating teacher training during their pre- and in-service training. Although such a system has been used several times, it inhibits teacher agency. Policies and teacher training become forced requirements that teachers might not be motivated to use in their teaching practice. The current study proposes, instead, a bottom-top system wherein the observed experiences and practices of STEM teachers who are ET users can be used as a model by both school administration and teacher training institutes. Similarly, the perceived experiences of STEM teachers who are non-ET users can also inform school administration and teacher training institutes on the kind of support they will require. By using the lived and perceived practices of STEM teachers, other teachers would be more inclined to utilize ETs. Conversely, policies and teacher training that are responsive and supportive of the teachers' reported needs would be more readily accepted by teachers.

The next section presents the methods used in the current study to collect and analyze its data. The section includes a description of the samples used in the study,

METHODOLOGY

Research Design

The study used a qualitative research design to determine teachers' practices and experiences with emerging technologies. This includes their opinions on its potential benefits and challenges to its integration into their teaching practice. Moreover, the study also wished to determine the perspectives of specific groups of science teachers; particularly, between teachers teaching at Public Science High Schools and those teaching at regular Public High Schools and between teachers who have used emerging technologies in their teaching practice and those who have not used emerging technologies but wished to use these. Although the study involved a small number of participants, a case study involving representatives from each of the target groups of teachers would provide a better insight into the lived experiences or perceived notions of teachers on the integration of emerging technologies.

Participants

Six (6) teachers participated in the study. The participants were given a formal letter of invitation to participate in the study, including a consent form. After the participants had given their consent to participate in the study, schedules for their interviews were agreed on.

Table 2 below presents the profile of the participants by their gender. Five (5) of the participants are female, while only one (1) participant is male.

Table 2: Profile of Participants by Gender

Gender	n	%
Male	1	17
Female	4	83

In terms of age, the profile of the participants is presented in Table 3. It can be noted that five (5) of the participants are in their 40s, while only one (1) participant is in their 30s.

Table 3: Profile of Participants by Age

Age	n	%
30s	1	17
40s	4	83

Eleven (1l) of the participants are High School teachers from Public High Schools. The profile of the participants in terms of the type of High School they are employed in is presented in Table 4. It can be noted that half of the participants are currently teaching at regular Public High Schools while the other half are teaching at Public Science High Schools.

Table 4: Profile of Participants by Type of School of Employment

Type of School	n	%
Regular Public HS	3	50
Public Science HS	3	50

Five (5) of the participants are teaching at a school in NCR, while only (1) teacher is teaching at a school outside of NCR. Conversely, two (2) of the participants have taught for 11-14 years, while the other four (4) have taught for 18-20 years. At the time of conduct of the study, half of the participants taught Junior High School level while the other half taught at the Senior High School level. Four (4) of the participants have taught High School Science, while the other two (2) have taught High School Mathematics.

METHODS

The data for the study were collected through key-informant interviews and focus group discussions (FGD) conducted online via Zoom. Each Zoom meeting was recorded with the permission of the participants. To keep the identity of the participants confidential, the participants were coded T01 to T05 based on the sequence of their interview schedule. Four (4) of the participants (T01, T02, T03, and T06) were interviewed on separate schedules while the other two (2) participated in the focus group discussion. The two (2) participants (T04 and T05) worked at the same High School and requested to be interviewed on the same schedule.

The interview and FGD were semi-structured; the participants were first asked personal questions about their age, gender, and work details. In the latter part of the meeting, the interview questions focused on the study's research questions. Follow-up questions were asked so that participants could clarify or expand on their answers.

The participants were initially asked if they had experienced using emerging technologies in their teaching practice. Based on their response, the participants were classified into those who have used emerging technologies and those who have not. For convenience, the participants who indicated that they had used emerging technologies in their teaching practice were called Group 1. In contrast, those who had not used emerging technologies in their teaching practice were called Group 2. Each group of participants was then asked a specific set of questions appropriate to their classification.

Group 1 participants were asked to name the emerging technologies they have used and describe how they have used these in their teaching practice. They were then asked their reasons for using emerging technology in their teaching practice. They were also asked to share if their use of emerging technology affected their students' learning based on their observations.

On the other hand, Group 2 was asked which emerging technologies they would like to use in their teaching practice and how they would use these. Since the group has no experience in using emerging technology in their teaching practice, they were asked to speculate how using emerging technologies can affect their students' learning, if ever, and how these will be received by their students.

The next set of questions given to the participants pertains to the challenges encountered by those who use emerging technologies or the perceived challenges for those who have not used emerging technologies. Lastly, Group 1 was asked about the kind of support their respective schools or school divisions extended to them. And, if no support was given to them, they were asked the same question given to Group 2. Since Group 2 has not used emerging technologies, they were asked for the kind of support from their schools or divisions to encourage them to use emerging technologies.

Analysis

The recordings of the Zoom meetings were downloaded and partially transcribed. The selected transcriptions focused on the key responses of the participants to each research question. A descriptive and thematic analysis of the responses of each group of participants was conducted to determine common themes. The emerging themes from both sets of responses were also compared in the analysis, especially regarding the kind of support that both groups of teachers would need to effectively integrate emerging technologies into their teaching practice.

