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Pedagogical Content Knowledge: A Case of in-Service Biology  
Teachers in Tanzania**



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## Exploring Teachers' Professional Development Based on Pedagogical Content Knowledge: A Case of in-Service Biology Teachers in Tanzania

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### Abstract

**Purpose:** This study aimed to reveal the impact of the professional development program on the enhancement of pedagogical content knowledge (PCK) among in-service biology teachers. Instructional strategies, students' misconceptions and learning difficulties, representation of the content, context for learning, and curriculum knowledge were some of the main PCK themes.

**Methodology:** Eighteen secondary school teachers from six regions in Tanzania were involved in the intervention program. The study adopted a mixed-methods and case-study research design to collect both quantitative and qualitative data.

**Findings:** The study revealed a positive transformation in the teachers' conception of teaching and learning processes by shifting from a traditional teacher-centred approach to a more constructivist approach. Teachers are competent with the new trends in teaching and learning biology, including the use of technology and improved instructional materials, utilization of the local environment, and integrating academic content knowledge with everyday life.

**Unique contribution to theory, practice and policy:** Based on the findings, it is recommended that in-service teachers' professional development programs be an ongoing process with the ultimate goal of offering opportunities to learn contemporary teaching methods, improve teaching skills, and acquire a broad knowledge of how students learn biology.

**Keywords:** *PCK; Professional development; In-service biology teachers; PCK themes*

## INTRODUCTION

Student interest in science subjects at school has been linked to achievement and the intention to study or work in science and technology to stimulate the industrial economy and use technology for national development (Palmer *et al.*, 2017; Mosenda, 2023). Around the world, there has been a decline in the number of students interested in studying science during school years (Potvin and Hasni, 2014; Nkurlu, 2017; Mkimbili and Kayima, 2022; Steidtmann *et al.*, 2023). In Tanzania, a significant number of secondary school students are performing poorly and losing interest in pursuing science subjects, including biology, and they presume these subjects to be more difficult and irrelevant (Nkurlu, 2017). For example, the results of the Certificate of Secondary Education Examination (CSEE) 2022 released by the National Examination Council (NECTA) showed a weak performance pattern in science subjects. In those results, statistics for biology showed that a total of 520,399 candidates sat for the CSEE exam, out of which 4.13% got grade A, 6.55% got grade B, 25.86% got grade C, 31.30% got grade D, and 32.16% got an F grade (NECTA, 2023; Mosenda, 2023). Correspondingly, in the CSEE 2021, 325,656 (67.23%) of the candidates passed and 158,741 (44.81%) failed (NECTA, 2022). Moreover, in the CSEE 2020, the general performance in biology was average, whereas 55.18% of the 435,420 candidates passed and 191,135 (44.81%) failed (NECTA, 2021).

Several studies have established that science teaching and teaching quality are the key factors that affect students' interest in science (Steidtmann *et al.*, 2022). Furthermore, it has been identified that inappropriate science teaching methods in secondary schools is among the significant factors contributing to students' poor performance and ultimately deterring students from taking these subjects (Nkurlu, 2017; Komba and Mwakabenga, 2019; Mkimbili and Kayima, 2022). Thus, in order to improve the efficiency and quality of teaching science, teachers should be equipped with up to date methodologies and skills in a resourceful and motivated way. This is essential to achieving quality teaching through gaining different classroom management techniques, different teaching strategies to cater for different students' levels and needs, and in-depth, updated subject-matter knowledge (Ayoubi *et al.*, 2017; Shaaban and Abou, 2018).

Furthermore, teachers' qualities, experience, and education play a critical role in transforming and communicating science knowledge to enhance students' conceptual understanding of science concepts and influence students' achievements. In this context, one of the most viable solutions is to allow teachers to participate in professional development programmes that could improve the efficiency and quality of education delivery and hence facilitate the achievement of learning outcomes during teaching-learning processes (Nkurlu, 2017; Mapulanga and Chituta, 2018; Boniface, 2020; Mkimbili and Kayima, 2022). Moreover, professional development programmes are supposed to be a continuous process because teachers need to develop subject-matter knowledge, pedagogical knowledge, technical knowledge, new skills, motivation, and competencies in their respective teaching subjects in order to improve their expertise in the classroom as well as their positions in the school

system (Ayoubi *et al.*, 2017; Mapulanga and Chituta, 2018; Shaaban and Abou, 2018; Komba and Mwakabenga, 2019; Mapulanga *et al.*, 2023).

As noted in the preceding section of this document, becoming a professional biology teacher is a continuous process starting from the undergraduate years through the first years in the classroom until the end of a professional career. This is attributed to the fact that knowledge acquired after graduation and workplace experiences cannot effectively and continuously support a teacher since biology, like other science disciplines, has a rapidly changing knowledge base as well as the dynamic nature of knowledge and the environment (Boniface, 2020; Mkimbili and Kayima, 2022).

In Tanzania, it has been observed that in-service teacher professional development is facing numerous challenges, including the predominance of traditional approaches involving seminars and workshops, difficulties in timetabling, and an insufficient budget (Komba and Mwakabenga, 2019; Boniface, 2020). Regardless of the observed challenges, the authors have identified several opportunities that could be useful for engaging in-service biology teachers in continuous professional development in Tanzania. One opportunity for effective in-service teacher professional development is the availability of different communication networks and the national optic fiber. With this development, teachers could participate in self-directed professional development through access to online modules as well as an online community of practices (CoPs) through social networking sites such as Facebook, Telegram, and WhatsApp. Similarly, Liljekvist *et al.* (2021) have noted that in-service teachers, in their respective subject-specific topics and subject-specific theme CoPs', could also get an opportunity to engage in professional development through sharing knowledge, giving and receiving advice, and sharing and discussing curricular materials. This could be done by installing Moodle and social networking sites on their smartphones, as well as making them accessible through computers.

