The Impact of Cl4STEM Online Community of Practice on Science and Mathematics Teachers' Knowledge and Professional Development in Nigeria

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ABSTRACT

Connected Learning for STEM (CL4STEM) is an innovative teacher capacity-building project piloted in Nigeria. It aimed at science, technology, engineering, and mathematics teachers' capacity building to foster higher-order thinking with inclusion and equity (HOTIE) in their classroom practices. It adopted a model of mobile-based communities of practice (CoP) as one of the strategies for CL4STEM teacher professional development. Hence, this study investigated the impact of the CL4STEM project online CoP on science and mathematics teachers' subject matter knowledge, pedagogical content knowledge, and professional practice for achieving HOTIE in their classrooms. The study adopted a survey research design involving documentary content analysis and a one-group pre-test-posttest design to collect qualitative and quantitative data to achieve the objectives of the research. The population of the study was all science; biology, chemistry, and physics teachers in senior secondary schools in selected states in Northern Nigeria. Purposive sampling was used to select one newly qualified biology, chemistry, physics, and mathematics teacher per subject area from twenty sample schools in the population, thus a target sample size of 80 science and mathematics teachers, 20 each per subject. Content analysis of the module reports and evaluation of lesson plans were used to obtain qualitative data on the science and mathematics teachers' CoP practices and professional learning. The Pre-test and post-test on the teachers' subject matter knowledge and pedagogical content knowledge were the instruments for quantitative data collection. The instruments were validated by the project consultant and science and mathematics education experts. Four research objectives and four corresponding research questions guided the study. Descriptive statistics, descriptive content analysis, and descriptive narrative were used to analyze the data. The study revealed that online CoP has remarkably impacted teachers' subject matter and pedagogical content knowledge and professional development.

Keywords: CL4STEM, online Community of practice, subject matter knowledge, pedagogical content knowledge, pedagogical content knowledge.

INTRODUCTION

In Nigeria, the teaching of STEM in all the nation's schools has been described as generally ineffective and

the student's achievement in terms of knowledge and skills is yet to meet the expectation (Adedokun, 2018; Ayeni, 2021). Several literatures have implicated the teacher, and how science is taught as part of the problems (Olawuwo, 2015; Ayeni, 2021). It is reported that many science and mathematics teachers are not familiar with effective teaching strategies that could promote critical thinking and problem-solving skills in implementing the Nigeria STEM curriculum (Mustapha, 2013;). Also, a good number of teachers in the school system are far from being computer literate and are incapable of applying technology in teaching science (FMOE, 2013; Shittu, et al, 2019). Weak subject content and pedagogical knowledge, and low quality of pre-and in-service teacher training are central concerns in teacher development, particularly in many countries in the global south, especially in science and mathematics subjects (KIX, 2023). In Nigeria, it was also reported that most teacher education courses at the pre-service level do not provide meaningful contexts for applying ICT to enhance teaching and learning and that even though ICT is included in teacher education programme, teachers are not sufficiently trained to use ICT in instructional setting (Tayo, 2015). From this standpoint, it is obvious that newly qualified teachers (NQTs), and generally STEM teachers in Nigeria need to be provided with professional development to acquire new pedagogical knowledge, skills, and practices and, in the method of integrating ICT in teaching and learning. The connected learning for STEM (CL4STEM), offers the opportunity to meet the strong needs for science and mathematics teachers' capacity in pedagogical knowledge, skills, and practice.

The Connected Learning for STEM (CL4STEM) project is an offshoot of the connected learning initiative CLIx developed by TISS, India to strengthen secondary STEM learning, pedagogic content knowledge of science teachers and their practice at scale in four states in India with proven effectiveness. CLIx project was the award-winning project of the UNESCO-King Hamad Prize for the use of ICTs in Education in 2018 and the OER award for Excellence in Collaboration-2019 (https://clix.tiss.edu,). The CLIx project was scaled through a process of knowledge diffusion and adaptation as CL4STEM to a new country context that is based on a South-South collaboration among higher education institutions involving Ibrahim Badamasi Babangida University, Lapai, Nigeria, Samtse College of Education, Bhutan, and Open University Tanzania.