The results from the thematic analysis were further analyzed to identify the role of emerging technologies in education in the concept of globalization. Furthermore, implications for Philippine education, School Administration, and Teacher Training will be explored in light of the results of the study.

RESULTS

This section of the study presents the results of the analysis conducted on the responses of the participants during the interviews and the focus group discussion. Before the results of each research question were presented, the participants were first classified into two groups using the question shown in Table 5 below.

Table 5: Response to Grouping Question

Have you used any emerging technology in your teaching practice?	n	%
Yes	4	67
No	2	23

Most of the participants (4 out of 6) stated that they have used emerging technologies in their teaching practice, while 2 out of 6 stated that they have not. For the participants who answered "Yes", they were further asked to describe in what capacity they have used emerging technologies.

T01 stated that they have used "moving pictures from the internet" in their lesson presentation materials. T02, on the other hand, stated that their students are taught how to create 3D designs and to 3D print these designs. Similarly, T05 stated that they have been using emerging technologies in their research classes, especially for prototype-making. They added that they have been using several emerging technologies, including Robotics technology, intelligent machines, and Artificial Intelligence in their Robotics and Physics class. Lastly, T06 stated, "I have used AI in such a way that I taught my students to utilize Generative AI tools to help them in writing their scientific research…"

The succeeding paragraph presents the responses of the participants to each research question after they have been grouped.

What emerging technologies have teachers used or would wish to use in their classroom practice? How?

The participants were presented with a list of emerging technologies, and they were asked to identify which emerging technology was familiar to them. The summary of the selection of the respondents is presented in Table 6.

Table 6: Summary of Types of ETs Participants are familiar with Type of Emerging Technology

	n	%
Artificial Intelligence	6	100
Internet of Things	4	67
3D Printing and Additive Manufacturing	3	50
Virtual Reality / Augmented Reality	3	50
Big Data Analytics	2	33
Blockchain Programming and Coding	2	33
5G Networks	2	33
Robotics and Automation	1	17
Nanotechnology	1	17
Clean Tech and Smart Homes and Cities	1	17

Both groups 1 and 2 stated their familiarity with Artificial Intelligence. Most of those in Group 1 have indicated that they have used ChatGPT, particularly in preparing their learning materials and making inquiries regarding their lesson subject matter.

On the other hand, those in Group 2 indicated that they had heard of ChatGPT and other AI (Artificial Intelligence) tools but had not tried using them. When they were asked why they had not tried using any AI tool, T04 replied,"…di ba kailangang ng internet nyan…eh wala namang wifi sa school at magastos kung data ko ang gagagmitin sa lahat ng class ko….di kakayanin…". Similarly, T03 stated that the wifi in their school was very slow and that, "…mauubos lang ang class time kung mag-try magconnect….magturo na lang ko ng normal…marami pa kailangan i-cover na topc, saying lang ang oras…".

Aside from Artificial Intelligence, three (3) of the participants from Group 1 and one (1) from Group 2 stated that they were familiar with "Internet of Things". When asked to expound on their answers, T01 from Group 1 reiterated their use of "moving pictures from the internet" which they use as a visual aid. The researcher asked if T01 was referring to "animated gifs" when they described "moving pictures", T01 confirmed, and said they forgot what these were called. Another participant from Group 1, T05, explained that they were using the "Internet of Things" in their Robotics and Physics class. Specifically, T05 shared,

"May robotics kit ang mga bata, may LEGO® mindstorm kami…pati Arduino®… may problem ako na bibigay sa class tapos dapat ang mga bata magdesign ng solution nila using yung kit or Arduino®…kailangan rin nila i-program yun robot so gagamit sila ng software sa computer….".

The 3rd participant, T06, who also indicated their familiarity with the "Internet of Things," stated they encountered an online AI app called "ThinkSpeak," which can process real-time data from sensors. T06 stated, "…free yon (ThinkSpeak)…may Math analysis pero…hindi ko pa nahimay. Balak ko this year kung may oras pa ko".

Lastly, the only participant from Group 2, T05, who was part of the FGD with T06, stated that they were also familiar with the Internet of Things "kasi nakikita kong ginagamit ng co-teachers ko sa klase nila…sa Robotics nila…". This was about the reply given by T06, who was their co-teacher in the same school.

The third type of artificial intelligence that the participants were most familiar with was "3D Printing and Virtual Reality or Augmented Reality technologies". With regards to 3D Printing, T02 and T05 from Group 1 and T03 from Group 2 have stated their familiarity with this type of emerging technology. T02 shared that their school recently purchased one (1) 3D printer after they attended a Geogebra and 3D Printing seminar

workshop. But before they purchased a 3D printer, T02 stated,"….gumagawa na ang bata namin ng 3D designs…sa TLE nila….gamit ang CAD software…".

