International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

https://gssrr.org/index.php/JournalOfBasicAndApplied/index

Connected Learning Initiative: A Novel Tool for Teacher Capacity Development in Nigeria

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Abstract

All three tiers of education in Nigeria (primary, secondary, tertiary) lay emphasis on STEM subjects. The methods and strategies employed by STEM teachers in most Nigerian schools have remained teacher-centred and textbook-oriented. This paper has brought together some elements of the innovation achieved in the Connected Learning Initiative (CLIx) to address the identified challenges in STEM education in Nigerian junior secondary schools through the CL4STEM project to build processes for long-term systemic dialogues and networking. CLIx was seeded by the Tata Trusts and led by TISS and MIT, USA, to strengthen secondary STEM learning, pedagogic content knowledge of teachers and their practice at scale in four states in India. The programme's interactive STEM OERs, subject teacher CoPs on mobile devices, tech design for under-resourced context, participatory and localised ecosystem approach to adoption and scaling, are identified as innovative and scalable models. Data were collected in three phases, baseline, midline, and endline. The findings from interviews indicate that teachers' understanding of CL4STEM innovation seem to improve from baseline to endline.

Received: 10/5/2023
Accepted: 11/16/2023
Published: 11/26/2023

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At the baseline 2 teachers were still learning how to effectively navigate CL4STEM modules and Telegram group (CoPs) while none was at the endline. There is an increase in the number of teachers exploring ways of improving CL4STEM teaching strategies through further refinement of the modules and CoP participation and/or alternative ways of achieving better results from 1 at midline to 5 at endline. There is a decrease in the number of teachers that are exploring ways of collaboration with other teachers and educators to help impact student learning using CL4STEM teaching strategies from 11 at the midline to 3 at the endline. Other changes from baseline through midline to endline, generally positively, with respect to perception, voluntariness, relative advantage, compatibility, image, ease of use, research demonstrability, and visibility have been recorded here-in.

Keywords: Connected Learning; STEM; CLIx; OER; CoP; Teacher capacity development.

1. Introduction

Science and technology constitute the cornerstone for national development. For Nigeria, the provisions of the National Policy on Education [1] support the scientific development and the utilization of science and technology-based programs at all levels of the Nigerian education system. These provisions are evident in the recognition of the role played by STEM education in the national, scientific, and technological development serving as a gateway to socio-economic advancement, industrial development, and self-reliance [2]. All the three tiers of education in Nigeria (primary, secondary, tertiary) lay emphasis on STEM subjects. The quality and standard of the national STEM curricula being used in Nigerian schools are locally relevant, globally accepted, and among the best in the world [3]. However, the teaching of STEM in Nigerian schools has been generally described as ineffective and students' achievements in terms of knowledge and skills are yet to meet expectations [1, 4]. Science teachers and the manner in which science is taught have been identified as part of the problems [5, 4].

The methods and strategies employed by STEM teachers in most Nigerian schools have remained teacher-centred and textbook-oriented [2, 5]. This is contrary to the recommended inquiry-based teaching strategies recommended by the national STEM curriculum that emphasizes learner-centred and inquiry-based teaching strategies and methods that involve hands-on and minds-on learning activities. Furthermore, a good number of teachers and support staff in the Nigerian school system are far from being computer literate and are incapable of applying technology in teaching science. Researchers have reported that most teacher education courses do not provide meaningful contexts for applying ICT to enhance teaching and learning and even though ICT is included in the teacher education program, teachers are not sufficiently trained to use ICT in the instructional setting [6]. In moving the Nigerian situation forward, the Global Partnership for Education's Knowledge and Innovation Exchange (KIX) thematic group has identified three key challenges in improving teaching and learning processes in the context of developing countries.

1. The poor quality of support to teacher development, including weak initial teacher education and subsequent professional development programmes leaving teachers with weak content and pedagogical knowledge and classroom skills (including instructional practices).

2. Inadequate teaching methods and learning materials**,** particularly in local languages and accessible to

learners, including in terms of being aligned with their current level of understanding.

3. Lack of robust systems for recruiting, managing and engaging teachers, in terms of attracting and retaining the most qualified individuals to the teaching profession, teacher deployment to underserved and difficult areas of the country, reducing unauthorized teacher absences and maximizing instructional time, and engaging teachers in policy dialogue and reform.