In Nigeria, the CL4STEM project was piloted at scale in selected Nigeria secondary schools involving newly qualified teachers (NQTs) who had been given orientation training to pilot the OER modules and to develop new pedagogical practices. The ultimate goal of CL4STEM is to bring change in secondary school science and mathematics teachers' knowledge, practice, and attitudes to enhance higher-order thinking with inclusion and equity (HOTIE) in their classrooms. Online CoP is one of the component features of the CL4STEM project designed to introduce the teachers to the CL4STEM project initiatives. It harnesses ICT and online CoP to give academic support to teachers to pilot the project's teaching innovations. In the context of the CL4STEM project CoP, the expert teacher educators provide academic and technical support for NQTs to take active pedagogy and universal design learning (UDL) principles into science and mathematics classrooms in piloting the subject modules. This is expected to impact the teachers' subject content, pedagogical content knowledge, and teaching. Hence, this study explores how the CL4STEM project online CoP engagement by science and mathematics teachers has impacted the teachers' knowledge and practice in the Nigerian context.

Engaging the NQT teachers in the online CoP is to offer the teachers the opportunity to network, and have access to more expert peers, to share knowledge and experiences with colleagues, and to innovate their daily practice in the implementation of the subject modules while also receiving professional guidance from expert teacher educators. The CL4STEM project adoption of online CoP is to allow teachers a safe space to seek support, interact and share knowledge and experiences, discuss their experiences and challenges, and discuss solutions that could lead to more effective ways to pilot and implement the innovative subject-based OERs modules. The interaction is believed would enhance the teachers' content knowledge, and apply inclusive pedagogical principles in their classroom practice.

CoP has since been recognized as a useful and powerful model for teacher professional development

(Khalid et.al, 2013). It provides opportunities for professional learning among colleagues and provides a more sustainable professional development strategy (Baraba & Duffly, 2000).

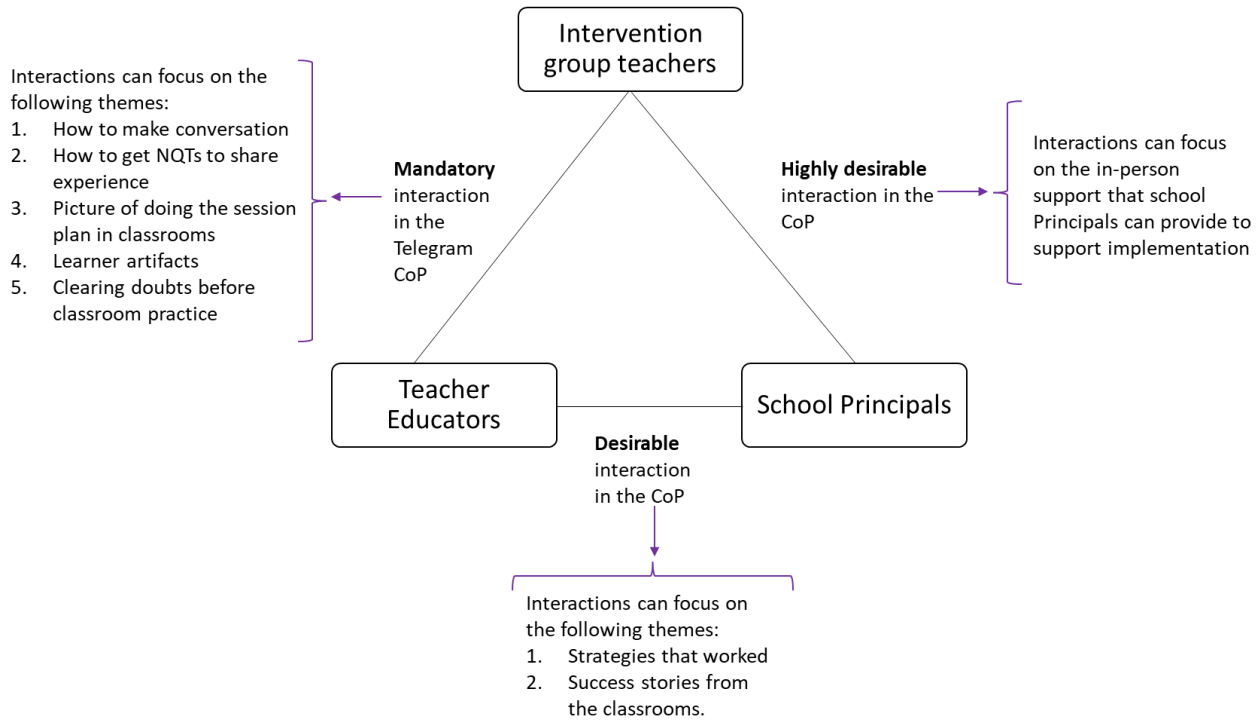The CL4STEM online CoP model is represented as follows;