Now that their school has a 3D printer, T02 stated, "…pwede na i-print ng students yung 3D designs nila…".

Similarly, T05 shared that their school has also recently purchased 3D printers and that selected Science teachers have received training in 3D design and 3D printing. T05 also added that since they were a Science High School, their city is very supportive of emerging technologies and will give their school some 3D printers that they can use in the next school year.

On the other hand, T03 from Group 2 stated that their school was offering a 3D Printing class as an interest class for their Grade 12 students, but "…tagalabas yung lecturers ng 3D Printing class...". When asked to clarify their statement, T03 stated that the class was for a pilot implementation, so the lecturers and equipment were not the school's property. Moreover, T03 shared that the Science teachers of the school were intended to take over the class, but they lacked the training, and they did not know if the school would be able to procure their equipment.

Now, with regards to VR or AR technologies, the participants who selected these were T05 and T06 from Group 1 and T03 from Group 2. All three (3) participants indicated that they have not used VR or AR but were familiar with it from exhibits from tech suppliers during events and videos.

After the participants had shared the types of emerging technologies they have used in their teaching practice (Group 1) or those they are familiar with but have not used (Group 2), the participants were then asked their reasons for using emerging technologies. Their responses are presented in the succeeding section.

What are the reasons for integrating (or wanting to integrate) emerging technologies in your practice?

The participants' reasons for using emerging technologies (Group 1) or for wanting to use emerging technologies (Group 2) in their teaching practice were similar despite their differences in the use of emerging technologies. Their responses were classified into four (4) themes, namely: Teaching Aids, STEM Education and Careers, Teaching Trends, and Future Users.

There are participants like T01 and T02 of Group 1 and T03 and T04 of Group 2 who have stated that the use of emerging technology has potential as a teaching aid. T01 has stated that using emerging technologies allows "information to be easily shared" and that it helps students "have a better view of what is being discussed".

Moreover, T02 stated that students "can see the applications of what they are learning in real life" through the use of emerging technologies.

Similarly, T04 of Group 2 stated that, "…it (emerging technologies) could help students understand some concepts…". T03, on the other hand, stated that they believe" Emerging technologies can engage students, keep them interested, and keep them focused on the subject…improve student collaboration.".

It can be noted from the responses of the participants, particularly those in Group 2, T03, and T04, that despite not having used emerging technologies in their teaching, they recognize their use as a powerful teaching aid that will not only help teachers teach better but help students understand the lesson better. T04 stated,"..it can help us to understand the things we are not familiar with…lalo na kung hindi mo sya field of expertise".

Because of the perceived benefits of using emerging technologies, T03 stated that "…these would be a significant addition to my usual and current teaching practice…".

In terms of emerging technologies as a means of promoting STEM education and careers, T05 stated that they are promoting STEM careers to their students in their school since it is a Science High School. They want to "create more engineers, scientists, and mathematicians….using these technologies really open my learners to pursuing STEM education in college".

The last category of response pertains to emerging technology as a Teaching Trend. Most of the participants stressed the ever-changing and evolving "education landscape" and that teachers also need to adopt new strategies. T06, in particular, stated"it is already a trend di ba? so baka ito na talaga ang future natin sa teaching…we cannot live in the past with our traditional chalkboard lectures….if we want 21st century learners, we must be 21st century teachers…".

T06 added, "yung pedagogies or strategies used by teachers must match the demands of the new Science and Technology subjects" and that, "without the use of technology parang you are left behind, back to the old age…technology is already there so why not use it to our advantage".

This statement was supported by T05 when they said, "…it is already here. We have to utilize it. We have to learn and become experts of it kasi, if not, we will not be able to explore more opportunities outside the classroom".

The participants in Group 2 echo the same ideas as those in Group 1. T04 stated,"We need to embrace these technologies hindi lang kasi bago ito pero kasi makakatulong sa students natin…yun naman ang importante…"

In addition to the view of emerging technologies as a current trend in teaching, T03 stated,"These technologies are becoming so common and being used widespread…teachers need to know how to use them and if possible, include them in our lessons…"

Finally, one participant indicated that the main reason for using emerging technologies was for the benefit of the students as current and future users of these technologies. T02 specifically stated, "Our students should be taught with emerging technologies…they should learn how to use these, kasi they are mostly the current users and future contributors of this emerging technologies.".

When prompted to explain their response, the response of T02 implied that teachers should help their students become familiar with these technologies so that they can use them well and responsibly in the future.

Since some of the reasons that the participants gave to validate their use of emerging technology pertain to students, the next section presents their responses to their observed effects of using emerging technologies in their classroom instruction (Group 1) or their perceived effects if they use emerging technologies in their instruction (Group 2).

What are the perceived or observed effects on students' learning when emerging technologies are integrated into their instruction?

The responses given by the participants were similar regardless of their groupings. This implies that whether teachers are using emerging technologies or not in their instruction, both groups of teachers inherently recognize the possible impact of these technologies on their students' learning. The participants' responses were categorized into two (2) themes: observed or perceived positive and negative effects.