This paper has brought together some elements of the innovation achieved in the Connected Learning Initiative (CLIx) to address the identified challenges in STEM education in Nigerian junior secondary schools through the CL4STEM project to build processes for long-term systemic dialogues and networking. The Connected Learning for STEM (CL4STEM) project is piloting and researching the innovation for professional development, the Connected Learning Initiative (CLIx), developed and implemented as an innovation to address quality of secondary education in India (www.clix.tiss.edu), and now taken to new country contexts of Bhutan, Nigeria, and Tanzania through a South-South collaboration of higher education institutions engaged in Teacher Education. Attention in this paper is on the impacts in Nigeria. CLIx was seeded by the Tata Trusts and led by TISS and MIT, USA, to strengthen secondary STEM learning, pedagogic content knowledge of teachers and their practice at scale in four states in India. CLIx was awarded the UNESCO-King Hamad Prize for the Use of ICTs in Education in 2018 and the OER award for Excellence in Collaboration-2019 (www.clix.tiss.edu). The programme's interactive STEM OERs, subject teacher CoPs on mobile devices, tech design for under-resourced context, participatory and localised ecosystem approach to adoption and scaling, are identified as an innovative and scalable model.

2. Methodology

Connected Learning for STEM (CL4STEM) as a project consists of one major research study--the Innovation Diffusion Study--which was used to generate knowledge on the processes and aspects that support adapting the innovation for specific local contexts, and practice and conditions to support scaling in these contexts. This was done using qualitative research methods and through process documentation and reporting. In Nigeria, an impact study was conducted on learning outcomes on NQT/ITE teachers - **the CLIx innovation impact study**, following a common design and tools customised to Nigerian context. The impact study generated evidence of the effect size of the intervention for the intended design using mixed methods and quasi-experimental design. Analyses were done Nigeria-specific yielding knowledge relevant for improving teacher quality at scale in developing context. The study focused on developing the capabilities of STEM teachers and emphasizes the pedagogical and techno-pedagogical content knowledge requirements of STEM teachers in Nigeria. The implementation of the innovation took place in 3 stages:

Stage 1: knowledge transfer of the CLIx approach to TPD; Stage 2: adaptation and development of contextually relevant design of innovation; Stage 3: development of a contextually relevant implementation and plan for roll-out.

Knowledge transfer

The knowledge transfer process under Stage 1 was led by the faculty of TISS in Mumbai, India. Teacher educators of the three collaborating universities participated in virtual workshops and created 13 modules for teacher professional development based on the programme's theory of change. The workshops focused on the following elements:

1. Mathematics and science PCK
2. Beliefs regarding inclusion, active and hands-on learning
3. Skills to integrate hands-on learning into the classroom, to integrate ICT (where available) into the classroom, to use resources to enhance student talk and quality of questions asked to develop higher-order thinking and adopt inclusive practices.
4. Management of a subject-based online CoP to share experiences and build contextual pedagogical content knowledge collaboratively.
5. Use of ICT in education, and its role in peer-learning and the professional development of teacher educators.

In total 13 modules were collaboratively developed, contextualized and implemented in all three participating countries- Bhutan, Nigeria and Tanzania. Each participating teacher was enrolled in four modules on the Moodle platform; one Common Pedagogy Module and 3 modules from one of the subjects (Mathematics, Biology, Chemistry and Physics). They had to respond to the designed assignments embedded in the modules. Following are the list of modules.

Table 1: CL4STEM subject specific modules

Subjects	**Mathematics**	**Science**		
		Biology	**Chemistry**	**Physics**
Topics	Proportions	Genetics and Heredity	Atomic Structure	Electromagnetism
	Algebra	Introduction to Ecology	Chemical Bonding	Force and Motion
	Geometry	Cell Structure & Organisation	Organic Chemistry	Work, Energy and Power

Communities of Practice (CoP) was an essential element of CL4STEM TPD model as they offer a social learning space for all the participating teachers, the principals of their schools, and the teacher educators to interact and discuss their experiences with the modules. All of these participation activities lead to a greater likelihood of reflective classroom practice. One common Telegram Group was created for all subject teachers (80) and 4 separate subject groups. Each participating teacher was connected in two groups; common CoP and subject specific CoP. Teacher Educators were assigned as the Course Instructor for each of the twelve subject modules and the common module. This implied that respective teacher educators were responsible for the teacher's participation in their modules. Adequate access to online modules and an online CoP were ensured for all participating teachers. This implied installing Moodle and Telegram on their smartphones and also making them accessible through their laptops/desktops whenever feasible.

The associated research focused on two broad areas. First, the Impact analysis, focused on the impact of innovation on teachers' Knowledge, Attitudes and Practice (KAP) for higher-order thinking, teaching and learning of Science and Mathematics inclusively and equitably. Second, the Innovation Diffusion research generated knowledge on the processes of adoption of the innovation for specific local contexts and the conditions that support scaling. Results generated from the different stages were disseminated to stakeholders in federal/provincial ministries of education and relevant regulatory and professional bodies to seed it into the policy agenda of the respective countries.