Fig. 1: CL4STEM mobile CoP structure

This study focused only on the participation of NQTs and Teacher educators as the principal actors in the CL4STEM CoP. The NQTs are to actively participate in the Telegram CoP to share their practices and teaching/learning activities, seek support in the implementation of CL4STEM pedagogy in their classrooms and post and share their innovative practices and completed module activities/assignment and their session (lesson) plans. The teacher educators are expected to provide professional, administrative and possible technical support to the NQTs and to prepare a module level impact report. Therefore, the objectives of CL4STEM online CoP are to;

1. offer the NQTs the opportunity for professional development, to enhance and improve their content knowledge and pedagogical skills and practice,
2. empower the NQTs to using ICT (telegram/mobile technology) to link with each other and with expert teacher educators for collaborative learning activities, experience and knowledge sharing, clearing doubts and gaining understanding of different pedagogies, subject matter content of the modules.

Purpose and Objectives of the study

This study is aimed at finding out how participation in CL4STEM online CoP has enhance the newly qualified teachers' subject matter and pedagogical content knowledge, and classroom practice for higher order thinking with inclusion, and equity (HOTIE). The specific objectives of this study are;

- Examine professional and academic activities/practices by newly qualified teachers from participation in CL4STEM online community of practice
- Explore how the participation of newly qualified teachers in CL4STEM online community of practice

has impacted on their professional development.

- Determine the impact of CL4STEM online community of practice on newly qualified teachers' subject matter and Pedagogical content knowledge and practice.
- Find out if the CL4STEM CoP impact differently on newly qualified biology, chemistry and mathematics teachers.

Research Questions

To achieve the objectives of the study, the following research questions were stated to guide the study:

1. What professional and academic activities/practices are carried out by the newly qualified biology, chemistry and mathematics teachers participating in CL4STEM online CoP?
2. Does participation in CL4STEM online CoP enhance science and mathematics teachers' professional growth to promote HOTIE?
3. What is the impact of CL4STEM online CoP on the NQTs specific subject matter knowledge, pedagogical content knowledge and pedagogical knowledge, and practice?
4. Is there any perceived difference of the impact of online CoP on newly qualified biology, chemistry and mathematics teachers?

LITERATURE REVIEW

Many research studies have established that CoP is useful for teacher professional development (Qi and Wang, 2018; Unwin, 2017; Wesley, 2013), and it is believed that online learning communities can improve instructors' professional development, especially with the growth and accessibility of the internet, thus, erasing time constraints and distance (Rosell-Aguilar, 2018). Qi and Wang (2018) reported that WeChat was effective in enhancing teachers' interaction with one another in both synchronous and asynchronous ways to work and reflect together and share experiences and ideas. COP inspires teacher inquiry and encourages teachers to develop their existing use of the innovation further, and work together and develop shared practices (Goodyear et al. 2014). Similarly, Wesely (2013) identified that CoP built on Twitter promoted activities for members to share ideas and practices. A COP has the capacity to make certain tasks, activities, or a series of events easier (Hoadley 2012) and makes professional development to be more practical, adaptable, and capable of providing just-in-time support for participating teachers (Wang and Lu 2012).