Given the above descriptions, it is very obvious that students' poor performance and teachers' professional development are interconnected issues in education. In general, the level of teachers' pedagogical content knowledge (PCK) affects how they comprehend the subject matter and the knowledge of the students (Lucenario *et al.* 2016). The PCK describes teachers' understanding of the subject-specific content, ways to help learners understand the concepts, and ways of making the content accessible to learners. Thus, a lack of a well-developed teachers' PCK could account for the lack of understanding of a subject matter (e.g., biology) among learners, as it suggests that teachers are unable to make biology accessible to learners (Mapulanga *et al.*, 2023). In this context, biology teachers need to be able to meet students' learning needs so that they can understand the biology concepts being taught to them. By understanding the needs of their learners, teachers could also consider ways to improve their teaching practices with consideration for the learners. Improving the way biology is taught could be one of the key approaches to increasing the number of students interested in the subject and their performance in the examinations as well.

Thus, in order to improve the efficiency and quality of teaching biology in secondary schools in Tanzania, a special professional development intervention programme for in-service teachers was conducted in six regions. The programme was focused on the conceptual principles of PCK to foster higher-order thinking in teaching and learning biology in secondary schools. Furthermore, it was engaged in curated online biology modules based on Open Education Resources (OERs) and through participation in online communities of practice (CoPs).

In this study, three biology modules for cell structure and organisation, genetics and heredity, and balance of nature were developed. The three modules were developed based on three higher-order thinking and subject OERs. Moreover, their design complied with the national curriculum framework to support teachers' continuing professional development (CPD) in content enhancement, technology use, and inclusive and competency-based pedagogies. The adopted approach for professional development of secondary school teachers for the present study has been successfully implemented and scaled in India through the Connected Learning Initiative (CLIX) for capacity building of secondary school teachers in science and mathematics to foster higher-order thinking with inclusion and equity.

Therefore, the intervention programme was prepared to enable in-service biology teachers to develop new teaching and learning skills in order to be up-to-date with new trends in teaching biology, including the use of technology and improved instructional materials. Likewise, it emphasised developing teachers' subject matter knowledge and the preparation of lesson plans based on new teaching methodologies and techniques. For that reason, this study sought to reveal qualitative and quantitative feedback from in-service secondary school biology teachers who took part in an intervention programme to develop pedagogical content knowledge (PCK) competencies and consequently enhance their quality of teaching. The study aimed to answer the following research question: To what extent did the in-service biology teachers' PCK improve after attending and implementing the intervention programme on professional development?

## **1. METHODOLOGY**

### **2.1. Research Design**

The study adopted a mixed-methods and case study research design to collect both quantitative and qualitative data to evaluate the development of PCK among the participant in-service biology teachers. In this context, the events reflecting the PCK of each sub-component of teaching professional development were determined and analyzed and the findings were compared with other situations. Moreover, baseline and end-line surveys were used to understand the development and changes in PCK and knowledge, attitudes and skills for inclusion and OERs.

### **2.2. Research Participants**

A total of eighteen in-service biology teachers from sixteen secondary schools participated in the intervention program. Fourteen were males (78%) and four were females (22%). Participants were selected from six different regions and zones of Tanzania: Dar es Salaam (Eastern), Arusha (Northern), Mwanza (North-Eastern), Dodoma (Central), Iringa (Southern Highlands), and Mtwara (South-Eastern). Regarding the academic profiles of the participants, the most significant proportion (63.2%) were the holders of a bachelor's degree in education, and holders of a diploma in education contributed the remaining portion (23.5%). The number of years of teaching experience ranged between  $\leq 5$  years (45.6%), 6 to 10 years (25.0%), and  $>10$  years of teaching experience contributed 29.4% of the participants. The participating biology teachers were purposefully selected from eighteen secondary schools spread across six regions and zones of Tanzania. The participants were selected because they teach biology but before the commencement of the program, informed consent was obtained from all participants. Furthermore, after they consented to participate in this study, the participant teachers were engaged in a one-day workshop on online module implementation and the use of CoPs for professional development.

### 2.3. Data Collection Instruments and Procedures

In order to answer the research question stated above, qualitative and quantitative data were collected using different instruments, including semi-structured interviews, feedback surveys, and classroom observations.

- **Semi-structured interviews:** The interviews were administered to the participant biology teachers in two sessions: baseline and endline for collecting qualitative data. Interviews with participant teachers were conducted electronically through Zoom meetings and/or audio (phone calls). Then, audio files and generated transcripts were uploaded to their respective folders.
- **Classroom observations:** the participant biology teachers were observed by the researcher in their school setting before, during, and after classroom practices. These were administered to collect qualitative data.
- **Questionnaires and feedback surveys:** Questionnaires and surveys were administered to the participant biology teachers at the beginning and end of the intervention to collect quantitative data. The two were administered through an online platform.

Research data was collected in three phases: baseline data, which took place between June and July 2022; midline data, which mainly focused on classroom observations as well as pre- and post-classroom observations, was held from September 2022 to November 2022. The third item was endline data collected between November 2022 and January 2023.