The HOTIE rubric explicitly presented the different levels of teachers' KAP to evaluate the impact of the intervention. Stages of Concern and Levels of Use were used to capture the varying needs and concerns of participants during the pilot implementation. These insights led to the development of the scaling and sustainability strategies. Along with CBAM, Moore and Benbasat's innovation diffusion framework[7] was also used to understand the teachers' perceptions. This framework comprised of 7 characteristics:

1. Voluntariness: the perceived degree to which participants voluntarily participate.
2. Relative advantage: the extent to which the teachers perceived CL4STEM suggested strategies to be better than the existing ways of teaching.
3. Compatibility: the degree to which CL4STEM is compatible with the existing context of the teachers.
4. Image: it focuses on how does participating in this project affect the teachers' social or professional status.
5. Ease of Use: this characteristic focused on the teachers' ability to successfully participate in CL4STEM modules and CoPs, as well as, implement the lesson plans.
6. Results Demonstrability: the degree to which the results from participation in CL4STEM could be tangibly demonstrated and communicated to others.
7. Visibility: the extent to which the results of participation in CL4STEM would be observable in the schools

Data Collection

Data were collected in three phases, baseline, midline, and endline. Each of these phases had two specific foci- to study the impact of the implementation on change in teacher knowledge, attitudes and practice, and to study teachers' perceptions of CL4STEM as they evolved overtime. Teachers were the main participants in the implementation. There were 80 teachers in total (20 each from Physics, Chemistry, Maths, and Biology) who participated in the pilot intervention. Out of these 80, 20 teachers (5 each from Physics, Chemistry, Math, and Biology) were in the focus group. The only difference between focus group and other teachers was that focus group teachers were interviewed at every stage of data collection (baseline, midline, and endline). Table 2 shows how many participants responded to each research instrument.

Table 2: Overview of baseline data

Baseline Tools	Teacher Profile	Teacher Perceptions Survey	Subject Impact Survey	Interviews
Focus Group	5	5	5	5
Others	15	15	15	0
Total per subject	20	20	20	5
Total (all subjects)	**80**	**80**	**80**	**20**

Baseline tools consisted of

1. Teacher and school profile surveys to collect the demographic data about the participants and understand the context in which teachers would be working in.
2. Teacher perception surveys to capture the expectations of teachers before they participated in CL4STEM. This tool was designed on the Moore and Benbasat's characteristics of innovations [7]. Stages of Concern and Levels of Use from CBAM were not used in Baseline data collection as the participants were not exposed to the intervention at all at that time frame.
3. Subject impact surveys that assessed teachers' existing subject matter knowledge, pedagogical content knowledge, and general pedagogical knowledge for their subject. This survey was based on the HOTIE framework described earlier.
4. And Interviews, to complement the subject impact and teacher perception surveys data. Interview questions focused on understanding the teacher's conceptual understanding of Science/ Mathematics, knowledge and attitudes towards general pedagogical knowledge, pedagogical content knowledge, equity and inclusion, ICT based teacher professional development, online communities of practice, and perceptions towards implementation of CL4STEM.

Baseline data collection happened in June and July 2022. As indicated in the table above, Baseline survey data was collected for all sets of teachers, newly qualified teachers, experienced teachers, and as well as control group teachers. However, interview data was collected only from focus group teachers. Data was collected from control group teachers, even though it has not been analysed in this report. Midline data collection focused on capturing the qualitative aspects of the implementation. A key component of the midline data was classroom observations. Research fellows conducted classroom observations for 2 teachers per subject (8 teachers in total), and 3 observations per teacher– 24 observations in total, while also interviewing the same teachers. Table 3 shows how many teachers were observed, and how many times.

During the classroom observations, the research fellows wrote detailed descriptions of the lesson+ that they observed. They also conducted a pre and post observation interview with the teacher to understand the context of the lesson. Along with classroom observations, qualitative interviews that focused on their knowledge and attitudes towards SMK, PCK and GPK, participation in online Telegram CoPs, and the teacher's perceptions of CL4STEM. The perception questions also included questions on Levels of Use and Stages of Concern from the Concerns Based Adoption Model (CBAM), along with Baseline questions on adoption. Midline data collection went on from September 2022 to November 2022.

Table 3: Midline data overview

Midline Tools	Classroom Observation	Interviews
Total per subject	6 (2 teachers x 3 observations)	5
Total (all subjects)	24	20

Lastly, the Endline tools consisted of the following:

1. Subject survey, which was a repeat of the baseline subject impact survey and measured teachers' knowledge and attitude towards high order teaching and learning with equity and inclusion by assessing their subject matter knowledge, pedagogical content knowledge, and general pedagogical knowledge.
2. Innovation diffusion survey, which was also a repeat of the innovation diffusion survey conducted in baseline. It also included questions on the Stages of Concern and Levels of Use with regards to CL4STEM, as asked in the midline data collection phase.
3. Interviews with the same set of teachers who were interviewed in baseline and midline. These interviews focused on innovation diffusion, by capturing teachers' perceptions about the innovation after the completion of implementation. The interviews also focused on capturing teachers' knowledge, attitudes and practices around higher order teaching and learning for equity and inclusion, to supplement the survey data. These interviews also captured teachers' experience in the project, as well as their reflections on participating in the module and online CoPs.

