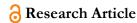
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# STEM Teachers' Use of E-Learning Resources in Scripted Lessons: Endeavours Toward Teacher Professional Development

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#### **Abstract**

Globally, teacher professional development is increasingly gaining recognition as an intervention that ensures practitioners are equipped with the teaching competencies needed to keep abreast of a rapidly evolving educational environment. Developing professional competencies is critical to a science, technology, engineering, and mathematics (STEM) teacher's growth. Empirical studies indicate that regular STEM teacher professional development (STEM-TPD) is necessary to develop these competencies. Drawing on the Technological, Pedagogical, and Content Knowledge (TPACK) framework, this mixed-methods study examines how beneficiaries of a Continuous Professional Development Certificate in Innovative Teaching Mathematics and Science (CPD ITMS) apply acquired skills to integrate e-learning resources into the teaching rehearsals of STEM subjects. Four purposively selected teachers take turns teaching scripted Mathematics, Biology, and Chemistry lessons. The teachers and one hundred and seventy (170) learners are participants in the study. Data is generated from Lesson Observations and Focus Group Discussions (FGDs) sessions. Findings reveal that the teachers' abilities to integrate e-learning resources in teaching and learning were at different levels. The majority of them applied integration strategies that were teacher-centered rather than learnercentered. Other findings show that teachers' inability to navigate within the Technological Pedagogical Knowledge (TPK) and Pedagogical Content Knowledge (PCK) aspects of the TPACK caused most of their challenges. Overall, lesson scripting provided for consistent teacher rehearsals and learners' engagement that potentially heightened opportunities for teacher professional growth and sustained STEM-learning motivation for students. The study recommends sandwiched scripting that alternates with non-scripted, individually designed lessons to wean STEM teachers into sustainable capacity development.

Keywords: E-Learning Resources, Essential Technology Component, Scripted Lesson, Teaching Competency, Professional Development

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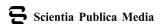
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## 1. INTRODUCTION

The global drive for STEM (Science, Technology, Engineering, and Mathematics) education has meant a shift in focus on teaching the discrete disciplines constituting STEM. While previous methodologies centered on advancing disciplinary knowledge of particular subjects, STEM education calls for integrative approaches that seek interdisciplinary or cross-disciplinary teaching. The integration of knowledge and learning has emerged as a key driver of value creation in the twenty-first century. In response to this shift, educational communities have increasingly emphasized the integration of STEM disciplines (Song, 2020). Educators entrusted to provide instruction in these STEM disciplines must be fully competent in the requirements for teaching the subjects in a manner consistent with the new demands. Despite this renewed focus on teaching STEM disciplines, ways of how an integrative approach can be adopted in the



classroom have remained uncertain because a majority of initial teacher education programmes are devoid of content relating to integrative approaches and novice teachers may also lack comprehensive training in scientific inquiry, technology integration, design, and engineering to teach the relevant practices proficiently (Yip, 2020).

Teacher competency is key to successfully integrating the STEM disciplines (Song, 2017; Song, 2020; Thuy et al., 2020). Accordingly, effective STEM education necessitates that teachers possess the ability to actively share and interconnect knowledge, skills, and perspectives across disciplines (Corlu et al., 2014). In this regard, Song (2020) identified three essential domains of teacher competence in implementing integrated STEM education: cognitive characteristics (CC), instructional skills (IS), and affective characteristics (AC). Citing other scholars, Song (2020) posits that:

- CC of teacher competency relates to subject matter knowledge, teaching methods, curriculum application, instructional design, capabilities in the application of theories of child development and learning, adjusting to cross-cultural teaching, and interdisciplinary teaching.
- IS of teacher competency describes their abilities to organize instructional delivery, assess learners' challenges and progress, maintain learning motivation, integrate technology during teaching, initiate active engagement, and foster conducive learning environments.
- AC of teacher competence relates to the ethics of care and teacher practice, a belief in the dignity of the learners, their self-determination, and right to respect, be heard, and other affective characteristics.

Acquiring these competencies, particularly in STEM teaching, is difficult (Avery & Reeve, 2013; Stefanova et al., 2019; Warin et al., 2015). Many countries, such as Slovenia and Norway (Abina et al., 2024), Thailand (Faikhamta et al., 2018), and Vietnam (Nguyen et al., 2020), have sought to support their Mathematics and Science teachers in developing competencies through a series of CPD programmes. Similar CPD programmes have been implemented in Rwanda.

The Government of Rwanda, through the Ministry of Education (MINEDUC), National Examination and School Inspection Authority (NESA), and the Rwanda Basic Education Board (REB), is implementing the Quality Basic Education for Human Capital Development (QBEHCD) (MINEDUC, 2022; University of Rwanda, 2023). Among other strategic objectives, the QBEHCD project focuses on enhancing teachers' effectiveness for improved student learning, with sub-component 1.2 targeting the professional development and strengthening of the subject matter knowledge and instructional practices of Mathematics and Science teachers (MINEDUC, 2022). As articulated in these policy documents, key priorities within this initiative encompass improving teacher content understanding, enhancing teaching practices, ensuring access to instructional resources and technology, utilizing and effectively deploying these resources, and providing support for Mathematics and Science teachers (Nkundabakura et al., 2024). As a follow-up implementation programme to the initiative, the University of Rwanda College of Education (URCE) and the REB collaboratively designed the Continuous Professional Development Certificate in Innovative Teaching Mathematics and Science (CPD ITMS) (Nkundabakura et al., 2024).