Sijia, *et al* (2019) investigated teachers' perception of an online community of practice through WeChat for teacher professional learning. The finding shows positive perceptions about COP using WeChat were identified among participants on joining the teacher group, and revealed that their teaching practices were positively transformed. It also reported in the literature that Online CoPs allow greater flexibility than traditional, face-to-face mentoring, it also enhances members' professional growth through interactions with professional colleagues (Khalid, *et al.*, 2013, 2024)

Khalid, *et al*, (2014) investigated the factors influencing teachers' level of participation in online communities. The finding shows that the participating teachers view CoP participation as useful for getting new ideas and enhancing their pedagogical skills. Similarly, Juandi, and Jupri, (2013) reported that CoP provides the opportunity for group members to share ideas and experiences, and assist each other in adopting innovative strategies and approaches that is more professional. The Cop also enhance the teachers' teaching competence and improve the students' learning outcome and the quality of education (Juandi, & Jupri, 2013)

Theoretical Framework

This study is predicated on the Wenger (2000) concept of social learning, and the theory of change.

Community of practice evolved from the theories based on the idea of situated learning (Lave and Wenger, 1991) and social learning. Thus, CoP provides the idea of social learning that occurs when people who have common interests collaborate over an extended period to share ideas, values, beliefs, language, and ways of doing things (Wenger, 1998). CoP plays an integral role in teacher professional development (Schlager & Fusco, 2004; Qi and Wang, 2018) through a social learning process that enables collaboration and opportunities for teachers to gain access to new knowledge and practice. This study is predicated on the Wenger (2000) concept of social learning, and the theory of change. The theory of change on which the CL4STEM project is grounded predicates that;

1. Teacher educators' knowledge, attitudes, and practices about higher order teaching with equity and inclusion will improve when they meaningfully engage with the online practice-based reflective professional development through knowledge transfer and online communities of practices and engage in the designing, implementation, and monitoring of the online teacher professional development modules.
2. Teachers' knowledge, attitudes, and practices about higher-order teaching with equity and inclusion will improve when they meaningfully engage with the online professional development modules and participate in online communities of practice to support their professional development.

To support this theory of change and to explicitly assess teachers' knowledge, attitudes, and practices towards pedagogical content knowledge and equity and inclusion, a conceptual framework was developed. The conceptual framework is aimed toward science and mathematics teacher knowledge for promoting higher-order thinking among learners with inclusion and equity (HOTIE). The conceptual framework consists of subject matter knowledge, pedagogical content knowledge, and general pedagogical aspects Shulman (1986), Kind (2009), Ramchand (2022) and CAST (2018). This framework guided all analyses concerning the impact of CL4STEM on teachers.

Based on the postulation that technology supports collaborative learning and on the notion that network technologies erase time constraints and distance, enhance knowledge construction, and provide professional learning experiences, the CL4STEM project innovation draws from the use of technology as a powerful and useful tool for teacher professional development and adopted online CoP as a means of interaction between the teachers and between the teachers and expert teacher educators. The pedagogical framework incorporates the universal design learning principles (UDL) and pedagogical content knowledge through the teachers' engagement with OER subject modules as the basis for designing a learning environment that could lead to a change in the teachers' knowledge and professional practice to enhance teachers' capacity to foster high order teaching with inclusion and equity classroom practices. The possible impact of the deployment of online CoP is to bring about change in teachers' knowledge and practice is the concern of this study. The impact of mobile-based CoP is explained based on the theory of change.

METHODOLOGY

The study adopted a survey research design involving documentary content analysis and a one-group pre-test-posttest design to collect data to achieve the objectives of the research. The population of the study was all science; biology, chemistry, and physics teachers in senior secondary schools in 3 selected states in Northern Nigeria; Niger, Kaduna, and Kano states. Purposive sampling was used to select one newly qualified biology, chemistry, physics, and mathematics teacher per subject area from twenty sample schools in the population, thus a sample size of 80 science and mathematics teachers. However, only 60 teachers comprising 20 each per subject; biology, chemistry and mathematics teahers were used, based on available data for this study. Thus the physics cohort group whose data were not readily available are excluded in this study.