Endline data collection happened between November 2022 to January 2023. An overview of the Endline data collected is shown in the Table 3 below:

Table 4: Overview of endline tools

Endline Tools	**Innovation Diffusion Survey**	**Subject Impact Survey**	**Interviews**
Focus Group	5	5	5
Others	15	15	0
Total per subject	25	25	10
Total (all subjects)	**80**	**80**	**20**

3. Results and Discussion

The findings from interviews indicate that teachers' understanding of CL4STEM innovation seem to improve from baseline to endline. This suggests that teachers' participation seems to enhance their understanding. Levels of Use and Stages of Concern surveys come from the Concerns Based Adoption Model (CBAM) developed by Hall [8].

These surveys focus on understanding the practices and attitudes of participants towards a particular intervention. As discussed in the methodology section, Levels of Use focuses on the different levels of engagement and practice of participants with the CL4STEM model (Modules and CoPs).

In CL4STEM, interview participants (n=20) shared their responses for SoC and LoU questionnaires at both midline and endline. At the endline, along with focus group participants, all the participants in the intervention group participated in the SoC and LoU survey. Analysis of these surveys are hereby presented below.

3.1 Levels of Use

Levels of Use (LoU) identifies 4 levels of engagement for participants with an innovation— non-use, orientation, preparation and full use. In CL4STEM, 7 statements were used to capture these different levels of engagements.

Table 5: Results on level of use from the baseline to the endline surveys

Overall Levels of Use	**Focus group (20)**	
	Midline	**Endline**
Non- Use		
Little or no knowledge of CL4STEM, No involvement and/or no intention to be involved	-	-
Orientation		
Trying to know more about CL4STEM	-	-
Not yet assessed CL4STEM modules and Telegram groups (CoPs) but plan to do so soon	-	-
Preparation		
Still learning how to effectively navigate CL4STEM modules and Telegram groups (CoPs)	2	0
Comfortable with CL4STEM online module and Telegram groups (CoPs)/ Able to implement the teaching strategies in my class as per instructions given in the modules and discussions in Telegram groups (CoPs)	7	6
Full use		
Have adopted CL4STEM teaching strategies to meet the different needs of my students (without diluting the core objectives of CL4STEM- PCK+UDL/Higher order teaching with inclusion and equity)	3	1
Having internalized the CL4STEM teaching strategies, able to collaborate with other teachers around CL4STEM teaching strategies to meet the different needs of students	7	9
Having internalized the CL4STEM teaching strategies, now in a position to suggest well thought out modifications and alternatives to the present innovation	1	1
Total	**20**	**17**

The table reveals that none of the teachers at both the midline and endline interviews were yet trying to know more about CL4STEM and none also were yet to access the module at the midline and endline. At the baseline 2 teachers were still learning how to effectively navigate CL4STEM modules and Telegram group (CoPs) while none was at the endline. On the number of teachers that have internalized the CL4STEM teaching strategies, able to collaborate with other teachers around CL4STEM teaching strategies to meet the different needs of students, the number of teachers has moved from 6 at baseline to 9 at endline. The number of teachers at the baseline of those who are comfortable with CL4STEM online modules and telegram groups (CoPs)/able to implement the teaching strategies in class as per instructions given in the modules and discussed in the Telegram groups (CoPs) was 7 at baseline but decreased to 6 at the endline. The number of those teachers that have adopted CL4STEM teaching strategies to meet the different needs of students without diluting the core objectives of CL4STEM (PCK+ UDL/Higher order teaching with inclusion and equity) was 3 at the baseline but decreased to 1 at the endline. Seven teachers reported that, ‘Having internalized the CL4STEM teaching strategies they are able to collaborate with other teachers around CL4STEM teaching strategies to meet the different needs of students. Teachers choosing this level of use increased to 9 in the endline.

