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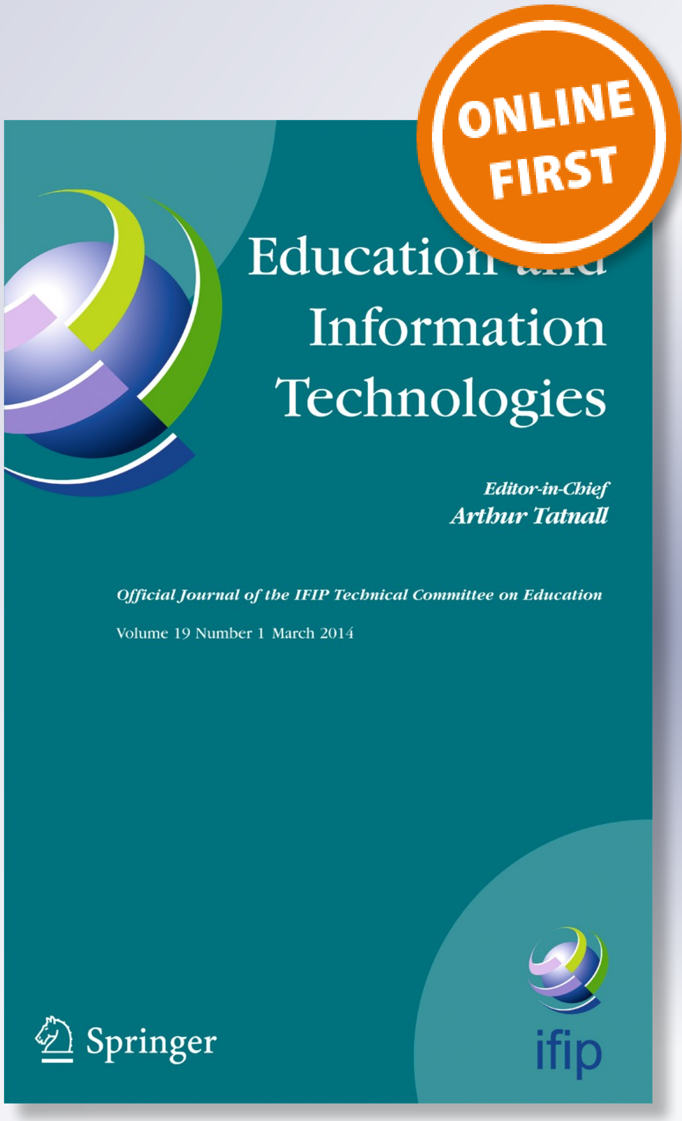

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Teacher design in teams as a professional development arrangement for developing technology integration knowledge and skills of science teachers in Tanzania

Ayoub Kafyulilo · Petra Fisser · Joke Voogt

Abstract This study investigated the impact of teacher design teams as a professional development arrangement for developing technology integration knowledge and skills among in-service science teachers. The study was conducted at a secondary school in Tanzania, where 12 in-service science teachers participated in a workshop about technology integration in science teaching and worked in design teams to prepare technology-enhanced biology, chemistry and physics lessons. Through collaboration in design teams, teachers were able to make science animations using PowerPoint and record videos to use in their teaching. The designed lessons were taught in the classroom and reflected upon thereafter by all teachers. In order to determine the change in teachers' technology integration knowledge and skills, data were collected before and after the professional development arrangement by using questionnaire, interview and observation data. Focus group discussion and reflection questionnaire data were used to assess teachers' experience of working in design teams at the end of the professional development arrangement. Findings showed an increase in teachers' technology integration knowledge and skills between pre- and post-measurements. Collaboration in design teams had the potential for teachers to share knowledge, skills, experience and challenges related to technology-enhanced teaching.

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1 Introduction

Technology integration in science and mathematics subjects is currently top priority in the education development programs of Tanzania (United Republic of Tanzania [URT] 2009). From 2002 the Ministry of Education and Vocational Training (MoEVT) endorsed that technology should not only be taught as a subject, but also be integrated as a pedagogical tool for teaching and learning in subject areas (URT 2007). Use of technology was expected to provide better learning outcomes in science and mathematics, and contribute to the improvement of the quality of teaching (URT 2009). The MoEVT considers technology as an important tool in addressing the potential shortage of science and mathematics teachers in the country, by providing teachers with the opportunity for synchronous and asynchronous communication with fellow teachers in other schools and with students. Teachers are expected to use technology as a tool for enhancing their own learning in addition to their students' learning in science and mathematics (URT 2009).