DATA COLLECTION

The pre and post-test instruments were designed based on the constructs of subject matter and pedagogical content knowledge contents of the curated OER subject modules; biology, chemistry, physics, and mathematics, and teacher educators' module reports were used as sources of data for this study. Each of the specific subject test instruments contains a specific number of objective test items on the subject matter, pedagogical content, and general pedagogical knowledge constructs. The test instruments were face-validated by the CL4STEM project Technical Consultant from TISS, India. The pre-test was administered to collect the baseline data at the commencement of the piloting of the subject modules. The post-test was administered at the end of the 6 weeks of the first and second phases of the module piloting and teachers' participation in the CoP.

The data for this study were obtained from the Moodle platform which hosts; teacher educators' module impact reports on teaching activities, module assignments, session (lesson) plans, and lesson reflection assessment grades based on higher-order thinking with inclusion and equity evaluation rubrics and the subject-specific pre-test and post-test data of the participating teachers.

DATA ANALYSIS AND FINDINGS

The data were analyzed using; descriptive statistics based on the research questions as presented in the tables;

Research Question 1: What professional and academic activities/practices are shared by the newly qualified biology, chemistry and mathematics teachers participating in CL4STEM online CoP?

Table 1. Analysis of frequency of professional and academic posts and modes

S/No,	Type of Post	Frequency	Percentage
1.	Pedagogical Content Knowledge	250	52.6
2.	Universal Design Learning	130	27.4
3.	Technical difficulties/challenges	37	7.8
4.	Communication/administration issues	58	12.2
	Total posts	**475**	
	Mode of post		
1.	Text only	246	53.9
2.	Images	190	41.6
3.	External links	20	4.4
	Total	456	

Table 1 revealed the professional and academic posts of the teachers on the CoP platform using ICT (telegram/mobile technology). Teachers' posts on PCK (52.6%) UDL (27.3%), Posts related to technical challenges in accessing the OER modules online/network/internet connectivity (7.8%), and administrative issues were related to school logistics, time management, lesson time table, and work schedules (12.2%) The greater number of posts, PCK, and GPK constituted 80% of the posts which are in the context of the CL4STEM innovation (HOTIE). This informed the teachers. perception of the area requiring their deeper understanding and experience sharing on the CoP platform. Although technical posts were less frequent (7.8%), the technical challenges faced by NQTs were due to unstable internet connectivity, module access,

lack of skill in the use of telegram, etc affected the efficiency of the CoP. Similarly, the administrative challenges also affected the ease and timeliness of piloting the modules and completion of assignments.

The use of text (53.9%), and images (41.6%) were the most frequent modes of posts on matters of professional learning activities, experience and knowledge sharing, and in seeking a better understanding of different pedagogies and on subject matter content of the modules. Providing external/website links as a means to information/knowledge sharing on classroom practices was 4.4%. This could mean that the teachers rarely link relevant websites or are faced with challenges in their teaching while implementing the modules.

Research Question 2

Does participation in online CoP enhance science and mathematics teachers' professional growth to promote HOTIE?

The data analysis is based on task completion by the number of teachers in each subject group at the time of data collection. The analyses are shown in the tables 2-5

Table 2: CoP impact on mathematics NQTs professional development to promote HOTIE?