Only 1 teacher chose at both the baseline and endline that they had internalized the CL4STEM teaching strategies and was in a position to suggest well thought out modifications and alternatives to the present innovation at both the baseline and endline. It can be deduced that the teachers have improved from the low level of use of the modules at the midline to higher level of use revealing a trend towards higher order of engagement in the table. The reasons the teachers gave for their choice of the categories of the level of use are more of expression of positive perception for the project and which reflected the experiences the teachers have had in the implementation of the modules. The reasons given by the teachers reflect that they find the modules easy to understand, more capable of organising group work and employ the other CL4STEM teaching strategies, capable of engaging students in learning activities, well used to UDL principles and ensuring equity and inclusiveness in class, have capacity in adopting the UDL principles and other teaching strategies to teach other topics in the curriculum, capability to accessing online module more easily, and being able to implement the modules even when needed apparatus are not available, etc. The trend of teachers’ level of concern from midline towards higher levels of concern at the endline and their positive perception as reflected in the reasons given could be associated with the teachers’ participation in the implementation of the modules over the time. From the endline survey, the highest percentage of teachers (36%) reported that they are comfortable with the CL4STEM model and able to implement the teaching strategies in their class. Thirty percent (30%) of teachers reported that they have adopted CL4STEM teaching strategies to meet the different needs of their students. About 14% of teachers reported that they were able to collaborate with other teachers around CL4STEM strategies.

3.2 Stages of Concern

Stages of Concern (SoC) is another part of the concerns based adoption model. It focuses on the teachers’ attitudes towards the CL4STEM model. These various stages are: unconcerned, informational, personal, management, consequence, collaboration and refocusing. The original 35 item questionnaire from CBAM was adapted into a 7-item survey for meeting the practical constraints of implementation. The stages of concern analysis are presented next.

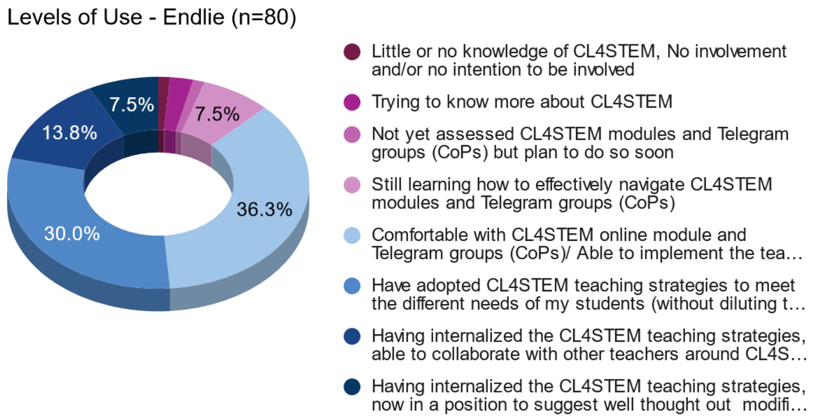

Figure 1: Percentage distribution of level of use at endline

Table 6: Counts of level of use between Midline and endline

Overall stages of concern	**Focus group (20)**	
	Midline	**Endline**
Not interested to participate in CL4STEM	-	-
Know about CL4STEM, and would like to use at some point in time	-	-
Concerned about the demands of CL4STEM vis-a-vis existing workload and how it fits in the existing working conditions	3	7
Grappling with how to effectively navigate the online modules and participate in the Telegram groups of CL4STEM	4	2
Evaluating how CL4STEM teaching strategies impact/help in student learning	-	-
Exploring ways of collaboration with other teachers and educators to help impact student learning using CL4STEM teaching strategies	11	3
Exploring ways of improving CL4STEM teaching strategies through further refinement of the modules and CoP participation and/or alternative ways of achieving better results	1	5
Total	**19**	**17**

Table 6 reveals that there is an increase in the number of teachers exploring ways of improving CL4STEM teaching strategies through further refinement of the modules and CoP participation and/or alternative ways of achieving better results from 1 at midline to 5 at endline. There is a decrease in the number of teachers that are exploring ways of collaboration with other teachers and educators to help impact student learning using CL4STEM teaching strategies from 11 at the midline to 3 at the endline. None of the teachers at the endline was still grappling with how to effectively navigate the online modules and participate in the Telegram groups of CL4STEM compared to 4 at the midline. At the midline and endline none of the teachers would want to know about CL4STEM, and would like to use it at some point in time. No teacher at both the midline and endline indicated not having interest in participation in CL4STEM. The teachers have chosen to be more concerned about the demands of CL4STEM vis-à-vis existing workload and how it fits into the existing working condition as this number increased from 3 at baseline to 7 at the endline. The reasons given by the teachers for their various choices of stages of concern are generally centred on the following challenges they experienced while implementing the modules at both the midline and endline;

i) High workload resulting in number of classes taught and large number of students.
ii) ICT facility and internet challenges.
iii) None alignment of the module with the school sessional calendar and the schools' time table

Consequently, the teachers have often scheduled separate lesson time for the teaching of the CL4STEM topics with this further compounding their workload. The survey conducted with all 80 participating teachers shows that the highest percentage of teachers (37.5%) reported that they are exploring ways of collaboration with teachers and teacher educators to help impact student learning using CL4STEM teaching strategies. Exploring how CL4STEm is impacting students' learning (23.8%), followed by ways of improving CL4STEM strategies (18.8%). In total 80% of participating teachers have selected sophisticated stages of concerns and it indicates a nuanced understanding of the CL4STEM model of professional development.