The CPD ITMS programme was designed to address specific challenges faced by STEM teachers in secondary schools. These challenges manifest in several ways, including the use of traditional teaching approaches, limited skills in integrating technology, and a lack of disciplinary knowledge in other STEM areas (Niyibizi et al., 2024). Thus, the CPD ITMS program endeavored to improve the teaching of mathematics and science by equipping teachers with contemporary trends in teaching approaches, integrating technology into classrooms, and providing supplementary content in these subjects (University of Rwanda, 2023). However, despite the implementation of the CPD ITMS, there is limited research illuminating how teachers enact the CPD-acquired competences in real classroom teaching. Research on STEM-Teacher Professional Development (STEM-TPD) highlights the importance of follow-up systematic observation of model lessons (Burke, 2013; Postholm, 2018), teaching rehearsals (Horn, 2010; Masters, 2020), and continual feedback from experts (Dede et al., 2016; Huang et al., 2022). The current study explores this gap to find out how the CPD ITMS beneficiaries apply acquired skills to integrate e-learning resources in the teaching rehearsals of STEM subjects.

#### 1.1. Research Questions

Specifically, the study is guided by the following questions:

- 1. How do the STEM teachers integrate Technology in their scripted lessons?
- 2. What challenges do the teachers experience in using e-learning resources in scripted lessons?
- 3. What professional development benefits do the teachers derive from their efforts to integrate e-learning resources in teaching and learning?

#### 2. LITERATURE REVIEW

#### 2.1. Theoretical Framework

The present study is framed within the Technological, Pedagogical, and Content Knowledge (TPACK) model, introduced by Mishra and Koehler in 2006. This framework serves as an ICT integration model that emphasizes the interplay of technological, pedagogical, and content knowledge as essential for the effective incorporation of ICT into the teaching and learning process. According to Mishra and Koehler (2006), the framework guides classroom practitioners' understanding of students' learning outcomes while providing a sound approach to integrating ICT when implementing the curriculum.

The framework encompasses three forms of knowledge that guide classroom practitioners in successfully integrating ICT, namely technological, pedagogical, and content knowledge. The first form of knowledge is Content Knowledge (CK), which is the subject matter knowledge that teachers should possess to be effective in implementing the curriculum. The other component of knowledge is Pedagogical Knowledge (PK), which is the knowledge of methods and strategies that classroom practitioners employ to enhance learning in the classroom. Technological Knowledge (TK) refers to the type of knowledge related to e-learning resources that teachers can strategically engage in the teaching and learning process. In this kind of knowledge, the teacher needs to demonstrate his/her ability to choose appropriate ICT tools to deliver lessons. This type of knowledge enables the teacher to understand how they can effectively utilize the internet and other application software, such as Plickers. The three knowledge types intersect further to yield union sets of technological content knowledge (TCK), technological pedagogical knowledge (TPK), and pedagogical content knowledge (PCK), as shown in Figure 1 below.

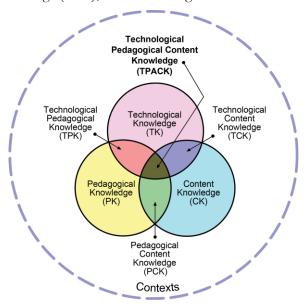


Figure 1. The TPACK framework for ICT integration (Source: Mishra & Koehler, 2006)

TCK relates to the content presentation possibilities that technology creates for teachers. It describes how teachers can change the way learners engage new concepts utilizing technology (Barakabitze et al., 2019). For instance, virtual reality can be used in STEM subjects to present concepts and procedures that require a high level of abstraction and complexity, due to the countless variables involved and the great number of interrelations among them (López & Caceres, 2010). The other aspect, TPK, relates to the

teachers' technological pedagogic knowledge that assists them in using ICT. In other words, teachers need different sets of pedagogical skills to teach using various technological gadgets. Thus, teachers require particular skills to utilise video technology for self-reflection, assessment of learning accomplishments, and supporting hands-on class assignments with the learners, while a different set of pedagogical skills could be needed when teaching using a projector (McNulty & Lazarevic, 2012).

The last aspect is PCK, a concept coined by Shulman that has seen widespread use in several disciplines of education, such as Physics, Chemistry, Physical Education, and Mathematics. Shulman argued that PCK "...represents the blending of content and pedagogy into an understanding of how particular topics, problems and or issues are organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). Thus, teachers' understanding and conceptualization of the pedagogical ICT skill sets needed to teach a particular topic, the teacher's ability to tease out the learners' prior knowledge and worldviews about a topic and/or ICT content/skills, his/her knowledge about ICT tools that can be used to teach particular content, at various grade levels, and the content representations and ICT approaches that can be integrated to aid learners' understanding or circumstances are vital aspects of PCK (Ward & Ayvazo, 2016).

## 2.2. STEM Teacher Professional Development (STEM-TPD)

STEM teachers are critical to the development of competencies in the learners. Their competences matter because, without the necessary skills for STEM teaching, most endeavored programmes suffer a stillbirth. STEM teachers are critical mediators of knowledge, and their teaching actions, behaviors, and performance can directly influence students' knowledge acquisition and their learning experiences (Huang et al., 2022; Irwanto et al., 2022). This need for effective STEM teacher competences, coupled with the rapid development in STEM fields (Zhan et al., 2022), calls for regular STEM-TPD (Huang et al., 2022). Professional development ensures that STEM teachers' competencies are honed and their pedagogical knowledge is kept up to date with contemporary trends (Anbar & El Naggar, 2024; Niyibizi et al., 2024).

Teacher professional development (TPD) implies individual or institutionally related enhancement initiatives that teachers engage in to positively change their beliefs about teaching or teaching behaviours to realise growth in teaching competence repertoire. Huang et al. (2022) broadly defined TPD programs as activities, including courses and workshops, mentoring and coaching, degree programs, and informal dialogue between teachers, that nurture and foster an individual teacher's professional mindset, skills, knowledge, expertise, and other characteristics. Despite this apparent conceptualization of TPD, the characterization of a STEM-TPD framework is still elusive (Chai, 2019).