### 2.4 Data Analysis

The quantitative data that was collected using the questionnaires and surveys was analyzed to generate descriptive statistics. The interviews were audio recorded, transcribed verbatim, and

analyzed by coming up with themes and trends related to pedagogical content knowledge (PCK). Likewise, all classroom observations and teachers' pre- and post-observation interviews were deductively coded using the HOTIE framework and perception frameworks after deductive coding into the themes. The data was then triangulated to gain an in-depth understanding of emerging themes.

### **2.5 Ethical Considerations**

Permission to conduct the study in the selected regions, districts, and schools was obtained from the Tanzania Commission for Science and Technology (COSTECH). Approval was granted by the leaders of the study regions, districts, and schools to visit and conduct this study in the areas under their jurisdiction. The teachers voluntarily consented to participate in the study, and it was possible to withdraw from the study at will. To ensure participant anonymity, the name of the school was not disclosed, and numbers were used to identify the participant teachers. Furthermore, we appreciate the support and cooperation from the Open University of Tanzania (OUT) management and the UNESCO chair in teacher education and curriculum at OUT.

## **3. FINDINGS**

The purpose of this study was to investigate the impact of the professional development program on in-service secondary school biology teachers' pedagogical content knowledge (PCK) improvement after being involved in the intervention program. The PCK components used for this study are described as composed of five major themes: instructional strategies, students' misconceptions and learning difficulties, representation of the content, context for learning, and curriculum knowledge. Thus, the study findings from those five themes are as follows:

### **3.1 Instructional Strategies**

The study was interested in knowing how the intervention program has improved the ability of biology teachers to use different instructional strategies and resources to tackle the different needs of the learners. During different sessions of individual interviews, teachers consistently attested to positive changes in instructional strategies. The quoted narrations from one teacher seemed to represent the ideas and perceptions of many other participants in the project. The teacher's comments during baseline and endline sessions are as shown in Table 3.1.

Furthermore, the classroom observations and module impact reports have indicated the change in teaching approaches of the majority of biology teachers from teacher-centred to learner-centred strategies. The participating teachers seemed to improve their instructional strategies, ranging from teachers' abilities in explaining concepts to bringing the lesson to life through group discussions, questions, and answers to engaging students in classroom activities and demonstrations using diagrams or prepared teaching materials. The coded interview responses, which showed an increase in the use of a variety of strategies (60%) and, at 150%, an increase in knowledge and resource utilization, support the aforementioned

quotations. Similarly, the surveys have indicated a positive impact on instructional strategies, in which the proportions of the desired results were 71.4% against 28.6% of the undesired results. Therefore, the intervention program has adequately equipped teachers’ knowledge and skills to meet up with better teaching strategies and resources for developing scientific thinking skills.

**Table 3.1:** Knowledge of Using Instructional Strategies

Baseline interview response	Endline interview response
<p><i>I use mixed teaching strategies. Most of the time, I use group discussions and group work-based activities as per directives of the competence-based curriculum, but sometimes due to limited time, I use the lecture method (teacher #2504, Community school, Baseline)</i></p>	<p><i>I choose the teaching resources, firstly by considering their relevance to the lesson and secondly, the references which I should use to teach the students; Apart from the effective use of locally available resources, I also learned about the crafting and importance of good lesson introduction for students' clear understanding of subsequent stages (teacher #2504, Community school, Endline)</i></p>

### 3.2 Students’ Misconceptions and Learning Difficulties

The study wanted to identify teachers’ responses to the students’ common misconceptions and associated learning difficulties in biology. The module impact reports and baseline findings for the present study have revealed mixed results on knowledge of areas students find difficult as well as the ability to use students’ errors to understand their way of thinking. Nearly all teachers in government and community schools acknowledged that students' poor spoken and written English proficiency was a major contributor to their learning challenges in biology; however, this was not the case for the private schools involved in the project. It was also established that a shortage of learning resources, deprived students’ backgrounds in science, and classroom crowding were some of the factors contributing to learning difficulties and misconceptions among students.

Following intervention, the teachers showed a positive change, hence being able to distinguish between non-misconceptions and students’ misconceptions. Subsequently, the teachers prepared and started their lessons by tracing learners’ prior conceptions, misconceptions, and learning difficulties. Similarly, most teachers have admitted that they have started to use students’ errors and feedback in designing learning experiences to teach biology effectively and efficiently. The following quotes from one of the project participants (Table 3.2) nicely illustrate this observation.