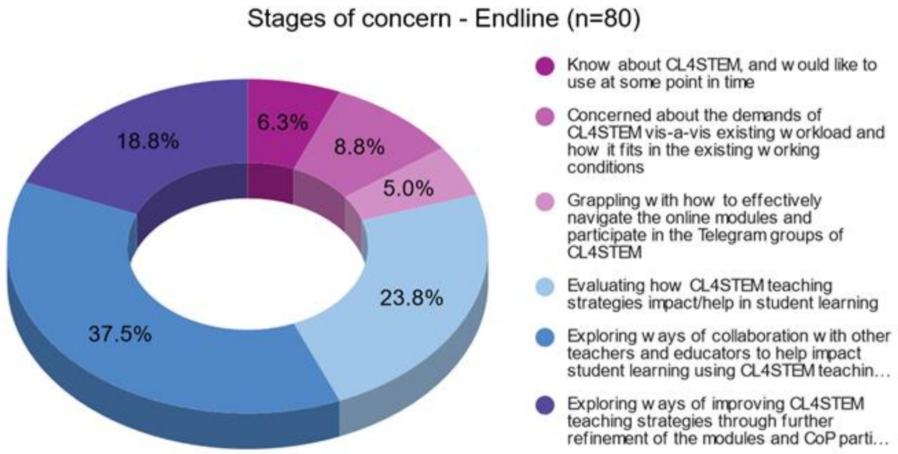

Figure 2: A pie-chart showing the percentages of stages of concern at the endline survey

3.3 Perceptions

Perception survey was designed based on the Moore & Benbasat (1991) instrument to measure the perceptions of adopting an information technology innovation. The survey had 23 items on seven themes. The changes from baseline to endline on these seven themes are presented below.

3.4 Voluntariness

In the context of CL4STEM, voluntariness seeks to ascertain whether the participating teachers freely joined and participated in the project or were compelled by their principals or head of their schools to participate in the

CL4STEM project. Data from interviews on voluntariness indicated that most teachers were nominated by their principals but they were not compelled by the principals to stay in the project. Ten of the respondents in the baseline simply indicated "voluntary participation". There seems to be an increase in teachers' (15 teachers in the endline compare to 12 in the baseline) voluntariness. It is logical to conclude that even though the teachers were selected by their principals or school management, they generally agreed to participate. One of the teachers highlighted that we filled a consent form therefore, he was not compelled to participate. These findings could have implications for scaling of this project in Nigeria. Only 15% of teachers agreed that the school principal did not require them to participate in CL4STEM project in baseline and it decreased by 8% in the endline. Forty six percent (46%) of teachers agreed that participation is not compulsory and it increased by 9% in endline. This indicates that principals' permission was required for participation but it was not compulsory. Voluntariness was on average 31% in the baseline and there was no change in the endline. When the data was sliced[1] based on gender, female teachers have shown a positive change of 6% towards voluntariness; there is negative change (-2%) reported by male teachers. Teachers with five or lesser years of experience have shown negative change (-4%) while more experienced teachers have reported 3% increased towards voluntariness. When the responses were compared between state and federal government school teachers, there was no change in federal government school teachers while teachers from state school reported slight increase in voluntariness (1%). Chemistry and physics teachers have shown 5% increase but biology (-5%) and mathematics (-3%) teachers have reported negative change.

3.5 Relative Advantage

Relative Advantage is the degree to which science and mathematics teachers perceive CL4STEM or the innovation associated with CL4STEM instructional practices as better than their existing classroom practices which are mostly characterised by traditional classroom practices. Interview data on the relative advantage of CL4STEM indicates that teachers' responses clearly indicated that the project has relative advantages over their usual classroom practices. Generally, all the twenty focus group teachers indicated that CL4STEM has helped them to teach their students better. In the baseline itself the average agreement to the five statements was 88%. And there was a 6% average increase in agreement with all statements in the endline. This shows that teachers perceive the CL4STEM model of TPD as more advantageous than the existing ones. Change from baseline to endline for male and female teachers with regards to relative advantage of cl4stem was same (+6%). Female (96%) teachers had slightly more agreement than male (92%) teachers in the endline. Teachers with five or less than five years of experience have reported more positive change (+13%) than more experienced teachers (+2%). Federal (-18%) government school teachers have shown a negative change towards relative advantage while teachers from state government schools reported a positive change of 8%. Amongst the subject teacher mathematics (12%) and physics (+17%) teachers reported positive change in agreement. There is no change amongst chemistry teachers. Biology teachers have shown negative change (-6%).