Chai (2019) has suggested a STEM-TPD theory-in-practice model that posits a core phenomenon for STEM-TPD as comprising a set of interacting variables such as intervening contextual conditions (existing challenges, keeping abreast with contemporary trends, availability of technological resources, learner preparedness, and technical expertise); casual conditions (demands from emerging technologies, future employment demands, student progress with STEM disciplines, and national economic needs); and forms and properties of the TPD processes (CoPs, school-industry partnerships, universities-school collaborations, and TPD dimensions and foci). Thus a STEM-TPD (i) establishes existing gaps in teachers' TPACK for STEM lesson design; and (ii) formulates action plans such as funding, policy adjustments, engagement of engineering professionals, formation of CoPs, public engagement outreach programs with materials, visits to STEM organization, workshops, and resource sharing; and (iii) specify the pedagogical, duration, dimensions, and nature of the TPD foci (Chai, 2019).

Several STEM-TPD scholars have focused on the activities practitioners can engage in to develop competencies in STEM teaching. In a systematic literature review study, Suryad et al. (2023) observed that STEM-TPD for pre-service teachers covered three areas, namely: inclusion of integrated STEM theory in existing courses, outreach programmes, and the development of new regulations or modules. Accordingly, essential elements of a STEM-TPD program for pre-service teachers included real-school teaching, microteaching, presenting STEM learning designs, interrogating STEM existing integration approaches, theoretical foundations about STEM, and doing STEM activities as students (Suryad et al., 2023).

Huang et al. (2022) identified key STEM teacher professional development themes and corresponding professional development approaches. The authors argue that in-service training could be done under the following themes and the corresponding activities, namely:

- Theory and practice alignment- Equip the teachers with knowledge through lectures, seminars, research, online tutorials, and self-directed learning resources.
- Lesson Observations- Demonstration lessons, model lessons, showcase best practices, and model exemplary work.
- Reflexivity- Sharing critical and constructive feedback on micro-teaching videos, reflecting on teaching practices, action research, and lesson study.
- Trying out different lesson designs- inquiry teaching practices, educational experimentation.
- Collaborating with peers- co-teaching, peer mentorship, and creating a community of practice (CoPs).
- Field Visits- Field experiences (e.g., visits to other schools), peer learning visits.
- Providing continual feedback- Teacher supervision, resource person/expert feedback, and progress reports.

Despite being a recognizable professional development approach similar to those stated above, scripted lessons are rarely mentioned in the literature on STEM-TPD (Nsengimana et al., 2024).

## 2.3 Scripted Lessons

Scripted lessons are drawn from the broader concept of a scripted curriculum. Although this type of curriculum was prevalent earlier, the scripted curriculum gained prominence in the period of American legislation, the Individuals with Disabilities Education Improvement Act (IDEA) of 2004 and the No Child Left Behind Act (NCLB) of 2001 which resulted in commercially developed programmes that came with prepackaged curriculum and staff development materials (Jimenez et al., 2014; Wyatt, 2014). The No Child Left Behind Act (NCLB) focused on standards and quality education, opening the door for standardized curricula. Its funding models for public schools essentially required the use of scripted curriculum materials, assuming these were the only ones that qualified as scientifically based (Carl, 2014). According to the public perception prevailing at the time, scripted materials were scientifically based and were helpful to ill-prepared teachers who needed further pedagogic scaffolding after being newly employed by the government (Mwandia & Mwanza, 2022). The scripted lesson is thus a prepackaged and guided lesson directing teachers towards particular steps to sustain consistency in teaching strategies. Its strict adherence to the script is targeted more toward schools with high-performance lag so that there is uniformity in concept delivery, with the expectation that the students will understand the lessons more clearly (Mwandia & Mwanza, 2022).

Scripted instruction has often been criticized for undermining teachers' professional autonomy. The reliance on a prescribed script limits their freedom to select instructional strategies and materials that best meet the needs of their students. Such an approach is frequently regarded as a sign of distrust toward teachers, positioning them as mere technicians who are stripped of their creative capacity and disciplinary expertise, since they are prevented from drawing upon their professional knowledge in favor of externally imposed scripts (Milosovic, 2007; Reeves, 2010). According to Reeves (2010), scripted instruction programs—which require teachers to deliver lessons and even verbal expressions directly from standardized scripts—are widely condemned for stifling teacher creativity and professional growth. This criticism is closely linked to the behaviorist underpinnings of the approach, in which skill acquisition is developed progressively from micro- to macro-levels. Within the behaviorist framework, instruction follows a sequential, step-by-step pattern that is tightly regulated by teachers or curriculum developers (Reeves, 2010).

Advocates of the scripted instruction approach (e.g., Fang et al., 2004), however, argue that scripting represents the first stage of teacher empowerment. Arguing that practice through scripting provides the teacher with some guidance and direction on the performance of tasks that may initially be regarded as complex. Fang et al. (2004) argue that becoming a teacher is a journey and that professional development efforts in education must recognize the complex, multifaceted, and lifelong nature of becoming and being an effective STEM teacher. In essence, initiating STEM-TPD with scripted instruction may assist STEM teachers in developing what Reeves (2010, p. 256) refers to as "adaptive expertise and a conceptual map for teaching". In contexts where technology integration skills are still developing, new technologies are

introduced at a wide scale, or/and schools are being put under pressure to perform on a standardized curriculum, the use of scripted teaching programs can be an aid for the in-service development of teachers to make a head start (Mwandia & Mwanza, 2022). Mwandia and Mwanza (2022) further caution that scripting is not meant to eliminate teacher preparation, but is to be used as a scaffold for teachers to adhere to the topics and skills required of students and, in the process, internalize the requisite skills required for their job.

