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INVESTIGATING THE IMPACT OF GAMMA-TUTOR ON THE DEVELOPMENT OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE IN CHEMISTRY TEACHING FOR SCIENCE TEACHERS

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Abstract

Numerous studies have examined teachers' Pedagogical Content Knowledge (PCK) at a topic level in various subjects, particularly in mathematics and science, drawing on frameworks like Shulman's PCK and Mishra and Koehler's TPACK. However, limited research addresses the professional development needs of physical science teachers regarding TSPCK development for post-COVID-19 teaching. This study focuses on South African curriculum reforms, emphasizing the integration of technology in teaching. It investigates the impact of Gamma-Tutor, an educational tool, on TPACK development among chemistry teachers, employing a mixed-methods approach with 20 participants. Quantitative assessments track changes in TPACK, while qualitative data from observations enrich understanding. Quantitative measures involve pre- and post-Cluster-Based professional development designed to gauge the baseline TPACK of participating teachers and track changes over the intervention period. Statistical analyses, including paired samples t-tests, are applied to discern patterns and trends in TPACK development. Concurrently, qualitative data is collected through classroom observations providing a deeper understanding of teachers' experiences, challenges, and perceptions related to Gamma-Tutor integration. Thematic analysis is utilized to extract key themes from the qualitative data, enriching the narrative. Results indicate improved pedagogical strategies and student engagement with Gamma-Tutor integration, suggesting its potential to enhance teaching practices and student achievement. This study underscores the importance of effective technology integration in enhancing pedagogical content knowledge, particularly in stoichiometry teaching, offering insights for educators and policymakers.

Keywords: *Gamma-tutor, technological pedagogical content knowledge, stoichiometry teaching, science teachers, cluster-based professional development.*

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1. Introduction

In contemporary society, the utilization of science and technology is pivotal for the advancement of both industrialized nations and developing countries (UNESCO, 2010). Technology, as an integral part of modern life, plays a crucial role in shaping societal norms and transforming educational practices, including science teaching and learning (Campbell et al., 2015). The incorporation of technology in education has garnered increasing attention due to its potential to revolutionize traditional teaching methods and enhance student engagement and learning outcomes. However, despite the widespread adoption of technology in educational settings, there remains a gap in understanding its impact on teaching practices. This is problematic because it is impossible to employ explicit teaching strategies without their competency of the various aspects of teaching with technology (Hilton et al., 2016).

Moreover, the pedagogical knowledge possessed by experienced science teachers is instrumental in effectively delivering complex scientific concepts such as stoichiometry. Pedagogical Content Knowledge (PCK), as conceptualized by Shulman (1987), emphasizes the integration of subject matter expertise with pedagogical approaches tailored to specific topics. In the context of stoichiometry teaching, this specialized knowledge, termed Topic-Specific Pedagogical Content Knowledge (TSPCK), encompasses various components crucial for effective instruction.

The emergence of the Technological Pedagogical and Content Knowledge (TPACK) framework by (Mishra and Koehler, 2006) underscores the importance of integrating technology into teaching practices. TPACK highlights the synergy between content knowledge, pedagogy, and technology,

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emphasizing the need for teachers to adeptly navigate these domains. However, research examining teachers' TPACK in stoichiometry teaching, particularly concerning Gamma-Tutor integration, remains limited. This paper investigates the impact of Gamma-Tutor, an innovative technological tool, on the development of TPACK in stoichiometry teaching for science teachers.

2. Research question

The research questions guiding this study is: “To what extent does the integration of Gamma-Tutor contribute to the development of in-service physical sciences teachers' TPACK for effective stoichiometry teaching?”

3. Research objectives

This paper aims to explore the impact of Gamma-Tutor on the development of Technological Pedagogical Content Knowledge in stoichiometry teaching.

4. Literature review

The importance of stoichiometry education has been recognized on a global scale, highlighting the necessity for effective instructional strategies to improve students' grasp of quantitative chemical concepts (Taber, 2017). Incorporating models and representations into stoichiometry instruction, spanning macroscopic, sub-microscopic, and symbolic levels, has been identified as a key facilitator of meaningful learning engagement and conceptual understanding (Tang & Abraham, 2016). However, learners often struggle with connecting visual and conceptual representations, leading to misconceptions and learning obstacles (Al-Balushi & Al-Hajri, 2014).