In terms of the observed (for Group 1) or perceived (for Group 2) positive effects of using emerging technologies in their instruction, most of the participants indicated that students are more motivated and more interested to learn and find their lessons more enjoyable. The following are examples of responses given by the participants:

"Yes. It motivates them more." (T02)

"In the classroom, they become more interested lalo na pag alam nila na gagamit kami ng Robotics kit at mag proprogram…" (T05)

"Yes, I have seen my students become more curious especially sa mga questions nila pag gumagamit sila ng GenAI tools." (T06)

"Naka-capture yung attention ng students which can lead to a deeper understanding of the topics…" (T03)

"Usually, students appreciate these additions (use of emerging technologies). Novelty kasi di ba so it captures their attention and piques their interest." (T04)

The participants from Group 1 further shared their observations of their students' reception to the use of emerging technologies. Their students are mostly appreciative of using these technologies in class. The following are the statements made by some of the participants regarding this:

"As Science High School students, my students are excited of the new technologies offered to them". (T05)

"My students are happy that I am not "anti-AI" tools." (T06)

In addition, T06 mentioned that "students know that these tech should be incorporated in teaching as a tool to get more info and data" which implies an awareness in High School students of the advantages of using these technologies and that these should be used in their classroom.

Furthermore, because the students of T06 have been using AI tools, they have "become more wary of the information that they get". This was, according to T06, about how some outputs generated outputs from ChatGPT need to be fact-checked. Moreover, T06 stressed that this was a skill that we need learners to learn. T03 gave a similar reply, stating that "we live in the digital age, as technology advances, it is critical that students gain key skills."

Although the comments made by T06 and T03 about the skills that students need to learn as they use emerging technologies might not fall under the positive effects of emerging technologies on student learning, this is an important insight that any teacher should consider before they use emerging technologies in their instruction.

On the other hand, some participants have shared their views on the observed or perceived negative effects of emerging technologies. Some participants mentioned that although students would readily welcome emerging technologies in their lessons, some might not. The following are some of the responses given by the participants on this:"…to some of them yes but for others, no…some are happy to use it, some are not paying attention to it…" (T01 of Group 1)

"I am not sure…maybe some will be delighted, maybe some will not…" (T04 of Group 4)

When asked to explain their answers further, T04 repeated an earlier statement about the novelty of emerging technologies and hinted that if the students' interests are not sustained, this novelty will easily wear off. T01 also mentioned students' individual differences, saying,

"hindi pare-pareho ang estudyante…yung iba gusto pag may kakaiba sa klase pero may iba rin na gusto lang ng simpleng lecture…".

After sharing the observed or perceived effects on students' learning when emerging technologies are used in their instruction, the participants were then asked about the challenges in integrating emerging technologies. The results of their responses are presented in the next section.

What are the perceived or observed challenges teachers encounter in integrating emerging technologies into their classroom practice and instruction?

The participants in Group 1 were asked to share the challenges or difficulties they have experienced while integrating emerging technologies into their classroom practice and instruction. The participants in Group 2 were asked their thoughts on the possible challenges that they will encounter when they integrate emerging technologies into their classroom practice. The responses from both groups of participants were again similar despite the difference in their use or lack of use of emerging technologies. Their responses can be categorized into four (4) themes: Resources, Training, Integration, and Misuse. The first three (3) categories were common to both groups, while the fourth category was mentioned by a participant from Group 2.

Most of the participants cited resources as the primary challenge in integrating emerging technologies. Resources based on the participant's response refer to devices or gadgets, learning materials integrating emerging technologies, and internet/wifi connection. Some of the responses of the participants are presented below:

"…kailangan ng mga devices pati internet speed…" (T01)

"…not all learners can afford to have such technologies…the school cannot provide a 1 to 1 kit for the students." (T05)

"…I do not currently have access to these resources." (T03)

"I need to have access to the resources that are relevant to my subject." (T03)

The second category, Training, was the second most cited challenge by both groups of participants. T03 from Group 2 stated that the first thing that they would need is to "be trained on how to use it (emerging technologies) and how to incorporate these technologies into my lessons." This was confirmed by T05 from Group 1, who mentioned that before they started teaching Robotics in their school, they received training on how to use the kits from their equipment supplier.

The third category, Integration, was cited by some of the participants as a challenge in integrating emerging technologies. Integration covers time in terms of the period for the integration and the preparation time for the integration. It also refers to integration points in the curriculum where emerging technologies can be utilized.

Some of the statements made by the participants on this are:

"There is not enough time to integrate it with the required competencies….not enough preparation for me where to integrate it in the lesson." (T02)

"It is difficult for me to decide which lessons will employ specific technologies…" (T03)

The last category, Misuse, was identified by T04 from Group 2, who said that one of the issues that will arise with any technology used in the classroom is the abuse of these technologies. This was also mentioned by T06 when talking about the need for teachers to be trained. Specifically, T06 said, "…I need to learn it (emerging technologies) first and that I have to know in detail, so I know whenever my students abuse the use of these tools.