#### 2. METHODS

## 2.1. Research Approach and Design

The study employed a mixed-methods approach, supported by a concurrent design, to integrate the qualitative and quantitative components. The mixed-methods approach allowed for the combination of data from the structured observation instrument, the Technology Integration Assessment Instrument (TIAI), with field notes to provide a detailed narrative for each scripted lesson, aligning with the study's research questions (Lindorff & Sammons, 2018). A concurrent triangulation design was preferred in the current study. According to Cresswell et al. (2003), the design facilitates the collection and analysis of data at the same time to ensure findings within a single study are cross-validated and corroborated.

## 2.2. Research Participants and Study Context

The study setting is Rwanda, where four purposively selected teachers, beneficiaries of the CPD ITMS, apply acquired skills to integrate e-learning resources in the teaching rehearsals of STEM subjects. As part of the CPD ITMS programme requirement, each teacher rehearses the integration of the Plickers Quiz and other technology for teaching and assessment in scripted lessons. The formative assessment tool Plickers is a technology-based student response system (SRS) that employs quick response (QR) codes printed on paper, functioning as paper-based clickers (Elmahdi et al., 2018; Kent, 2019). Each QR code is designed so that its orientation indicates one of four possible choices (A, B, C, or D), while every card is uniquely numbered (1–63) to correspond to individual students (Kent, 2019). Associative technologies used in conjunction with Plickers during the rehearsal lessons included smartphones, Internet connections, projectors, and laptops.

## 2.3. Data Collection

The teaching rehearsal was a 40-minute Biology, Chemistry, or Mathematics lesson. The subject teachers took turns preparing and teaching a lesson each. At the same time, two Mentor Teachers (Researcher 1 (R1) & Researcher 2 (R2)) and the other three (3) peers (rotating roles of Peer Tutor 1, 2, & 3) observed compliance with the provided CPD ITMS script. Data was collected using observation and focus group discussions (feedback sessions) with teacher participants and learners. At the end of every lesson, six (6) learners were randomly selected to participate in a group feedback session that provided a window for their voices' contribution to improving teaching and learning (Khokhotva & Elexpuru Albizuri, 2020). The CPD ITMS feedback form on scripted lessons (see Appendix 1) provided guideline standards for both teaching and observation.

## 2.4. Validity and Reliability

To ensure research validity, the observation data were collected using a trialed and tested protocol, the Technology Integration Assessment Instrument (TIAI) introduced by Britten and Cassady (2012) (see Appendix 2). TIAI assesses classroom teachers' planned use of technology, focusing on seven dimensions that cover lesson planning, content standards, educational technology standards (ETS), attention to student needs, use of technology in learning, use of technology in teaching, and assessment. Each dimension is rated on a Likert-type continuum beginning from technology not present (0), non-essential technology component (1), supportive technology component (2), through to essential technology component (3), with zero (0) and three (3) representing weak to very strong integration levels respectively (see Appendix 2, for

the description of levels). The percentage of absolute agreement index was used to measure the researchers' observation consistency and inter-rater agreement (IRA). IRA measures the degree to which two or more raters assign the same precise value for each observed item (Chaturvedi & Shweta, 2015). IRA values of 0-0.4; 0.5-0.7; and 0.8-1 were considered low, medium, and high agreement, respectively.

## 2.5. Data Analysis

The initial analysis began with the preparations for lesson delivery, way before the classroom observations. Scoring on the TIAI provided quantitative data that provided insights that were followed up on in FGDs. Narrative themes and descriptive statistics were used as analysis tools for the data collected through the TIAI observation instrument and from the FGDs with the teacher participants and the learners.

#### 3. RESULTS

This section presents the results of the observations and FDGs conducted with the four teachers: Teacher 1, Teacher 2, Teacher 3, and Teacher 4.

#### Teacher 1

IRA value

Teacher 1 is a Mathematics specialist. He is aged between 24 and 30 and is relatively a novice with teaching experience of less than two years. He taught the topic "Graphical representations of linear inequalities in one unknown" to a Senior 3 class of eighteen (18) learners. The observations of the lesson that he taught are summarized in Table 1 below.

Dimension 0 3 R1 R2 Agreement Planning for technology integration 2 2 1 objectives, instructional (lesson technology) Standards (content standards per grade 3 3 1 level and content area) Technology 3 3 1 Educational Standards (ETS) (as provided in CPD ITMS script) Attention to student needs 3 3 1 Implementation (use of technology in 2 2 learning) Implementation (use of technology in 3 3 1 teaching) Assessment 3 3 1

Table 1. Observation Rating and IRA on Teacher 1's Technology Integration

Note: Technology not present=0; Non-essential technology component=1; Supportive technology component=2; Essential technology component=3

Table 1 shows a high IRA of 1. Overall, Teacher 1's integration abilities were high. He scored the maximum possible points of 3 on five TIAI dimensions. On the second dimension, for example, the teacher directly linked technology use to one or more set standards, making it possible to achieve the standards set out in the feedback form of the scripted lesson and the planned lesson objectives. Observations on the sixth dimension focused on the teacher's use of technology in teaching. Teacher 1 scored a 3 on this aspect, implying that equipment and technologies were built into lesson design and objectives and were discussed within the context of the lesson and not as an external component. For instance, after following the screened instructions on solving graphical representations of linear inequalities, the learners completed their assigned tasks, as shown in Figure 1.