Criteria	Number of teachers				Total
	Novice	Emerging	Proficient	Accomplished	
A. Subject Matter Knowledge					
1. Knowledge of Subject Matter		2(18.18%)	6(54.55%)	3(27.27%)	11
2. Nature of Science/ Mathematics		1(9.09%)	6(54.55%)	4(36.36%)	11
B. Pedagogical Content Knowledge					
3. Instructional Strategies			5(45.45%)	6(54.55%)	11
4. Students' misconceptions & Learning Difficulties			4(36.36%)	7(63.64%)	11
5. Representation of the Content			3(27.27%)	8(72.73%)	11
6. Context for Learning			3(27.27%)	8(72.73%)	11
7. Curriculum knowledge			3(27.27%)	8(72.73%)	11
C. General Pedagogical Knowledge					
8. Equity and Inclusion			3(27.27%)	8(72.73%)	11
9. Classroom Management			2(18.18%)	9(81.82%)	11
10. Assessment			4(36.36%)	7(63.64%)	11
Mean Total	0	0,3	3.9	6.8	
Mean %	0	2.7%	35.50%	61.80%	

Table 3: CoP impact to chemistry teachers' professional development to promote HOTIE?

Criteria	Number of teachers				Total
	Novice	Emerging	Proficient	Accomplished	
A. Subject Matter Knowledge					
1. Knowledge of Subject Matter			**5(25%)**	7(35%)	12
2. Nature of Science/ Mathematics		1(5%)	5(25%)	6(30%)	12
B. Pedagogical Content Knowledge					

3. Instructional Strategies			6(30%)	6(30%)	12
4. Students' misconceptions & Learning Difficulties		6 (30%)		6(30%)	12
5. Representation of the Content		6(30%)		6(30%)	12
6. Context for Learning		5(25%)	1(5%)	6(30%)	12
7. Curriculum knowledge		1(5%)	5(25%)	6(30%)	12
C. General Pedagogical Knowledge					
8. Equity and Inclusion	1 (5%)		5(25%)	6 (30%)	12
9. Classroom Management	1 (5%)		**5 (25%)**	6(30%)	12
10. Assessment		5 (25%)	1 (5%)	6(30%)	12
Mean Total	0.16(1.3%)	2.4(20%)	3.4(28.3%)	6.0(50%)	**12**

Table 4: CoP impact on biology teachers' professional development to promote HOTIE?

	Number of teachers				Total
Criteria	Novice	Emerging	Proficient	Accomplished	
A. Subject Matter Knowledge					
1. Knowledge of Subject Matter		2(10%)	**6(30%)**	5(25%)	13
2. Nature of Science/ Mathematics		1(5%)	6(30%)	6(30%)	13
B. Pedagogical Content Knowledge					
3. Instructional Strategies		2(10%)	5(25%)	6(30%)	13
4. Students' misconceptions & Learning Difficulties			5(25%)	8(40%)	13
5. Representation of the Content			6(30%)	7(35%)	13
6. Context for Learning		1(5%)	5(25%)	7(35%)	13
7. Curriculum knowledge		1(5%)	4(20%)	8(40%)	13
C. General Pedagogical Knowledge					
8. Equity and Inclusion		2(10%)	5(25%)	6(30%)	13
9. Classroom Management		2(10%)	4(20%)	**7(35%)**	13
10. Assessment			6(30%)	7(35%)	13
Mean Total/%		1.1(8.46%)	5.2 (40%)	6.7(51.5%)	**13**

Tables 2-4 are the analyses from the content of Teacher Educators module implementation reports relative to lesson plans, subject matter knowledge, pedagogical content knowledge, and general pedagogical knowledge of the NQTs. From the tables, the evidences on the teachers' professional development are revealed. The analyses are summarized for all the subject groups in table 5;

Table 5: CoP impact on the teaches' professional development to promote HOTIE? Combined subject groups: Mathematics, Chemistry and Biology teachers

		Number of teachers				Total
Subject Groups	N	Novice	Emerging	Proficient	Accomplished	
1. **Mathematics**	13		0	8.46%	40%	51.5%
2. **Chemistry**	12		1.3%	20%	28.3%	50.0%

3. Biology	11	0	2.7%	35.5%	61.8%
Mean %		**0.4%**	**10.5%**	**34.6%**	**54.3%**

The summary shows that the majority of the teachers have transformed from novice to proficient and accomplished higher level of professional development; 34.69% and 54.3% respectively and cumulatively, 89%. Thus, the participation of science and mathematics teachers in the CoP has greatly enhanced their professional development.