Now that the participants have shared their experiences, opinions, and challenges in integrating emerging technologies, they were asked the kind of support they would need to sustain or encourage them to integrate these in their teaching practice. Their responses are presented in the next section.

What mechanisms/structures should be in place to enable or support teachers in integrating emerging technologies into their classroom practice and instruction?

In order to identify the mechanisms/structures that are needed to enable or support teachers in integrating emerging technologies in their classroom practice, the participants were first asked to assess how supportive their school or division is of the integration of emerging technologies in education. Then, they were asked to provide details on the kind of support extended to them or the kind of support they would need.

Surprisingly, the participants in Group 2 both indicated that their schools were very supportive. T03 said, "The school is supportive to the point of implementing and launching courses like 3D Printing."

However, it can be noted that the 3D Printing course offered in the school of T03 is conducted by an outside lecturer and that the school does not have its own facility. T04 also stated that their school, which is a Science High School, and their division were "very supportive." Interestingly, despite this support, T04 has indicated their lack of use of emerging technologies in their teaching practice.

With regards to the responses from Group 1, three of the four (3 of 4) participants shared that their respective schools or divisions don't provide any support for the integration of emerging technologies. Some of the responses of the participants from regular Public High Schools regarding this are:

"I can't see any support." (T01)

"They don't really provide anything when it comes to tech dev…it's up to the teacher to get resources and to introduce these to students." (T06)

The participants from the Public Science High Schools have contrasting answers with regard to the support system. T05 indicated that their school was "very supportive". When asked to clarify their response, T05 stated that "all necessary support" was provided by their school, including requests from LGU and other agencies, trainings, etc. Similarly, T06 shared that their division gave them sets of Robotics or Electronics kits and that they attended a one-day training on the use of LEGO® and AI robots. It can be noted that T06 teaches in a regular Public High School and that they were given access to these technologies by their school division.

On the other hand, T02 stated that their school was "…passive…the school prioritizes what is only mandated by a memo or an order from higher authority."

Moreover, "The school allows us to attend training, seminars….they verbally encourage us to use emerging technologies."

Surprisingly, T02 teaches in a Public Science High School, yet their school has limited STEM resources.

Other kinds of support that teachers will need are tech staff and access to paid online apps. T03, in particular, stated that the training that will be given to them should not only be for teachers.

"There should be personnel in the school with the necessary technical knowledge to support and troubleshoot potential issues. Technical issues and downtime can disrupt lessons and frustrate both teachers and students." (T03)

In addition, T04 stated that most of the online apps are paid, and they can only use these for a limited time, so they hope that schools would be able to provide support to teachers on this.

ANALYSIS AND DISCUSSION

The current study investigated STEM teachers' observed experience in using ETs (ET users) and STEM teachers' perception of integrating ETs (non-ET users) in their teaching practice, including their reasons for using or wanting to use ETs, the challenges or issues encountered or perceived with their use, and the kind of support that has enabled them to use ETs or will facilitate their use of ETs. The succeeding paragraphs present a discussion of the findings of the study and the corresponding analysis.

One of the major findings of the current study was that the perception of integrating ETs in their teaching practice, the challenges it will entail, and the kind of support that they will need to use it did not differ in terms of gender, years of teaching experience, STEM subjects taught, and type of Public High School. This would then imply that the findings from the STEM teachers are similar to the experiences and perceptions of non-STEM teachers on the integration of ETs in education. This finding concurs with the literature reviews of Montoro et al (2019), Van Mechelson et al (2022), Nikitina and Ischchenko (2023), Leavey et al (2023), and Dublar (2023), who reviewed articles and studies on the subject-independent ETs integration.

Type of Emerging Technologies in STEM Education

In terms of the type of ETs that STEM teachers are familiar with, all of the participants indicated Artificial Intelligence. Perhaps this is because of its current popularity among all types of ETs, like IoT or 3D Printing. Another reason for its popularity is the lack of "specific hardware or equipment" required for its use. Most of the participants stated that an internet or wifi connection is the only thing needed to use AI, granted that they

have a computer or laptop for their use. This is significantly different from other types of ETs, which require physical equipment for their use, like Robotics or STEAM kits, 3D Printers, etc.

AI can be heard and used anywhere. Its potential impact on human life has necessitated the development of policies like the UNICEF guidelines for 'AI and child rights policy' which promotes "the rights of children, as current users of AI-enabled systems and the future inhabitants of a more AI-saturated world, must be a critical consideration in AI development" (Van Mechelson, 2022).

In addition, it can be noted that although most of the participants were familiar with Artificial Intelligence, they have only indicated ChatGPT as the AI they use or would wish to use in their teaching practice. ChatGPT is a type of Generative AI that generates text outputs based on text inputs or queries from the user. One of the participants stated that they use ChatGPT clarifications regarding the content that they will be teaching (T03), while another stated that they allow their students to use ChatGPT in writing their research papers (T06). The findings indicate that the participants have limited knowledge of AI, AI applications, and their potential use in Education. Most of the participants would seem to see AI as a tool to generate content; hence, they appear to be only familiar with one type of AI, which is Generative AI. AI has more profound applications beyond content generation, which industries and companies are using. Teachers should make sure that learners are made aware of these as future consumers and producers of these technologies.