In the realm of education, there has been ongoing debate regarding the integration of technological tools into daily teaching practices (Boateng et al., 2022). Abboud and Rogalski (2017) argue that technological tools can significantly influence learners' attention, motivation, autonomy, and academic achievement. Tools like Gamma-Tutor hold promise in supporting teachers' adoption of reformed-based science instructional practices (Yurtseven Avci, O'Dwyer & Lawson, 2020). Suh and Park (2017) further contend that teachers are at the forefront of bringing about change and innovation in education. To integrate technology into teaching, teachers need not only to acquire computer literacy, but they need TPACK and skills to be able to navigate through the Gamma-Tutor tool to make chemistry concepts accessible and understandable to learners. Bell et al., (2013) concludes the debate by stating that despite challenges such as teacher confidence with technology and inadequate professional development support, integrating technology into teaching shows potential for enhancing student outcomes.

By focusing on teachers' development of Technological Pedagogical Content Knowledge (TPACK) for specific topics, researchers can gain valuable insights into effective methods of integrating technology into teaching practices and enhancing Pedagogical Content Knowledge (PCK). TPACK recognizes the dynamic nature of teaching and underscores the importance of ongoing professional development. Therefore, examining TPACK development for specific topics can help identify effective professional development strategies to assist teachers in integrating technology into their teaching practices, particularly in the context of the fourth industrial revolution.

5. Theoretical framework

Shulman's (1986) concept of Pedagogical Content Knowledge (PCK) underscores the importance of teachers' specialized knowledge in teaching specific content areas. In the terms of Carlson et al., (2019), the first realm refers to PCK acquired in a formal course where public and published knowledge about PCK is discussed, referred to as collective PCK. The PCK at a personal level, demonstrated through planning to teach as PCK in planning (plPCK), and in classroom teaching as the enacted PCK (ePCK). This study has a special focus on the topic-specific grain of PCK acquired through collective PCK. We track how the demonstrated plPCK is translated to the ePCK dimension. As mentioned earlier, the key competence in demonstrating acquired TSPCK lies in the manifestation of the reasoned ‘knowing what to do’ through planning for teaching, and ‘doing what you know’ in classroom enactment, drawing on the different content-specific components of the construct in an interactive manner. Thus, evidence for TSPCK components interaction is key in this study. It is the succinct feature consistently targeted in tracking the journey of in-service teachers’ TSPCK across the planning–enactment settings.

The Technological Pedagogical and Content Knowledge (TPACK) model, developed by Mishra and Koehler (2006), an extension of Shulman's framework, emphasizes the integration of technology into teaching practices. Consistently, Santos and Castro (2021) state that TPACK recognizes the integral role of technology in effective teaching and proposes that teachers need a combination of content, pedagogical, and technological knowledge.

6. Research methodology

This study adopted a congruent mixed-methods (CMM) approach, incorporating quantitative and qualitative data collection and analysis techniques. As Boateng et al. (2022) asserts, understanding in-service physical science teachers' professional knowledge bases require multiple sources of knowledge, including experiential, epistemological, and ontological views. The CMM approach appeals to those at the forefront of new research procedures, as it offers a sophisticated and complex approach. Moreover, it can be useful in situations where a small group's thinking differs significantly from that of the majority, as CMM design provides a better understanding of the research problem than either approach alone (Poth, 2018). Data collection methods included Class Observation Checklist and teacher responses. In addition, participants' biographies were also of interest in this study as these had been identified in other researchers as factors contributing to TPACK development among in-service teachers and their eagerness to participate in professional development that involves technology in rural contexts. Since we were interested in comparing observations before and after the professional development intervention, we used inferential statistics. In this case the statistical test deemed appropriate for paired observations (i.e., each teacher observed before and after the intervention), was a paired samples t-test. Furthermore, themes were developed for qualitative data analysis.

The population involved all in-service physical sciences teachers participating in the Cluster-Based professional development (CBPD) program in the OR Tambo Inland district, Eastern Cape Province, South Africa. The participants were selected using purposive sampling. This technique involves deliberately choosing participants based on their qualities being relevant to the study (Etikan et al., 2016). This sampling technique was suitable for this study because it helped decide what needed to be known and to identify information-rich cases (Etikan et al., 2016). A total of twenty participants who participated in the CBPD program were visited several times to collect the necessary data through Class observations, of which data from these educators are presented in this study. Due to their exposure and experiential knowledge, participants could "communicate experiences and opinions in an articulate, expressive, and reflective manner" (Etikan et al., 2016, p. 2).