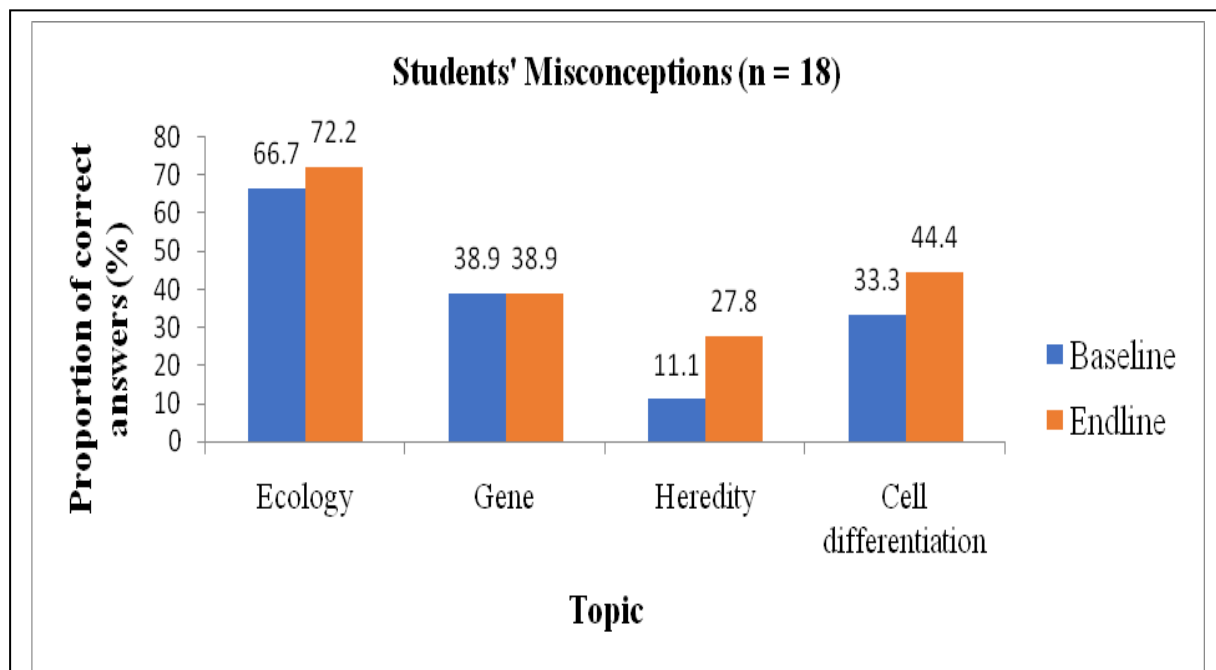


**Table 3.2:** Students’ Misconceptions

Baseline interview response	Endline interview response
<i>“The challenge I face when teaching is lack of resources like books and laboratory chemicals”</i>	<i>‘I start a lesson by asking questions to check student's prior knowledge and if there is any misconception and clear the doubts as I continue with teaching and learning process’</i>

Further, the classroom observations identified that teachers could categorically distinguish students’ misconceptions and learning difficulties over time and address them. For example, a participant biology teacher, #2714, in one of the visited secondary schools was able to spot and clarify that *“Food webs and food chains are not only found in national parks and game reserves where plants and animals interact but they are found everywhere, even in our local environments.”*

Concerning Figure 3.1 below, the question on ecology has reported a higher proportion of teachers identifying the common misconceptions in comparison to other topics studied



**Figure 3.1:** Proportion of correct answers issued during the survey to determine the level of identification of common misconceptions in biology

Nevertheless, the frequency of responses recorded both in the module impact reports and during surveys does not provide any considerable difference between baseline and end-line

surveys in identifying the students’ misconceptions and learning difficulties for designing learning experiences.

### 3.3 Representation of the Content

The study inquired about how the biology teachers involved in the intervention could employ multiple approaches to present the same essential learning materials in more than one medium or manner. In the course of program implementation, teachers have acknowledged the use of multiple approaches in the representation of the learning materials through charts, pictures, models, slides, clips, and real objects, as well as the use of school immediate environments. Furthermore, they employed the use of ICT in searching for materials that met the diverse needs of the learners. The quotations in Table 3.3, recorded during baseline and endline interviews with one of the participating teachers validate these observations.

**Table 3.3:** Trends in Representation of the Content

Baseline interview response	Endline interview response
<p><i>“I use computers, tablets, and smartphones. But also, I prefer the use of a head projector to teach my students, but in my school, it is not available” (teacher #2113 from a private school)</i></p>	<p><i>“I was ignoring the use of technology and multi-media in teaching; I was unaware of the different ways of presenting materials using technology, thinking that it is difficult. Now I know that only my smartphone can be useful enough for this purpose” (teacher #2113 from private school)</i></p>

In the course of this program, most teachers displayed an understanding and deployment of multiple forms of representing the contents, depending on the nature of the topic as well as the availability of the teaching and learning resources.

During the classroom observations and engagements in the CoPs, the majority of the teachers displayed mastery of multiple ways of representing the contents. They showed a high degree of flexibility in their ability to switch from one type of instructional approach to another according to their need. They could use words to explain concepts, use the local environment, laboratory tools and specimens, charts, drawings, illustrations and group discussions to represent the contents of the lesson plan to be taught. For instance, a teacher from a community school carefully prepared his materials to use in teaching by using charts, diagrams, figures, and laboratory specimens and models for students’ effective learning. He also used the immediate school environment, locally available materials and different types of laboratory specimens to represent the contents. Likewise, another teacher in the Telegram-based CoPs has acknowledged the use of locally available resources to illustrate some genetics concepts to students in the implementation of module 2, Genetics and Heredity.

In most instances, during pre- and after-classroom observational talks, the majority of the teachers acknowledged that the intervention program has been influential in their performance

as it has added and updated their teaching skills and knowledge of the representation of the content. In general, findings obtained from the classroom observations have had a positive impact on their responsibilities as a result of the intervention.

Table 3.4 below shows an increase in the proportion of respondents using resources, with a lower figure for those not using them in 4 items (57.14%) out of 7 items. There was no change in the proportion of those using resources as observed in 2 items (28.57%), and a decrease in resource use tied together with an increase in the percentage of non-use of resources was noticed in only 1 item (14.3%) across the baseline to end-line surveys. An increase in the use of resources (57.14%) was noted to be a dominant response among participating Biology teachers.