Aside from the limited knowledge of AI, it would seem that most of the participants are unaware of the second most "familiar" type of ETs, which is the Internet of Things. Perhaps because of its name, teachers think that this type of ETs refers to applications or websites that are accessible via the internet, hence the name, Internet of Things. Unfortunately, only one teacher showed significant knowledge of IoT due to their experience of use. The teacher teaches Physics and Robotics using Robotics kits that are programmable and use sensors that collect data that can be analyzed via applications on the internet.

With regards to the third-ranked most familiar ETs, 3D Printing, the teachers who selected these have first-hand experience in using this technology either in their teaching practice or have attended workshops demonstrating its operation. These participants have indicated the potential of this technology in their teaching practice, but similar to IoT, the acquisition and maintenance of hardware poses a challenge to teachers.

Reasons for Integrating ETs in STEM Education

The findings of the current study revealed the reasons why STEM teachers use or would like to use ETs in their teaching practice, particularly as a tool in teaching the subject-matter content, to promote STEM Education and encourage students to pursue STEM-related careers, as a new teaching trend with potential applications, and as a means of preparing or training the future users of ETs. Since ETs are technically "tools" that can be used in teaching, teachers would be more inclined to use them as a teaching tool similar to a PowerPoint presentation.

Similarly, due to the popularity or trending status of ETs, most teachers prefer to be up-to-date with all the teaching trends. Ibrahiim (2024) stated that continuous learning opportunities empower educators to stay abreast of the latest technological advancements and pedagogical strategies, fostering a dynamic and adaptive teaching environment. Unfortunately, using ETs as a teaching tool or due to their popularity may indicate a limited understanding of their potential in education. Since these technologies are somewhat different from other education technologies used, there might be some pedagogies that teachers should be aware of to maximize the benefits of their utilization for their students.

Conversely, Nikitin and Ishchenko (2023) stated that access to modern computers, software, and technologies such as 3D printers and robotics plays an important role in skills development and research in STEM fields. This supports the findings of the current study that participants recognized the potential of ETs to promote STEM education and careers and to develop the learners' Future Skills. This is also similar to the recommendation of Leavey et al (2023) that ETs in education serve to develop learners' 21st-century skills. Nikitina and Ishchenko (2023) also stated that among the skills that would be developed by engaging in technologies are practical skills, critical thinking and problem-solving abilities, and collaborative skills.

Ibrahim (2024) added that the integration of emerging technologies contributes to the development of essential 21st-century skills among students. He stressed that skills that are facilitated when using ETs are integral for students to compete in a globalized workforce where technological proficiency is increasingly valued.

Effect on Student Learning

The findings of the study revealed that integrating ETs can have either positive or negative effects on student learning. Positive effects include increased motivation and interest to learn and increased student engagement. These observed or perceived effects on student learning are similar to the findings reported by Montoro et al (2019), Dubhar (2023), Van Mechelen et al (2023), and Leavey et al (2023). Specifically, these papers reported that the integration of ETs in education, not only in STEM education, can develop positive attitudes and dispositions among students. Dubhar (2023) noted that there was a reported improvement in student engagement and student performance from the reviewed literature.

Conversely, Fulton et al (2002) stated that the use of technology enables children to create new cultures of communication and learning that are developing entirely outside of school. Although this was not mentioned by any of the participants in the current study, including the other cited literature, this could be investigated further in future research on ETs.

On the other hand, most of the literature cited in the current study reported only the positive effects on student learning; the current study found that there are potential negative effects of ETs. Some of the participants implied that after the novelty of ETs, this could easily wear off and cause a disinterest in students. Furthermore, some of the participants indicated that not all students would welcome the use since some might prefer a more traditional teaching strategy. The findings indicate differences in learners in terms of their preferred teaching-learning strategy. Perhaps, since the students have experienced the challenges in online learning (both synchronous and asynchronous), this might have caused "technology fatigue" among some of the participants' students, which was not explored in the current study. Since the participants in the current study did not include actual students, technology fatigue or the perceived negative effects of ETs are beyond the scope of the current study and can be proposed for future research.

Challenges or Issues in Integrating ETs in STEM Education

The current study identified four (4) observed or perceived challenges in integrating ETs into STEM education. Foremost is the lack of resources. The participants refer to resources as the infrastructure and equipment, including internet or wifi connectivity. Since all the participants are Public High School Teachers, the lack of resources, much less ETs resources, is a constant issue. Students cannot be expected and they cannot afford to buy this equipment for their use. Moreover, the acquisition and procurement of this equipment are highly dependent on the national budget allocation and the LGUs. One of the participants, (T05) from a Public Science High School, in particular, shared that when their school started their Robotics program, they had very few kits to use for their students. But over time, through the effort and support of their LGU, they were able to receive several more kits.