Research Question 3.

What is the impact of CL4STEM online CoP on the NQTs' specific subject matter knowledge, pedagogical content knowledge, and pedagogical knowledge and professional transformation?

Table 6: Analysis of CoP impact on mathematics NQTs' SMK, PCK, PK and professional transformation

Number of teachers		**Post Test** 10.25			
		Novice	Emerging	Proficient	Accomplished
Pre test 6.95	0-25% Novice	1 (5%)			
	26-50% Emerging		8(40%)		
	51-75% Proficient			7 (35%)	
	76-100% Accomplished				3 (15%)

For the mathematics group, the post score is greater than the pretest score with + 3.3 mean gain and the majority (75%) of the teachers transformed from novice to emerging (40%), and proficient (35%) professional levels respectively. 15% of the teachers have attained accomplished professional growth. 5% remain at the level of novice.

Table 7: Analysis of CoP impact on chemistry NQTs' SMK, PCK, PK and professional transformation

Number of teachers		**Post Test:** 12.61			
		Novice	Emerging	Proficient	Accomplished
Pre test 6.95	0-25% Novice	2(10.53%)			
	26-50% Emerging		8(42.1.%)		
	51-75% Proficient			8(42.1%)	
	76-100% Accomplished				1(5.26%)

For the chemistry group, the post score is greater than the pretest score with + 5,66 mean gain, 84,2% of the teachers transformed from novice to emerging (42.1%), and proficient (42.1%) professional level respectively, while only 5.26 %of the teachers have attained the accomplished professional growth. 10.53% of the teachers are still at the level of the novice.

Table 8: Analysis of CoP impact on biology NQTs' SMK, PCK, PK and professional transformation

Number of teachers		**Post Test:** 8.56			
		Novice	Emerging	Proficient	Accomplished
Pre test 7.58	0-25% Novice	1(5.26%)			
	26-50% Emerging		6(31.6%)		
	51-75% Proficient			10(52.6%)	
	76-100% Accomplished				2(10.52%)

For the biology group, the post score is greater than the pretest score with + 0.98 gain, 84,2%) of the teachers that have transformed from novice to emerging (31.6%), and proficient (52.6%) respectively. While only 10.52 %of the teachers have attained accomplished professional growth. 5.26% of the teachers are at the level of novice.

Table 9: Analysis of CoP impact on NQT SMK, PCK, PK, and professional development for all subject groups: Biology, Chemistry and Mathematics

Number of teachers		Post Test: 10. 47			
		Novice	Emerging	Proficient	Accomplished
Pre-test 7.16	0-25% Novice	1(6.6%			
	26-50% Emerging		6(37.6%)		
	51-75% Proficient			10(43,2%)	
	76-100% Accomplished				(10.26%)

Table 9, shows a cumulative increase in the science and mathematics teachers' SMK, PCK, and PK from an average of 7.16 at pre-test to 10.47 at the post-test This reveals a mean gain of + 3,31. Only 53..46% of the teachers have transformed from novice to proficient and accomplished, (43.2% and 10.26%) with higher professional levels of development Thus, the findings here show that the online CoP enhanced newly qualified biology, chemistry, and mathematics teachers SMK, PCK and PK resulting in the transformation of slightly over 50% from been novice to proficient and accomplished professional teachers.

 The findings from the above analysis revealed that teachers' participation in the CL4STEM online CoP has enhanced their subject content knowledge, pedagogical content, and pedagogical knowledge and has helped in their professional progression from novice and gradually to proficient and accomplished professional teachers. These findings are consistent with Qi and Wang (2018); and Rosell-Aguilar (2018) whose studies have established that CoP is a useful and powerful model for teacher professional development and that online learning communities can improve teachers' professional development. The finding also agrees with Sijia, Xiao, Xinli & Jiangzhi, (2019) that teachers were positively transformed in their teaching practices, and their pedagogical skills enhanced as a result of participation in a WeChat-based community of practice.