3.6 Compatibility

Compatibility in this study indicates the extent to which CL4STEM innovation is perceived as being consistent with teachers' instructional experiences in the classroom. In the context of this study, it could be seen as a state in which the innovation and teachers' everyday classroom are able to exist or occur together without conflict. The interview data seems to indicate that the innovation is very compatible with their experiences. A teacher believes that CL4STEM is compatible with his classroom activities but has reservations about its implementation on a large scale. Overall, teachers believe that the CL4STEM is compatible with their everyday classroom experiences. These findings seem to collaborate the results of the quantitative data. The perception survey had three 7-point Likert statements that aim to assess the compatibility, which according to Moore and Benbasat [7] is the degree to which CL4STEM (the innovation) is perceived as being consistent with existing values and past experiences of teachers. Average of 83% of teachers agreed that CL4STEM is compatible with their teaching. This agreement increased by 8% in the endline.

At the endline survey an average of 91% of both male and female teachers reported agreement with statements regarding CL4STEM compatibility with their existing teaching practice. It was 1% increase for female teachers and 11% increase for male teachers from baseline. Teachers with 0-5 years of experience (+11%) and more experienced teachers (+6%) showed an increase in agreement with the statements in the endline. There is a decrease in percentage of federal government school (-13%) teachers in the endline while there is positive change in state government school teachers (+10%). Except for biology teachers (-2%) other subject teachers reported increased agreement ranging from 5-22% in the endline.

3.7 Image

Image refers to deploying the CL4STEM practices that can enhance the image of the teacher. Interview data indicate that participating in the project by the teachers enhances their image and the image of their school. The teachers admit that the project has improved their image among their colleagues. The trends in the data show that 7 teachers at the baseline sample indicated that the project enhance their image but in the midline and endline, 14 teachers indicated that CL4STEM enhance their image and the image of the school. These findings which enhanced the image of teachers and the school have implications for CL4STEM project acceptability and scaling. Average of 76% of teachers indicated that participating in CL4STEM gives more prestige and is a status symbol. The percentage of teachers increased slightly to 78% in the endline. There was no change in percentage of female teachers while male teachers increased by 3% in the endline. Teachers with 0-5 years of experience showed a 12% increase while the percentage of experienced teachers decreased (-3%). Again, like with relative advantage and compatibility federal government teachers (-17%) percentage decreased in endline and state government teachers percentage increased (4%). With regards to subject teachers, biology (-7%) and chemistry (-2%) teachers decreased while maths (+2%) and physics (+15%) teachers increased in the endline.

3.8 Ease of use

Ease of use refers to CL4STEM practices that require a manageable physical and mental effort on the part of teachers to implement. Interview data was collected to explore teachers' perceived ease of use of the CL4STEM innovation. Ease of use could be a strong determinant of the adoption of the innovation. The findings seem to indicate that at the beginning the participating teachers did not find the module very easy to use or navigate which could be attributed to their level of ICT proficiency and other factors. Most of the respondents in the midline and end line perceived the module to be easy to use. In the baseline survey an average 84% of teachers agree to four statements on ease of use, that CL4STEM modules and CoPs are easy to use. This percentage increased by 7% and the average was 92% in the endline. So, overall teachers perceived that the CL4STEM model is easy.

When the data was sliced based on gender both male and female teachers' agreement increased, but not much difference. Teachers with 0-5 years of teaching experience (+10) had more positive change than more experienced teachers (+7%). Again, federal government school teachers have decreased in agreement (-13%) and state government teachers increased by 10%. Mathematics (+13%) and physics (+21%) teachers' percentage increased while there was a slight decrease in biology (-1%) and chemistry teachers (-2%).

3.9 Result Demonstrability

According to Moore and Benbasat [7], result demonstrability means the tangibility of the results of using CL4STEM modules and CoPs, including their observability and communicability. It refers to the extent to which implementing the CL4STEM innovation produces positive outcomes or benefits or the degree to which the use of the innovation is perceived to enhance the teaching and learning of science and mathematics. Results demonstrability was observed by 3 teachers who returned to school to share their knowledge with other teachers who were not participants in the CL4STEM project. The findings from interviews on results demonstrability could have positive implications for the scaling of the innovations to other subjects or other populations. From the survey conducted, it is observed that 79% of teachers have agreed that the results of participating in CL4STEM are clear and easy to communicate in the baseline and there is an increase of 3% in the endline. Both male and female teachers' percentage of agreement did not change in the endline. Teachers with 0-5 years of experience had positive change (+8%) while more experienced teachers had a negative change (-4%). The percentage of teachers from federal government schools reported a drop of 19% while there was an increase of 2% in teachers from state government schools. All subject teachers reported a decrease in endline with chemistry teacher (-11%) at the maximum, followed by physics (-4%), biology (-2%) and mathematics (-1%).