On the other hand, the school situation described by T02, who also teaches in a Public Science High School, indicates that their school is still in the initial stages of ETs integration, wherein the school shows support in stages. Currently, the school has procured one (1) 3D printer and intends to offer a 3D Printing class for interested SHS students in the next academic year. By doing this, the school is studying whether to procure more units and to continue offering the class. This rationale aligns with Fulton et al (2002), who stated that this allows education leaders to determine if the emerging technology is worth investing in due to its significant effects. Unfortunately, although the school's intent is commendable, their method will introduce many challenges to both the teacher and students, given the limited equipment for their use.

Moreover, Nikitina and Ishchenko (2023) stated that resources in STEM education play a crucial role in building students' knowledge and skills, and in preparing them to meet current and future scientific and technological challenges. This means that teaching students about technology requires them to get their

"hands-on" with the technology to explore and use it. Only then can they learn its functionality and its applications and develop technology and digital skills.

The second challenge identified by the participants was the lack of or insufficiency of training to use ETs effectively. The participants, whether they have used some of the types of ETs or not, all perceived that training is important for them to be able to integrate ETs into their teaching practice. Ibrahim (2024) supports this by stating that comprehensive training programs and resources are essential to empower educators with the necessary skills and confidence to leverage emerging technologies effectively. In order to maximize the opportunities that can be obtained from the integration of ETs in education, teachers need to be empowered through training and support. Ibrahim (2024) further stated that the significance of the integration of ETs in Education lies in its potential to equip educators with the tools and methodologies necessary to cultivate the skills and competencies demanded by the 21st century. Educators equipped with technological proficiency, according to Ibrahim (20214), are better positioned to facilitate cross-cultural learning experiences and prepare students for the challenges of a globalized workforce.

Aside from teacher training, one of the participants, T03, stated that teachers should also be provided with technical staff who will be in charge of the maintenance and condition of any ETs equipment. This is to ensure that the teacher will solely focus on the integration of ETs in their instruction. This is supported by Dubhar (2023) when they reported that the "need for ongoing technical support and maintenance" was one of the common challenges or limitations in their literature review.

The third issue in integrating ETs in Education was a lack of curriculum resources, indicating the points of integration and how integration should be done. According to Nikitina and Ishchenko (2023), resources in STEM education also play a crucial role in building students' knowledge and skills, and in preparing them to meet current and future scientific and technological challenges. Due to the relative newness of ETs in Education, there are limited "free" and "ready-to-use" resources that teachers can use. STEM Resources using ETs are usually developed by Education Technology companies, wherein access to their curriculum resources is bundled with the purchase of their equipment. This can be observed in the situation of T05, who shared that their Robotics Kit supplier was recommended by their LGU and school and has trained them extensively on the use of these kits, which include curriculum materials for their use. Unfortunately, for most teachers in Public High Schools, even in several Public Science High Schools, this might not be possible.

For most of the participants, when to integrate ETs and time was raised as an issue. Integrating ETs requires preparation time, which teachers might not have due to the demands of the curriculum. Furthermore, due to the lack of knowledge and training of teachers, they might not know when available ETs can be integrated into their current lessons and how they can be integrated. It is worth mentioning that one participant, T04, who teaches at a Public Science High School, indicated that integrating ETs is not required of the teachers, indirectly hinting at their reason for not integrating ETs in their teaching practice. This behavior was also noted by Atabek (2019), stating that negative attitudes and incompetence are obstacles to technology integration. The study indicated this to be an educational administrative issue that can be resolved by setting expectations on teachers and providing an incentive system for teachers as a "reward for using time-consuming technologies".

The last challenge identified in the current study is the issue of misuse of these ETs, particularly Artificial Intelligence. Intellectual honesty in light of the capabilities and accessibility of Generative AI tools is a current issue, not just in Education. Unfortunately, most of the literature of the current study did not explore this particular theme. But, according to Fulton et al (2002), leadership organizations should focus their efforts on key areas such as focusing on necessary skills for both teachers and learners, which includes an emphasis on digital-age literacy.

Implications of Integrating ETs to STEM Education, Administration, and Teacher Training

Fulton et al (2002) stated that real change at the classroom level is driven most effectively by teachers, but it cannot thrive unless it is supported by school structures. This is true based on the accounts of the participants who mostly stated that their respective schools and divisions provide limited to non-existent support with regard to technology integration in the classroom. One participant, T02, stated that although the school

"verbally" encourages them to use ETs, the support is nonexistent. Contrastingly, T05 has repeatedly stated the support of their school and LGU in not just providing them with equipment but training as well, including opportunities to compete in Robotics competitions. The same is shared by T06, who teaches in a regular Public High School wherein their LGUs provide most of their Public High Schools, not just the Public Science High Schools, with Robotics Kits.