Research Question 4: Is there any perceived difference in the impact of online CoP among the NQT subject groups?

The perceived difference in the impact of online CoP among the NQTs subject groups can be deduced from the analyses in Tables 6-8. For each of the subject groups, the average post-test scores are higher than the pre-test scores with knowledge gain for mathematics +3.30, chemistry +5,66, and biology +1,0 respectively. These indicate teachers' knowledge gain in subject matter knowledge. Comparatively, the biology group had the least knowledge gain. However, based on their classroom practice to promote HOTIE, about 63% of the biology teachers have attained higher professional competence (proficient and accomplished) while in mathematics 50% and chemistry 47.3 of the teachers have transformed from being novices to a higher level of professional competence to promote HOTIE in their classroom practices.

Across the subject groups, there are 10.53 %, of chemistry, 5.26% % of biology, and 5% of mathematics teachers yet at the novice level of classroom practices to promote HOTIE. This finding revealed that the online CoP impacted differently on the NQTs based on subject groups. From the descriptive analysis of the teacher educators' module impact reports based on submitted lesson plans and reflection reports this study

revealed further evidence of the impact of the CoP on the teachers;

The lesson plans developed by the teachers are reported generally as activity and learner-centred, complemented with illustrations, and integrated with the use of technologies, adoption of UDL principles with students assigned to work in groups, promoting cooperative learning, adoption of different instructional strategies and use of a variety of assessment modes that could prompt critical thinking and promotion of inclusion, and equity in the classrooms.

Teacher educators' reflections on the subject matter knowledge of the teachers and from the graded lesson plans also indicated that the teachers understood the subject matter and were able to stimulate students' conceptual knowledge and address misconceptions.

The teacher-educator report also revealed that the lesson plan provides evidence of the ability of the teacher to use multiple means of engagement, representation, and expressions that provide learning experiences that meet the needs of diverse learners. The reports further indicated that the teachers were able to relate content to appropriate pedagogy and technology. Thus, videos, internet links and pictures, and online diagrams were evident in the instructional strategies employed by the teacher and as reflected in the structure of their lesson plans.

The following were also deduced from the module report; the teachers acquired improved technical knowledge and skills in use of telegram and the use of videos, pictures, illustration technology-mediated activities, using cultural context and local language to clarify difficult concepts and misconceptions.

All these provided the evidence that CL4STEM online COP engagement impacted on the NQTs professional development and have enhanced their professional progressions. These teacher educator's reports support the quantitative finding of the impact of the CoP on the teachers' professional development at promoting HOTIE in their classroom practices.

CONCLUSION

This study provided evidence that CL4STEM online COP has a remarkable impact on the newly qualified biology, chemistry, and mathematics teachers' knowledge and professional development to promote higher-order thinking with inclusion and equity in their classroom practices. This finding supports previous studies that identified CoP as a powerful tool and therefore, CL4STEM online CoP is found to be an effective model for teacher professional development.

Based on the outcomes of this study, it recommended that;

1. CL4STEM online CoP be adopted as a model for a sustainable and effective strategy for in-service training of science and mathematics teachers and continuous teacher professional development,
2. CL4STEM online CoP be used as an orientation framework and support structure for newly employed qualified science and mathematics teachers, and also as an approach to introducing teachers to new educational reforms and teaching innovations.
3. It is also recommended based on the outcome of this study that mobile CoP and CoP practices should be adopted as school-based professional development and mentoring strategies in the Nigerian school system as it could enhance teachers' capacity in their daily classroom practices.
4. The finding also strongly suggests teacher training institutions to adopt or adapt the online CoP into their pre-service teacher education teaching practice/microteaching practicum. The online CoP approach if adopted could be more beneficial in providing field support to pre-service teacher professional development (TPD) than the traditional training model of school visits teaching practice supervision model. The online Cop would help promote greater links and interactions between the

teacher educator/supervisors and the teaching practice students, ensuring prompt guidance and solution to any teaching problems being faced by students, erasing constraints of time and distance between supervisors and the students in the field.

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