**Table 3.4:** Biology teachers’ response on the use of teaching resources (n=18)

Variable			I don't use this source		I don't have access to this source		Minor source		Major source	
			Freq	%	Freq	%	Freq	%	Freq	%
1	Own education in science/math	Baseline	1	5.6	2	11.1	5	27.8	10	55.6
		Endline			1	5.6	5	27.8	12	66.7
2	Textbooks/teaching materials	Baseline			1	5.6	2	11.1	15	83.3
		Endline			1	5.6	1	5.6	16	88.9
3	Other books, magazines, journals	Baseline			1	5.6	13	72.2	4	22.2
		Endline			4	22.2	12	66.7	2	11.1
4	Charts, models, worksheets, activities prepared by the teacher	Baseline			1	5.6	8	44.4	9	50.0
		Endline			1	5.6	5	27.8	12	66.7
5	Use of the surroundings, contexts, artifacts, real life experiences	Baseline			2	11.1	7	38.9	9	50.0
		Endline			1	5.6	5	27.8	12	66.7
6	Digital/ICT-based resources	Baseline	1	5.6	2	11.1	9	50.0	6	33.3
		Endline			2	11.1	7	38.9	9	50.0
7	Popular online/offline talks	Baseline			6	33.3	6	33.3	6	33.3
		Endline			4	22.2	11	61.1	3	16.7

Source: field data

Across baseline to endline-generated quantitative data, we have recorded a positive change in the use of resources (57.2%) among participant biology teachers. Regarding gender, relatively higher proportions of positive results were observed in males (57.14%) than in females (42.86%). In terms of teaching experience, teachers with five years or less in the profession showed to be very appropriate for innovation compared to those with six and above years of experience. In general, feedback from participating teachers indicated improvements in knowledge, skills, and attitudes regarding the use of multiple forms of content representation as well as the use of technology in the representation of content.

### 3.4 Context for Learning

The study also sought to know how biology teachers involved in the intervention program integrate the academic contents with real-world situations that students usually experience. On this item, the major concern was the environment that could support effective teaching and learning of science. The findings are clearly explained in this section. In studying this component of PCK, three subcomponents were taken into consideration. In the first subcomponent, the biology teachers were evaluated as to how they could identify and use the locally available resources for teaching and learning processes. The participating teachers' response shows that between baseline and end-line studies, there was a 22.2% increase in the number of teachers who used locally available materials in their classroom settings. Similarly, there was a 25% increase in the number of teachers connecting the big ideas in biology with topics covered in their respective classes. However, there were no changes in the number of teachers exploring science laboratories and using them for learning during the baseline and end-line interviews.

Observations from three subcomponents of context for learning suggest that the intervention created awareness and positively impacted the teaching-learning processes among participating teachers. Likewise, the use of locally available resources seemed to be more advantageous and simplified the teaching-learning processes for the majority of biology teachers involved in the program. The remarks made by participant number 2714, as shown in Table 3.5 below, could amply justify this observation:

**Table 3.5:** Importance of Local Resources in Classroom Practices

Baseline interview response	Endline interview response
<p><i>“local resources for teaching biology are available around the school surrounding. However, due to the larger number of students, sometimes the resources aren’t enough for all students, but the school has enough textbooks to use” (teacher #2714 from government school, baseline)</i></p>	<p><i>“When teachers use the resources available in their environment, it is easier for the children to understand, and the lesson is understandable and enjoyable by students. Now I plan to teach aids that are locally available, very common to my students, and low cost.” (teacher #2714 from government school, endline)</i></p>

Furthermore, the classroom observations and CoP conversations noted that participating teachers have developed knowledge, skills, and a positive attitude towards the context for learning. Knowledge of the school surroundings and context, which shapes their pedagogical choices and the use of locally available materials to meet the needs of learners were noted. During lesson preparations and classroom practices, the teachers tried to provide examples and explanations to suit the students' everyday lives and carefully chose them to shape learning towards the concept they were focusing on. In one of the observed lessons, teacher #2713 used the seeds to discuss plant cells; he gave an example of a honeycomb to examine the structural analogy of a cell. In another class, he was teaching the topic “Balance of Nature”. During that session, he used several examples from the local context to elucidate the biotic and abiotic components of ecosystems. The students also responded by giving examples from local ecological contexts.

### 3.5 Curriculum Knowledge

In this section, the present study sought to explore participating teachers’ knowledge, skills, attitudes, and practices about purposes, hierarchical sequences, and the design of integrated learning experiences in biology. The study findings have noted the teachers’ major considerations during lesson preparations, which include the goals, objectives, topics, subtopics, and lastly, the lessons in the classroom. They also noted the connections between biology and other subjects, as well as how to integrate them into the student’s experiences, environment, and everyday life. This observation could be precisely authenticated by the narrations of Teachers #2516 and #2306 during the baseline and end-line interviews. Their quotations are in Tables 3.6 and 3.7, respectively.