3.10 Visibility

Visibility seeks to measure the popularity of the innovation in schools. The findings on visibility appear to be mixed. Some highlighted that CL4STEM is visible in their schools while others objected to that. In the midline 6 teachers highlighted that the innovation is visible in their school. Many believed it was no longer a new idea to the school management and to some older science teachers. Because at the beginning of this term, they had a particular seminar to sensitize the teachers on how to use digital ways of teaching, and how to use the Internet to teach their students. There is not much change from baseline to endline survey in terms of visibility of teachers using CL4STEM in their schools. This also reflected in the interviews. Teachers mentioned that only mathematics and science teachers are involved, social science and language don't know about CL4STEM modules.

There was not much difference observed in terms of gender. In terms of teaching experience, teachers with 0-5 years of experience showed a decrease (-6%) in the endline while experienced teachers showed a slight increase (+2%). Percentage of federal government school teachers' agreement increased by 19% in the endline while state government teachers' percentage decreased (-3%). Mathematics (-25%) and chemistry (-8%) teachers reported a negative change while physics (27%) and biology (3%) teachers increased in the endline. In the baseline itself the percentage of teachers agreeing was more than 80% for relative advantage, compatibility and ease of use. Among the seven themes in the adoption of the CL4STEM TPD model, compatibility and result demonstrability had the highest increase of 8% in the endline. It was followed by relative advantage (+6%), result demonstrability (+3%) and image (+2%). Voluntariness was increased by one percentage and there was no change in visibility. There was no decrease in overall average for any of the seven themes. When the data was segregated on gender, years of experience, school type and subjects, except for teachers from federal government schools(n=8) and biology teachers every other category of teachers have shown a positive change in the endline.

4. Conclusions

From the situation analysis report that was written in the beginning of the project it could be seen that several government policies, programs, and interventions promote gender equity in the accessibility to education in Nigeria. However, literature has pointed out high gender inequality in terms of accessibility to education in favour of boys across all levels of education [2]. Women are grossly underrepresented in terms of enrolment, participation, and achievement in science, technology, and mathematics at all levels of education in Nigeria [4]. This was reflected in the CL4STEM intervention as well. There were fewer female teacher educators and teachers compared to male participants, especially in mathematics. There were more biology teachers and teacher educators. Female participation was low in research and implementation teams. So while scaling the project efforts will be made to make participation more gender inclusive. Nigeria is currently faced with insecurity that is ravaging and destroying households and destabilizing institutions. Many parents in the affected areas have withdrawn their children, especially female students, resulting in an increase in the number of out-of-school children [6]. Female students' drop-out of school and this widens the gender difference in going to school.

The innovation involved online OER modules and mobile phone messenger application for CoP it required teachers to have access to a smartphone. Some teachers' participation was affected by deficiency. Quality of the phone affected their participation. Also, the internet is expensive. The project supported teachers and schools with internet packs and the Moodle platform was chosen as it enabled navigating modules offline. This feature was well appreciated by teachers as they could refer to the modules whenever they could without the internet. The launch of the project was very successful, it attracted critical stakeholders such as the ministry of education, professional organisations like the Science Teachers Association of Nigeria (STAN), Mathematics Association of Nigerian (MAN), and the Nigerian Union of Teachers (NUT). Other educational stakeholders include the Nigerian Educational and Research Council (NERDC) and Science and technical school Board, among others. The project was well publicised among stakeholders. The CoP was well appreciated by the participating teachers, the interaction among the teachers and between the teachers and teacher-educators was enriching and meaningful. The CoP was well accepted by the participating teachers.

Like in many projects, there were things that did not seem to work out as expected. Some of the things that did not work include the slow start by the participants attributed to the poor proficiency in the use of digital devices. Consequently, in subsequent scaling time and resources should be committed to training the participants on the basics of the use of digital devices. The findings in this study with regards to teachers' instructional practices indicate a shift from traditional classroom practices to the instructional practices embedded in the CL4STEM modules. the teachers' knowledge attitudes and perception towards engaging their students in classroom practices was enhanced. Collaboration or group work was a prominent instructional practice employed by teachers, the students were engaged in intellectual exchange of ideas among themselves and between them and the teacher to address equity and inclusion. The collaborative classroom environment during the CL4STEM activities encouraged the children to construct arguments, ask questions, justify their claims, criticise each other and make decisions; these could enhance higher Order thinking skills. The positive impact of the project with regards to instructional practices, provide a very strong basis for further scaling of the project.

Acknowledgements

This CL4STEM project is funded by the Global Partnership for Education (GPE) through the International Development Research Centre (IDRC), Ottawa, Canada. The Tata Institute of Social Sciences (TISS), Mumbai, India, provided the technical support base. The Ibrahim Badamasi Babangida University, Lapai, Nigeria, provided the project leadership with immense support by the Management of the University and the Niger State Government. Dr Sangay Jamtso at the IDRC is highly acknowledged for overseeing the project and offering helpful advices at every stage.

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