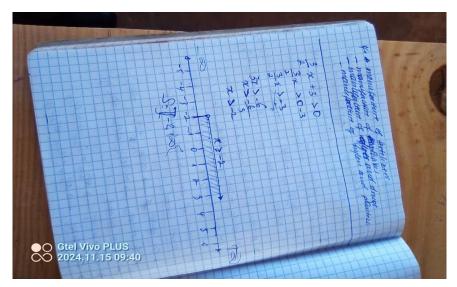


Figure 1. Sample Assignments that were Done in Pairs Following Task Instructions Projected on the Screen

The teacher used the Plickers Quiz at the formative assessment level perfectly. Technology products and processes were used to collect data on learners' performance, and learners were directly assessed on aspects of the content standards in real-time. His ability to involve every learner in the quiz was confirmed in the FGDs. The other teachers and the learners acknowledged that Teacher 1 had achieved very high integration levels of the Plickers quiz and the other technologies. Some of the learners had this to say, particularly about the Plickers technology:

We were involved in the lesson. I enjoyed the Plickers quiz. It was good because it made learning easy. Even the teacher did not waste time writing on the board. [Learner 2]

It was interesting to see the scoreboard without writing anything on paper. The teacher used to write our tests on the chalkboard and spent time marking. Now we get marks without any papers. [Learner 5]

However, despite the positive comments, the feedback discussion session with peers and the researchers highlighted additional technologies that could have been used in the lesson as well. For instance, the use of a selected video from the YouTube platform with relevant content to the topic was recommended. This implies Teacher 1 had successfully used technology to collect data on learners' performance, and his actions had generated a lot of interest among the learners, as shown by the sentiments they expressed.

Dimension R1 R2 Agreement technology 3 Planning 3 for integration objectives, (lesson instructional technology) 2 2 1 Standards (content standards per grade level and content area) 2 0 Educational Technology Standards 1 (ETS) (as provided in CPD ITMS script) Attention to student needs 1 1 1

2

2

2

2

1

1

1

1

Table 2. Observation Rating and IRA on Teacher 2's Technology Integration

Note: Technology not present=0; Non-essential technology component=1; Supportive technology component=2; Essential technology component=3

Implementation (use of technology in

Implementation (use of technology in

learning)

teaching) Assessment

IRA value

## Teacher 2

Teacher 2 also taught Mathematics. He is in his early thirties (30s) and has 2 years of teaching experience. The teacher's lesson plan showed that some e-learning resources, such as the projector, laptop, HDMI code, smartphone, Plickers software, and Plickers cards would be used during teaching and learning. The lesson topic was "Multiplication and division of rational numbers" and targeted 63 Senior One (1) learners. Observation made on the lesson is shown in Table 2.

Table 2 shows a high IRA value of 0.86. According to the observation made by the researchers, Teacher 2's ability to integrate e-learning resources in his teaching was not very impressive. On the content standards per grade level and content area, use of technology in learning, and use of technology in teaching dimensions, the teacher scored an average of 2, implying integration that did not quite meet the content and ETS standards. Regarding the fourth dimension (attention to students' needs), the researchers agreed on a score of 1. This meant that the teacher did not use technology in an adaptable fashion to attend to each learner's needs. Although all the students were given the Plickers cards, some were given the wrong cards or cards that did not match their names in the system. One learner exemplified the feelings of the majority of the learners. The learner said:

The lesson was boring because I did not see my performance when the marks were shown on the projector screen. However, I answered all five questions that were given in the exercise we did at the end of the lesson. Some marks were missing.

Although the Plickers technology was used, many challenges were observed. The following remarks were made by Teacher 2's peers during the lesson feedback discussion:

There was good integration to some extent. For example, steps to be followed in finding solutions to the problem tasks were projected. Which means the teacher concentrated on assisting learners rather than belaboring on explanations. However, the teacher distributed cards randomly without matching card numbers with learners as they appeared on the system. [Peer Tutor 3]

Some names of the learners did not reflect on the grid. As their cards probably belonged to absent learners. That means the final result shown by the system was not an authentic representation of the learners' efforts. [Peer Tutor 1]

From the sentiments of the Peer Tutors, Teacher 2's lesson started fairly well until he reached the formative assessment stage, where the Plickers system needed integration. For instance, instructions on the use of the Plickers cards were not clear to the learners. Image 2 below shows typical errors the teacher made.

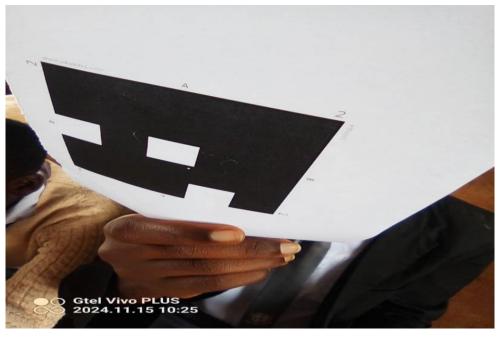


Figure 2. Some Typical Errors Made by Teacher 2 in the Attempt to Use the Plickers Quiz

A learner who chose "C" as the answer to the first question (as indicated in the notes in his notebook) raised the card randomly to make "A" the choice, without making sure "C" was at the top, as shown in Image 2. Overall, Teacher 2 made a good attempt, but the mix-up with Plickers cards led to an undesired scenario where some learners were left behind. It meant their voices were disregarded in the assessment process.

## Teacher 3

Teacher 3 is a Biology specialist. He is also a novice in the profession with one year of teaching experience. He was teaching the topic "The five kingdoms of classification" to a Senior 1 class of 67 learners. The teacher's lesson plan was well prepared following the CPD ITMS script. E-learning resources such as a projector, screen, smartphone/scanner, HDMI code, Plickers software, Plickers' cards, and online materials related to the topic were set for the lesson. However, other e-learning resources, such as models, animations, and simulations that are stipulated in the CPD ITMS script, are missing.