**Table 3.6:** Integrating biology with everyday life

Baseline interview response	Endline interview response
<p><i>“I am aware of the goals and purpose of teaching science, which is to impart knowledge to learners that are necessary for its application in real life” (teacher #2516 from government school)</i></p>	<p><i>There I was able to engage my students with significant interactions with their fellow students and me by integrating the principles of universal design of learning for more student participation in the lesson” (teacher #2516 from government school)</i></p>

**Table 3.7:** Importance of curriculum in teaching and learning biology

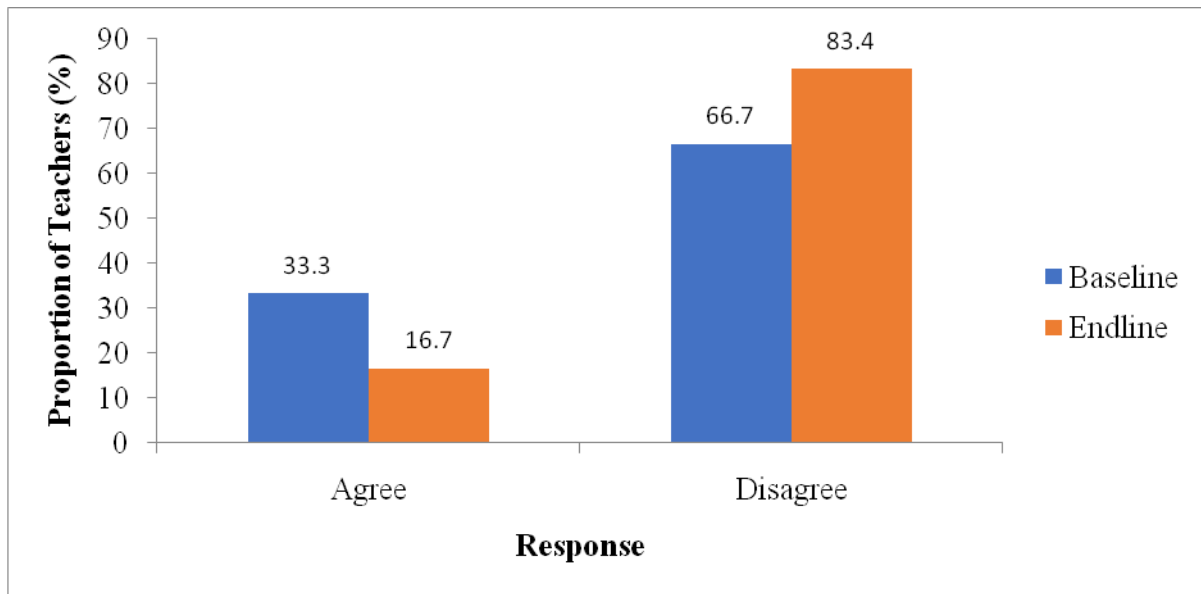
Baseline interview response	Endline interview response
<p><i>“the syllabus is important to study science subjects and mostly Laboratory facilitated with apparatus so that students can learn to get more knowledge in science subjects” (teacher #2306 from community school)</i></p>	<p><i>“When planning a lesson, I look at the subject matter I will teach, which is which topic and which subtopic. Then the objective of that topic and what my students should learn from that topic. I plan for the activities that will enhance learners' understanding, actually in the introduction, in the development of the lesson, and then I plan for the reflection, the assessment of the students, that is, if what I've taught is understood or not, so I plan for the assessment activities” (teacher #2306 from community school, endline)</i></p>

From the above quotes, one could determine an improvement in the general understanding of the purpose of teaching science (biology), the sequencing of teaching and learning activities, as well as linkages between biology and other school subjects, as a result of the interventions.

During the classroom observations, teachers were highly concerned with the immediate environment for getting the teaching and learning resources for their classes. Further, they made all classroom preparations using the objectives and other guidelines outlined in the syllabus. This implied that the teachers were highly concerned about curriculum guidelines in the preparation of lesson plans, teaching, and assessments. Likewise, they showed the alignment and connection of the classroom-taught concepts with the students' daily lives.

For instance, a participating biology teacher, #2714, showed a good gain in curriculum knowledge during the execution of the teacher’s activities in actual classroom practices. He showed, through real-life examples, the prey and predator relationships using the Tanzanian environment and settings. He cited examples of wildlife organisms from Serengeti National Park, which is very familiar to the majority of the students in the Lake Victoria zone.

Equally, Figure 3.2 indicates the understanding of the hierarchical sequence of foundational concepts across grade baseline and end-line surveys.



**Figure 3.2:** Comparison of the teachers’ responses to the hierarchical sequence of foundational concepts across grades

## 2. DISCUSSION

The purpose of this study was to investigate the impact of the Professional Development Intervention Program on in-service secondary school biology teachers’ pedagogical content knowledge (PCK) improvement after being involved in the intervention program. The PCK components used for this study are described as composed of five major themes: instructional strategies, students’ misconceptions and learning difficulties, representation of the content, context for learning, and curriculum knowledge. Thus, discussions of the study findings in relation to those five PCK themes are described hereunder.

In general, the study findings show that this intervention program enhanced the biology in-service teachers’ knowledge around all five major themes of PCK used in this intervention. Quotations from the baseline interviews for all PCK components under this study could precisely reveal that teachers had a traditional behavioristic conception of teaching and learning processes. However, the narrations of the teachers during the endline interviews convey the message that the program has positively transformed their conceptions as well as enabled them to acquire the skills for improving the teaching and learning processes. These findings have implications for the teaching and learning process, thereby improving student achievement. The findings of the present study are consistent with other studies such as Ayoubi et al. (2017), Shaaban and Ali (2018), Mapulanga and Chituta (2018), and Msamba et al. (2019), who advocated that in-service programs are a vital tool through which teachers improve their content knowledge, general knowledge, and PCK, which contribute to an improved teaching and learning process as well as the performance of learners.