A Classroom Observation tool was adapted from Center for Community College Student Engagement (CCCSE). Triangulation, the process of comparing data from multiple sources or methods, enhances the validity and reliability of research findings. By employing the Concurrent Triangulation design, researchers can triangulate qualitative and quantitative data, ensuring convergence and corroborating the results. The use of multiple data sources provides a more comprehensive understanding of the research topic, while also mitigating potential biases and limitations associated with individual methods.

Quantitative data were analysed through a statistical paired samples t-test. The statistical measures employed, including mean differences, standard deviations, t-values, degrees of freedom, and p-values, offer insights into the nature and significance of these differences. The qualitative data collected from teachers' comments were transcribed and responses from the participants were coded and developed into potential themes. The findings highlight the themes that emerged from the data, which helped answer the objective of this study. In our presentation of findings, we emphasize the relevance of the model (Mokhele, 2013) to the key findings as a justification for the educators' perceptions of the teacher-led cluster programs within the South African setting.

With regards to ethical considerations, Lichtman (2023) asserts that permission should be sought from all relevant participants and informed consent forms signed to validate the participants' willingness to participate in the study. After the findings were finalized, they were sent back to the participants to check for authenticity. Participants were consulted before any document for publication was submitted. Silverman (2011) emphasized the need for anonymity requirement even when not dealing with matters that seem to be particularly delicate or intimate. The study used pseudonyms as adherence to anonymity and in line with ethical standards for reporting empirical findings.

7. Results and discussions

7.1. Quantitative results

These results indicate significant differences between the observed teacher behaviours during Pre and Post CBPD classroom visits in all four paired categories, as evidenced by the very low p-values (< 0.05). The negative mean differences in Pairs 1, 2, and 3 suggest that post-CBPD tends to be lower than pre-CBPD, while the positive mean difference in Pair 4 suggests that post-CBPD tends to be higher than pre-CBPD. In summary, the results of the paired samples t-tests indicate that there are systematic and statistically significant differences between Pre-CBPD and Post-CBPD across all four pairs. The direction of these differences (negative or positive mean differences) provides insights into the nature of the changes observed between the samples.

Findings from the study highlight the impact of Gamma-Tutor on teachers' TPACK development and its influence on classroom practices. Themes emerging from the data underscore the significance of ongoing professional development and technology integration in stoichiometry teaching.

Table 1. Inferential Statistical Analysis of the quantitative results.

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	CompletelyT1 - CompletelyT2	-15,381	2,578	,563	-16,555	-14,207	-27,338	20	<,001	<,001
Pair 2	AdequatelyT1 - AdequatelyT2	-1,190	,981	,214	-1,637	-,744	-5,562	20	<,001	<,001
Pair 3	MinimallyT1 - MinimallyT2	,857	1,108	,242	,353	1,362	3,544	20	,001	,002
Pair 4	NotatallT1 - NotatallT2	15,571	2,461	,537	14,451	16,692	28,994	20	<,001	<,001

7.2. Qualitative results

Table 2. Categories and themes developed from the in-service teachers' responses.

Category	Themes
1. Classroom Learning Organization and Management	Active learning
2. Topic-Specific Pedagogical Content Knowledge of Stoichiometry	Lesson planning and presentation
3. Integration of Educational Technologies and Teaching Style	Teaching resources

Participants were requested to write some comments under each of the categories in Table 2. Emerging from the participants' responses, themes were drawn as in Table 2.

Active Learning: Most teachers' comments pointed out that before the CBPD intervention, learners were more passive during the lessons, and they performed very low in the science's paper two assessments as stoichiometric concepts appeared in most questions. For example, Teacher 14 stated, "*I have been a Physical Sciences teacher since Outcomes Based Education was introduced in the South African Curriculum and a learners' participation has always been a challenge, especially in stoichiometric calculations*." On lesson planning and presentation, Teacher 7 stated, "*I have always found it very difficult to plan and present stoichiometric related concepts but after the professional development, I can plan and present the stoichiometric concepts more confidently*." On teaching resources, Teacher 18 stated, "*Teaching chemistry through Gamma-Tutor has provided my learners with all more science resources including videos, tests, worksheets and a lot more.*"

8. Summary

This paper provides insights into the role of Gamma-Tutor in enhancing TPACK development in stoichiometry teaching. It underscores the importance of integrating technology into teaching practices to improve student learning outcomes.

9. Conclusions

In conclusion, this research contributes to the understanding of how Gamma-Tutor influences TPACK development in stoichiometry teaching. It highlights the need for continued research and professional development initiatives aimed at enhancing teachers' technological pedagogical content knowledge for effective science instruction.

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