The teacher follows an inductive approach to lesson presentation. The teacher follows a link on the internet that projects pictures showing the classification of living organisms. The learners identify what they observe in the image, after which they infer what the objectives and topic of the lesson are about. The other observations made during the lesson are presented in Table 3 below.

Dimension	0	1	2	3	R1	R2	Agreement
Planning for technology integration				√.	3	3	1
(lesson objectives, instructional technology)				√ .			
Standards (content standards per grade level and content area)				$\sqrt{}$	3	3	1
Educational Technology Standards (ETS) (as provided in CPD ITMS script)			$\sqrt{}$	$\sqrt{}$	3	2	0
Attention to student needs			$\sqrt{}$		2	2	1
Implementation (use of technology in learning)			$\sqrt{}$	$\sqrt{}$	2	3	0
Implementation (use of technology in teaching)			$\sqrt{}$		2	2	1
Assessment			$\sqrt{}$		2	2	1
IRA value							0.71

Table 3. Observation Rating and IRA on Teacher 3's Technology Integration

Note: Technology not present=0; Non-essential technology component=1; Supportive technology component=2; Essential technology component=3

The researchers achieved an IRA value of 0.71. From the observation data in Table 3 above, Teacher 3 scored highly on the first and second dimensions. The teacher used the Computer and other online web links in the planning and delivery of the lesson (e.g., Web Quest). In addition, the integration of equipment and technologies was embedded within the lesson design and objectives, being addressed in relation to the lesson itself rather than as an external element. The researchers concurred that the technologies employed were explicitly aligned with one or more standards, thereby facilitating the attainment of certain CPD ITMS standards.

Like Teacher 2, the only challenge in Teacher 3's lesson came during the integration of the Plickers quiz in the lesson. Teacher 3 had not allocated the Plickers' card numbers to the learners in advance and attempted to do so during the lesson. A lot of time was taken to allocate numbers that corresponded to their names. Fearing the loss of time, the teacher eventually allocated cards to a few of the learners, leaving others without cards to participate in the assessment quiz. It meant some learners were excluded from participation in the quiz as they did not have cards. Consequently, on the attention to student needs and the assessment dimensions of the TIAI, Teacher 3 scored 2 (See Table 3). The teacher failed to modify or adapt technology to meet the needs of the learners. The learners confirmed this in the FGD. Asked if they

had enjoyed the teacher's use of ICT in the lesson, they responded with mixed feelings. Those who had been included in the quiz answered in the affirmative, whilst those who had been excluded responded with "No" because they had not participated in the most interesting part of the lesson.

#### Teacher 4

Teacher 4 is a Physics and Chemistry specialist. He is aged between 30 and 35 and is a senior and the Dean of Teachers with a teaching experience of between 2 and 5 years. He was teaching the topic, "Effective ways of waste management" to a Senior 2 Chemistry class of twenty-two (22) learners. Like the other teachers, he was prepared with an array of ITC equipment such as the projector, smartphone, laptop, Plickers software, and Plickers' cards to embed in the lesson. Table 4 below presents observation data that represent his navigation through the scripted lesson.

Dimension R1 R2 3 Agreement  $\sqrt{}$ Planning 3 3 for technology integration  $\sqrt{}$ (lesson objectives, instructional technology) Standards (content standards per grade 2 3 0 level and content area) Technology 3 2 0 Educational Standards (ETS) (as provided in CPD ITMS script) Attention to student needs 3 3 1 Implementation (use of technology in 2 2 Implementation (use of technology in 3 3 1 teaching) Assessment 3 3 1

Table 4. Observation Rating and IRA on Teacher 4's Technology Integration

Note: Technology not present=0; Non-essential technology component=1; Supportive technology component=2; Essential technology component=3

Table 4 shows conflicting observations on the second and third dimensions of the TIAI. On the content standard dimension, R1 thought that the teacher used technology supports to promote the acquisition of standards in the lesson, but the technology was not directly tied to the standard itself, whilst R2 observed that the technology used in the lesson was directly linked to one or more standards, making it possible to acquire that standard. Furthermore, on the ETS dimension, R1 thought that ETS were present and integrated into grade-level appropriate learning goals, contrasting R2's observations, who thought that although the ETS were present and grade-level appropriate, they were not identified or embedded into the lesson as a learning goal. On the rest of the dimensions, the two researchers agreed, achieving an IRA of 0.71. Unlike Teachers 2 and 3, Teacher 4 paid attention to the students' needs, adapting technology to accommodate learners from diverse backgrounds. Specifically, the technology tool (Plickers quiz) and the subsequent formative assessment activity were designed to be adaptive to the learners' needs.

However, despite the observed success on the assessment dimension, Teacher 4 scored a 2 on the implementation (use of technology in learning). This component assessed the overall technology impact on the learning process. The observations made using the TIAI indicate that the teacher's use of technology had a limited impact on the process of learning. The feedback comments that Teacher 4 received during the FGD after the lesson confirm this observation. Peer Tutor 2 said:

You used technology very well. But I think there was an over-concentration on technology, so much so that you sometimes forgot to link the concept of waste management to real-life situations. For instance, maybe you could have highlighted how waste management is achieved in our country's cities or townships, or at least made reference to how waste management is done at our school.

Peer Tutor 3 had this to say:

You achieved very good results with the Plickers administration. However, I observed that the learners' results of the quiz that you gave were not very impressive. If I may estimate, it seemed the average score was 3 out of the 5 questions they were asked. This may imply that although technology was used, learners failed to master the concepts of waste management.