The classroom observations revealed that the majority of the biology teachers in the present study have improved their teaching strategies by shifting from a traditional teacher-centred

approach to a more constructivist approach, as recorded during the endline observations. Furthermore, the teachers in the present study are now aware of their major role as facilitators of the learning process rather than transmitters of knowledge. Through the implementation of biology intervention modules, participant teachers employed various active and participatory teaching approaches such as group discussions, questions and answers, and demonstrations using diagrams or prepared teaching materials. Likewise, teachers started letting their students engaging in experiments, interpret data, and draw conclusions, and linking classroom practices to the real world. This implies that during the intervention, in-service teachers had acquired multiple dimensions of techniques to facilitate smooth teaching and learning and were strongly oriented towards the modern view of education that emphasizes student-centred methods and focuses on constructivist learning approaches. A related remark was also documented by Ayoubi et al. (2017): that there is an urgent need to help teachers adopt “learning-oriented” strategies instead of “teaching-oriented” strategies that could facilitate the achievement of high-quality learning outcomes. This observation is also reinforced by Mapulanga and Chituta (2018) and that of Mkimbili and Kayima (2022), who stated that the use of teacher-oriented approaches such as lecturing and discussion is alleged to be one of the factors that affect the performance of students in biology examinations.

The fact that the majority of incoming biology teachers at the onset of the intervention program relied heavily on the conventional frontal teacher-centered teaching approach could indicate the common teaching strategy they could have adopted from the teacher educators in the teacher colleges. Likewise, it could be associated with a lack of knowledge about linking classroom practices to the real world, as well as the use of immediate environments to facilitate the process of teaching and learning. Results from the study by Mkimbili and Kayima (2022) observed that an instructor-guided teaching-learning approach was the dominant teaching practice in the teacher education colleges in Tanzania. In that study, the author observed several challenges as a part of the complete teaching-learning system such as low interest in science, overloaded curriculum, limited teaching-learning resources, forms of assessment that do not align with the desired teaching approaches, and difficulties with the instruction medium, English. Moreover, some factors associated with instructors’ lack of teaching competence to support their students and their own preparedness in their roles as science teacher educators were also identified as having impeded the implementation of learner-centred approaches (Mkimbili and Kayima, 2022) among the majority of biology teachers in Tanzania. So, in order to adapt to alternative teaching methods from the traditional, teacher-centred approaches it is important for the classroom teachers to undergo relevant training to promote actualized teaching-learning practices. Thus, the present intervention program has oriented participants to new teaching experiences that encompassed a range of pedagogical approaches and methods such as inquiry, constructivism, questioning, the nature of science, cooperative learning, and laboratory investigations.

At the beginning of the program, the baseline study reported noticeable students’ misconceptions and learning difficulties, but after the module implementation, the teachers



were quoted narrating successful stories on how they tackled those difficulties using different instructional methodologies and addressed the issues of teaching and learning materials. The combined effects of subject matter knowledge (SMK) deficiencies and difficulties in some teaching processes among biology teachers are thought to be the major reasons for the observed difficulties (Mapulanga and Chituta, 2018; Hamunyela *et al.*, 2022; Aydın and Turhan, 2023; Mapulanga *et al.*, 2023). Thus, the competencies of teachers in SMK, which is one of the basic elements of PCK, and the use of appropriate teaching methods that put the learner at the centre of the learning process, could provide an advantage in overcoming the students' misconceptions and learning difficulties in order to assist learners in the learning of biology (Mkimbili and Kayima, 2022; Aydın and Turhan, 2023). Furthermore, learners' knowledge could be improved by helping them acquire values and skills of high-order thinking such as analysis, comprehension, evaluation, critical thinking, problem-solving, and communication skills. The observed improvements in students' misconceptions and learning difficulties after the intervention could be attributed to the positive increase in the competence of the teachers. Also, teachers have started to use more student-centred approaches and a variety of teaching strategies, such as group work, lab work, technology, and the utilization of local environments in teaching (Ayoubi *et al.*, 2017). In support of this observation, Lucenario *et al.* (2016) commented that PCK is an essential element that helps teachers acquire more conceptual and technical knowledge, skills, and competencies in their teaching subjects and pedagogy in order to help students understand the subject-specific content.

The findings that the majority of the participant in-service secondary school biology teachers have started to use multiple active teaching approaches as well as the utilization of immediate environments and resources for classroom practices could mainly be attributed to the new experiences acquired from the intervention modules. The modules were developed in styles that focused on the active involvement of the learners, such as the use of laboratory investigations, technology, group discussion, teaching aids, and group work. Furthermore, they emphasized the utilization of the local environment, field trips, and linking biology content knowledge with everyday life. Thus, this intervention for professional development has assisted the participant biology teachers in adopting new teaching approaches in ways that seem to influence students' understanding of biology and science ideas in general. The main approaches were those that emphasize a student-centred learning environment, a problem-solving approach, and critical thinking. These findings could be well supported by the assumption that teachers' effective professional development programs should be an ongoing process that can assist teachers in developing knowledge, skills, and attitudes for effective application in the classroom (Shabaan and Ali, 2018). Likewise, the findings are consistent with the literature, which observes that improvement in teaching practice depends on the existence of student-centred conceptions of teaching that are more likely to lead to high-quality student learning outcomes (Ayoubi *et al.*, 2017; Mkimbili and Kayima, 2022).