Based on the responses given by the participants and the literature used in the current study, the support that they have identified in integrating ETs in STEM Education constitutes the following:

Teacher training on:

How to operate or use ETs

How to integrate ETs into teaching

How to create STEM lessons, activities, and assessments using ETs

How to handle student misbehaviors in using ETs

Resources:

accessibility and availability

technical support and maintenance

In addition, none of the above-listed areas of support will be able to sustain the teacher's integration of ETs without the assistance of the school administration, which creates policies for the teachers. Based on the accounts of T05, a progressive-minded school division will find ways to support its schools, especially if the objective of the program will benefit its students. It is then recommended that school administrators and education leaders attend seminar workshops on integrating ETs in Education with their constituents so that they understand the importance of integrating ETs and know the required assistance in terms of infrastructure, resources, personnel, and training that their teachers would need to successfully integrate ETs in their teaching practice.

The findings of the study on the challenges and support needed by teachers in integrating ETs into their teaching practice can guide curriculum development and teacher training institutions to design curriculum materials that would enable teachers to effectively use ETs in STEM instruction. Conversely, teacher training related to the list of training topics listed above will provide these institutions with information to design more responsive teacher training workshops to develop not only the teachers' digital and technology literacy skill but also their confidence in the use of these ETs.

Lastly, to effectively maximize the educational benefits of emerging technologies requires the following elements: 1. Collaborative effort among stakeholders, which include policy makers, school administrators, and teacher training institutions to ensure the relevancy and alignment of the STEM curricula with the future industry workforce demands; 2. Continuous professional development programs to enhance or upskill STEM teachers on digital literacy, operation of ET equipment, and pedagogical approaches in integrating ETs; 3. Investment in up-to-date infrastructure and resources (equipment and human) to support ET integration efforts of school teachers; and 4. Fostering a culture of research among STEM teachers to report successes and areas of improvement in ET integration in STEM Education.

Future directions of the study include increasing the number of STEM teacher participants from both public and private schools to capture nuances in their experiences with emerging technologies. Moreover, since the role of school administrators is crucial to the effective integration of emerging technologies in their educational institutions, the study can be extended to include them to inform them of them of their teacher's challenges with ETs so that they draft strategic plans and identify feasible implementation strategies to ensure the effective integration of emerging technologies in their respective educational institutions.

REFERENCES

1. Atabek, O. (2019). Challenges in Integrating Technology into Education. Turkish Studies – Information Technologies and Applied Sciences Vol. 14, No. 1, p.1-19. Retrieved from https://doi.org/10.7827/TurkishStudies.14810
2. Dublar, C. (2023). Assessing the Impact of Emerging Technology Integration on Knowledge and Skills Acquisition of K-12 Students in the Philippines: A Systematic Literature Review. DOI:10.13140/RG.2.2.29073.30561
3. Fulton, K. & Honey, M. (2002). Emerging Technologies in Education. Educational Technology Vol. 42, No. 4, pp. 6-8. Retrieved from https://www.jstor.org/stable/44428758
4. Halaweh, M. (2013). Emerging Technology: What is it?. Journal of Technology Management and Innovation Vol.8, No. 3. Retrieved from http://dx.doi.org/10.4067/S0718-27242013000400010
5. Ibrahim, U. (2024). Integration of Emerging Technologies in Teacher Education for Global Competitiveness. International Journal of Education and Life Sciences. Vol. 2, No.2, p. 127-138. https://doi.org/10.59890/ijels.v2i2.1334
6. Leavy, A., Dick, L., & Meletiou-Mavrotheris. (2023). The Prevalence and Use of Emerging Technologies in STEAM Education: A Systematic Review of Literature. Journal of Computer Assisted Learning vol. 39, Issue 4, p1061-1082. Retrieved from https://doi.org/10.1111/jcal.12806
7. Montoro, M.A., Ortiz Colón, A., Moreno, J.R., & Steffens, K. (2019). Emerging Technologies: Analysis and Current Perspectives. Digital Education Review No. 35, p 186-210. Retrieved from https://eric.ed.gov/?id=EJ1220161
8. Nikitina, I. & Ishchenko, T. (2023). Globalization of Education: Vital Approaches in STEM Education. Scientific Journal of Polonia University Vol.59, No.4. Retrieved from https://doi.org/10.23856/5910
9. Rotolo, D., Hicks, D., & Martin, B. (2015). What is Emerging Technology? Research Policy Vol.44, p 1827-1843. Retrieved from http://dx.doi.org/10.1016/j.respol.2015.06.006
10. Swargiary, K., & Roy, K. (2023). Empowering Education: Exploring Emerging Technologies in the 21st Century. Dodo Books Indian Ocean Ltd and OmiScriptum S.R.L. Publishing Group. DOI:10.5281/zenodo.8199585
11. Van Mechelen, M., Smith, R., Schaper, M., & Tamashiro, M. (2022). Emerging Technologies in K-12 Education: A Future HCI Research Agenda. ACM Transactions on Computer-Human Interaction Vol. 30, No. 3. DOI:10.1145/3569897

ETHICAL APPROVAL

The participants were given formal letters of invitation to participate in the study which includes a request for their permission to use their personal information, e.g. age and gender, with the assurance of non-disclosure of their identity, personal information, or the name of the institution.