## Peer Tutor 2, added:

The standard that we all failed to implement, that is a requirement for our scripting, is the aspect of allowing learners to ask questions, exploration of e-learning resources to answer the learners' questions or curiosity, and explanation of concepts by learners using e-resources. Allowing learners to explore concepts using the technology tools themselves was needed. Perhaps that may be the reason why the learners' average score was low, as my colleague observed.

Unfortunately, learners from this class were not allowed to deny or confirm sentiments made by the Peer Tutors because the FGDs did not take place due to time constraints.

#### 4. DISCUSSION

This study sought to explore STEM teachers' capabilities in integrating technology into their teaching, the challenges they encountered, and the benefits accrued from their professional development efforts. Results of the study reveal that teachers' competencies in technology integration were rated as "developing". That means there were several aspects that they did well, and other aspects that needed improvement. For instance, some of the teachers used the Plickers technology successfully while others mixed up the learners' codes, resulting in the exclusion of other learners from the lesson activities. The other observation included time management and the challenge of managing data for large classes, particularly when doing it for the first time. The results aligned with Oner's (2023) findings, where 24 preservice participants shared their experiences on the use of the technology, confirming similar challenges such as time management and the hassle of preparing the students' names one by one and uploading them into the system. Overall, lesson scripting provided for consistent teacher rehearsals and learners' engagement that potentially heightened opportunities for teacher professional growth and sustained STEMlearning motivation for students. For instance, in tandem with Song's (2020) description of teacher competences, teacher participants of the current study gained skills and abilities to organize instructional delivery, assess learners' challenges and progress, maintain learning motivation, initiate active engagement, and foster conducive learning environments.

The study explored how the CPD ITMS beneficiaries applied acquired skills to the integration of elearning resources in the teaching rehearsals of STEM subjects. The teachers went through professional development workshops. As a follow-up on what they learned in workshops, they were asked to microteach acquired skills through the implementation of scripted lessons that were supported through mentoring and reflective discussion sessions with peers. The approach aligned with other STEM-TPD models highlighted in the literature. According to Chai (2018), the most comprehensive STEM-TPD models encompass translating the knowledge acquired in a workshop through lesson development, followed by enactment, and sometimes with reflective refinement. The approach aligned with other STEM-TPD models highlighted in the literature. Chai (2018) stated that the most comprehensive STEM-TPD models involve transforming the knowledge gained in workshops into lesson plans, which are subsequently implemented and, in some cases, further refined through reflection.

From the findings of this study, the teachers' integration of e-learning resources was at different levels. Others, such as Teachers 1 and 4, did fairly well, but the others had challenges, such as failing to administer the Plickers Quiz with large classes, limited skills in embedding models, animations, and simulations, and the inability to actively engage learners with ICT tools. In other words, the teachers applied technology at the Type I rather than at the Type II level. Type I applications of the technology are defined as being passive or teacher-centered, while Type II applications of the technology are more learner-centered, and those that hold the potential to alter the effectiveness of teaching and ultimately the success of learning (Britten & Cassady, 2012). This inability to operate at the Type II level was evidenced by most teachers' low scores on dimension 5 (Implementation-use of technology in learning) of the TIAI.

The findings also indicated that some learners were dissatisfied with the way they were excluded from participation in sections of the lesson. In particular, at the formative assessment level, failure to capture the learners' correct credentials that aligned with assigned student numbers caused a mix-up. Some learners who attempted the quiz were missing from the tabulated performance screened from the system, while others not allocated any number were excluded from the onset. This finding illustrated the broader challenges teachers face when implementing STEM-integrated programmes. Thibaut et al. (2018) aver that the improper use of numerous technical and electronic materials and resources, such as measuring devices, software applications, and other design programmes, pause challenges that may offset some learners, resulting in their total exclusion from the learning trajectory. However, despite these challenges, some of the learners in the current study reported gains in motivation, learning excitement, and engagement that they attributed to technology integration. The present findings seem to be consistent with other research, which found that learners' positive comments about their experience with the Plickers quiz could be summarized in three themes-joyful learning, active engagement, and motivated learning (Chou, 2022).

We thought that the challenges the teachers faced were directly linked to the Technological Pedagogical Knowledge (TPK) and Pedagogical Content Knowledge (PCK) aspects of the TPACK. Particular sets of TPK skills were needed to deal with different ICT tools. For instance, a set of skills for utilising video technology for self-reflection, evaluating learning outcomes, and facilitating learners' handson classroom activities differed from the pedagogical competences involved in teaching with a projector (McNulty & Lazarevic, 2012). Furthermore, using Shulman's (1987) PCK concept, the teachers failed to blend the content and pedagogy into a coherent understanding of how specific topics, problems, or issues should be structured, represented, and tailored to accommodate learners' diverse interests and abilities. Thus, a lack of PCK was the reason behind Teacher 4's failure to connect content to real-life situations, Teacher 1's inability to utilize other technologies, such as video and simulation, that were relevant to his topic, and Teacher 2's dismal performance on dimension 2 (attention to student needs) of the TIAI.

Despite some challenges, the four teachers in this study practiced, rehearsed, observed others teaching, and collaborated and received constructive feedback from peers and mentor teachers. These approaches emphasized the active participation of teachers in the process, built links between e-learning resources integration, content knowledge, and classroom practices, and encouraged collective participation in developing expertise (Huang et al., 2022). In a study carried out in a similar context to the current, Nkundabakura et al. (2024) found considerable improvement in the teaching skills of the CPD ITMS beneficiaries. Such CPD programmes provided a structured environment for teachers to observe and learn from their colleagues, facilitating reflection on their practices, benefitting from constructive feedback from colleagues on strengths and areas for improvement, and fostering a collaborative culture where teachers can share strategies and best practices, ultimately leading to enhanced teaching quality across the team.