Regarding the context for learning, the baseline study found that at the beginning of the program, most teachers in the intervention group could be identified as traditional teachers

who often utilize passive approaches to transmitting knowledge without much consideration for the learners. Furthermore, they were unable to hold effective classroom practices since they were not provided with resources such as laboratory materials, textbooks, classrooms, and laboratories. It can thus be deduced that the way biology is taught and a lack of teaching and learning resources and facilities could be among the key factors that affect the performance and interest of students in taking biology and other science subjects around the world (Nkurlu, 2017; Mapulanga and Chituta, 2018; Komba and Mwakabenga, 2019). According to Hamunyela *et al.* (2022), effective teaching and learning processes should be associated with a sufficient quantity and quality of resources in schools.

Findings from the present study have revealed that, during the end-line study, most teachers started to use more active teaching approaches, linked content knowledge to everyday life, and used locally available resources and environments for facilitating teaching and learning practices. These findings show the positive side of the intervention program towards enhanced in-service secondary school biology teachers' professional development in Tanzania. These results are consistent with other studies showing that professional development programmes for in-service teachers improve their teaching practices by emphasizing active teaching methods, laboratory investigations, group work, the use of teaching aids, technology, and field trips (Ayoubi *et al.*, 2017; Shaaban Ali, 2018).

In the present study, in-service biology teachers under the intervention program showed improvements in the way they organized their classroom practices based on the requirements of the syllabus and the integration of the academic-taught concepts with the learners' daily lives and environment. The observed improvements in the way the teaching and learning processes are organized with maximum consideration of the learners and their environments could be a direct influence of the PCK on the teachers' enhanced pedagogical abilities. This observation concurs with other experiences that indicate that when teaching a concept, the order in which the material is presented should consider the needs of students (Meili *et al.*, 2020; Mapulanga *et al.*, 2023). Moreover, Meili *et al.* (2020) elaborated that teaching a concept can be started by teaching concrete concepts first and then moving on to more abstract concepts. Likewise, the study determines that the PCK of science teachers could be clearly illustrated by their ability to develop important concepts, their ability to describe important concepts, and their ability to choose the right pedagogy to teach those concepts. This could also be reinforced by Chen and Wei (2015), who argue that setting teaching objectives, recommending teaching strategies, and designing teaching activities should be considered and linked to the PCK of teachers.

On the other hand, the study findings have reported a new development among participating teachers in integrating the students' experiences, environment, and everyday life into their classroom practices. Ideally, integrated teaching seeks to place classroom practices in the context of real-world experience and subjects that are specific enough to be practical and broad enough to enable creative exploration. This observation could describe the situation where effective PCK could help teachers organize the teaching and learning contents in a

coherent thematic approach related to real life (Putra *et al.*, 2017). Therefore, it can be concluded that the PCK of teachers is an important factor that leads to teachers' adaptations of curriculum materials (Chen and Wei, 2015). However, findings from the quantitative study for undisclosed factors and difficult assumptions showed a significant increase in the proportion of participants giving disagreeing responses across the baseline and end-line surveys regarding teachers' need to know the hierarchical sequence of foundational concepts across grades (Figure 3.2). Though, in general terms, the intervention had positive impacts on developing the PCK of the participating biology teachers, this observation could tell that some parts need an extra dose to assist the teachers that, for one reason or another, have been left behind.

### **Conclusion and Recommendations**

Our results reveal that the intervention program implemented in this study enhanced the in-service secondary biology teachers' professional development. The program was an effective approach to improving teachers' PCK competencies, the adaptation of curriculum materials and skills to be used in the classroom, and students' achievement. Therefore, it could be concluded that the teachers' PCK is an essential and critical element in determining a teacher's success in handling the teaching and learning process as well as the performance of learners in terms of conceptual understanding and problem-solving skills in biology. Similarly, improved teachers' PCK and, hence, the quality of teaching and learning would promote positive students' perceptions and interest in studying science, as well as their ability to score good marks in the final examinations.

This study recommends that professional development for in-service teachers, especially in PCK, should be a continuous program in order to enhance their skills and keep them updated in relation to scientific knowledge, subject matter content, pedagogy, and exemplary contemporary teaching methods. This emphasis on PCK is justified based on the assumption that PCK can have a significant impact on the quality of instruction that the students receive and, thus, the quality of learning they experience in the classroom. Moreover, the participants in this study only represent a very small number of in-service biology teachers in Tanzania, but the findings presented in the current study could be applied to other teachers in the country. Hence, a further intervention program that would involve more in-service biology teachers should be implemented across the country, as well as other science subject teachers, such as chemistry, physics, and mathematics. However, because this approach to the professional development of teachers is new in our country, more research is also encouraged to continue testing and refining it to improve its effectiveness.

### **Limitation of the study**

This study covered a very small number of secondary schools and biology teachers in Tanzania. Thus, its findings cannot be precisely made useful in teaching and learning of Biology in all secondary schools across the country, further research involving more schools and teachers is recommended for more generalized outcomes. Moreover, the focus of the

present study was mainly on general PCK, future study should focus on topic PCK where specific teaching methods can be used to help students overcome learning difficulties and misconceptions about respective topic. Further, the ‘knowledge of students’ component of PCK should be given more attention in biology teacher education programs. Despite these limitations, the study findings suggest the need to intensify in-service training programs to help in-service teachers enhance specific components of PCK, which would, in turn, improve students’ performance.

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### **Disclaimers**

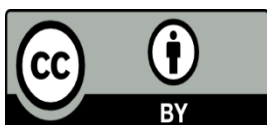
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