## 5. CONCLUSION AND RECOMMENDATIONS

This study explores how beneficiaries of a Continuous Professional Development Certificate in Innovative Teaching Mathematics and Science (CPD ITMS) apply acquired skills to integrating e-learning resources in the teaching rehearsals of STEM subjects. The study's findings reveal the varied capabilities of STEM teachers in integrating e-learning resources into their scripted lessons. Professional development efforts have enhanced teachers' familiarity with e-learning tools and their application in educational settings. While some teachers, like Teacher 4, effectively incorporated technology to meet diverse student needs, most technology use remained teacher-centered, limiting student engagement. The integration of technology frequently did not align with the Technological Pedagogical Knowledge (TPK) and Pedagogical Content Knowledge (PCK) components of the TPACK framework, leading to challenges in effective use.

The need for further STEM-focused professional development is evident, particularly training that embeds technology in a student-centered manner. Shifting from teacher-centered to student-centered technology integration is crucial for meeting diverse student needs and enhancing engagement. Additionally, linking lesson concepts to real-life situations can make learning more relevant and meaningful. The findings also highlight the importance of adequate time allocation during lesson preparation. Avoidable errors, such as issuing incorrect Plickers cards and some students not receiving cards, underscore the need for proper time management in lesson planning.

Future studies should gather evidence from a larger sample size for more comprehensive analysis and generalization. An enhanced professional development program focusing on the TPACK framework is recommended to help teachers effectively blend content, pedagogy, and technology. Ensuring teachers have access to a variety of technological resources and the necessary support is essential for successful implementation. Such a programme can utilize sandwiched scripting that alternates with non-scripted, individually designed lessons to wean STEM teachers into sustainable capacity development. By addressing these areas, educators can better leverage technology to enhance teaching and learning, taking particular care about its ultimate focus. This study argued for the Type II focus, where applications of the technology are more learner-centered and hold the potential to alter the effectiveness of teaching and ultimately the success of learning.

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# APPENDIX 1 Feedback form of the scripted lesson and e-resources/ICT

SN	Aspects to be observed	Observer's comments	General feedback/ comments (Provide both positive and areas of improvement with concrete examples)			
1		n that embeds e-learning resources, ICT tools, models,				
	animations, simulations					
	Selection of a lesson/scripted					
	<b>lesson</b> complying with the e-					
	learning resources, ICT tools,					
	models, animations, simulations					
2		Use of e-learning resou	rces, ICT tools, models, animations,			
	simulations					
	Use of ICT tools/equipment					
	Microteaching/try out using e-					
	learning resources					
	Lesson introduction with e-					
	learning resources.					
	-Arousing interest/engaging					
	learners					
	-Learners asking questions					
	Exploration of e-learning					
	resources to answer the learners'					
	questions or curiosity					
	<b>Explanation</b> of concepts by					
	learners using e-resources					

Other observations that ar	e specific to the use of	f the e-learning resource	s and ITC tools
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APPENDIX 2

Technology Integration Assessment Instrument (Source: Britten & Cassady, 2012)

	Technology	Non-essential	Supportive	Essential technology	
Dimension	not present	technology component	technology component	component	
Planning (materials, equipment, etc.)	No mention of technology.	Uses technology in lesson not related to the addressed standards.	Uses computer to plan for lesson. Makes mention of necessary equipment and technologies for replication purposes.	Computer is essential to the planning of lesson (e.g., Web Quest). Equipment and technologies are built into lesson design and objectives and are discussed within the context of the lesson and not as an external component.	
Standards (content standards per grade level and content area)	No mention of technology. OR No mention of content standards.	Uses computer to plan for lesson.	Uses technology supports or promotes the acquisition of standards in the lesson, but is not directly tied to the standard itself.	The technology used in the lesson is directly linked to one or more standards, making the acquisition of that standard possible.	
Educational Technology Standards (ETS) (as provided in CPD ITMS script)	No mention of technology. OR No mention of ETS.	ETS are present but not identified or embedded into lesson as a learning goal. ETS addressed are not up to the expected grade level.	ETS are present but not identified or embedded into lesson as a learning goal. ETS are grade- level appropriate.	ETS are present and integrated into grade-level appropriate learning goals.	
Attention to student needs	No mention of technology.	Technology is not used in an adaptable fashion. All students use the same technology tool or complete the same technology-based activity.	Technology can be modified by the teacher or student to meet the needs of students from diverse backgrounds.	Technology is the only means by which this lesson can be adapted to meet the needs of students from diverse backgrounds; that is, the technology tool or activity is designed to be adaptive.	
Implementation (use of technology in learning)	No mention of technology.	Technology is not expected to impact learning directly.	Learning is impacted in time, quality, or wealth of resources by the use of technology.	Technology impacts learning by presentation, product, or process.	
Implementation (use of technology in teaching)	No mention of technology.	Lesson uses technology but does not impact implementation (product-oriented technology).	Lesson is facilitated with technology, but learning goals could be achieved without technology in place (process-oriented and/or product-oriented technology).	Equipment and technologies are built into lesson design and objectives and are discussed within the context of the lesson and not as an external component.  Lesson requires the use of technology (process and product is dependent upon technology).	

Dimension	Technology not present	Non-essential technology component	Supportive technology component	Essential technology component
Assessment	No mention of assessment. OR No mention of technology.	Technology is not used in the assessment component (neither the use of technology nor a product of technology).	Technology-based product is assessed, or technology application is used to deliver and/or score the assessment instrument. However, similar assessment could be replicated without technology.	Technology products and/or processes are directly assessed, or assessment relies upon the use of technology for delivery or collection. Identified assessment could not be conducted without technology. ETS are identified as part of assessment.