Although efforts to integrate technology in education as a pedagogical tool in Tanzania started in 2002, the resulting outcomes are not yet appealing (Swarts and Wachira 2010). In most cases technology is not integrated as a tool for instructional delivery. In limited circumstances, especially in private schools, technology is being used for teaching information literacy (Hare 2007). Swarts and Wachira (2010) report that computers are mostly confined to administration purposes and some limited uses for teaching basic computer knowledge. Voogt et al. (2009) argue that for teachers to use technology as an instructional tool, they need to learn the potential of technology and learn how to apply new pedagogical approaches. That is, teachers need to develop an understanding of the relationship between science subjects, instructional strategies, and the representations of particular science or mathematics topics by using technologies for demonstration, verification, and drill and practice (Niess et al. 2009). Science teachers in Tanzania are not yet integrating science, technology and teaching methods, and there is no established in-field teacher professional development program to develop these capabilities. Although teacher education colleges are preparing teachers to use technology in teaching (Kafyulilo, Fisser, and Voogt, 2011), studies from secondary schools report limited use of technology for instruction (Hare 2007; Swarts and Wachira 2010).

In an attempt to address the low uptake of technology for instruction; Authors (2011) introduced a professional development arrangement to pre-service teachers at Dar Es Salaam University College of Education to develop knowledge and skills for integrating technology in science and mathematics teaching. Their professional development program incorporated four important components: (1) a workshop to introduce the concept of technology integration in teaching, (2) participation in collaborative lesson design (cf. Agyei and Voogt 2012; Alayyar et al. 2011), (3) Microteaching (cf. Jimoyiannis 2010; Peker 2010; Voogt et al. 2009) and (4) reflection with peers (cf. Voogt et al. 2011; Peker 2010). The opportunity for pre-service teachers to participate in a collaborative lesson design with peers and reflect on the designed and taught lesson had an impact on their understanding of the interplay between technology, pedagogy and content. In addition collaborative lesson design, implementation and reflection offered an opportunity for pre-service teachers to interact and share knowledge, skills, and experiences of using technology in science and mathematics teaching (Kafyulilo, Fisser, and Voogt, 2011).

Building on studies by Agyei and Voogt (2012), Alayyar et al. (2011) and Authors (2011) which adopted teacher design teams for pre-service teachers, the current study was developed to investigate if this approach would also be successful with in-service science teachers. In the current study, teacher design teams were adopted as a professional development arrangement for developing in-service science teachers' knowledge and skills of integrating technology in science teaching.

2 Theoretical underpinnings

2.1 Technological pedagogical content knowledge (TPACK)

In this study, we consider technological pedagogical content knowledge (TPACK) as a conceptual framework for developing teachers' knowledge and skills in integrating technology in science teaching. The concept of TPACK emerged in 2005, when two studies were published (Koehler and Mishra 2005; Niess 2005) regarding the integration of technology with pedagogy and content. Koehler and Mishra (2005), Mishra and Koehler (2006) and Niess (2005) describe TPACK as a framework for describing the knowledge basis that teachers need to develop in order to effectively integrate technology in teaching. Jimoyiannis (2010) describes TPACK for science education as Technological Pedagogical Science Knowledge (TPASK). Jimoyiannis provides a range of educational environments and applications for science education provided through technology (e.g., simulations and modelling tools, microcomputer based laboratories (MBL), Web resources and environments, and spread sheets and databases) which offer a great variety of affordances for both students and teachers in science learning. According to Jimoyiannis (2010) TPASK for science teachers is different from the knowledge of a disciplinary expert (a physicist, chemist, or biologist), or a technology expert, and also from the general pedagogical knowledge shared by teachers across disciplines. Instead, it represents what science teachers need to know about technology in science. Jimoyiannis presents the knowledge requirement for science teachers to effectively integrate technology in science teaching (TPASK), which includes the knowledge of the pedagogical affordances of technology, knowledge and skills to identify pedagogical properties of specific software, knowledge and skills to evaluate educational software and ability to select tools supporting specific learning approaches. He further argues for teachers to develop the ability to support experimental practical work, use constructivist approaches and foster collaborative learning, scientific inquiries and scientific explanation by using technology. While we prefer to use the general TPACK model in this study, we make use of Jimoyiannis' understanding of TPASK for science within the context of Tanzania.

2.2 Teacher design teams

In this study, we adopted teacher design teams as a professional development arrangement for in-service teachers developing knowledge and skills of integrating technology in science teaching. Handelzalts (2009) describes a teacher design team as "a group of at least two teachers, from the same or related subjects, working together on a regular basis, with the goal to (re)design and enact (a part of) their common curriculum" (*p*. 7). This approach was considered promising for the development of teachers' knowledge and skills to integrate technology in teaching, because of the opportunity it offers to share knowledge, skills and experiences. Research (cf. Voogt et al. 2011; Handelzalts 2009) shows that in design team teachers have the opportunity to meet, evaluate their practices, and propose improvement measures. Tondeur et al. (2012), citing Angeli and Valanides (2009), argue that collaboration with peers provides a time-effective, high-challenge, low threat learning environment for teachers, contrary to many technology learning experiences that can induce anxiety and failure avoidance. Next to this, Voogt et al. (2011) argue that teachers' collaboration that aims to improve students' learning should not only focus on collaborative curriculum design but also on curriculum implementation as part of the activities of the teacher design team. Citing Deketelaere and Kelchtermans (1996), Voogt et al. (2011) argue that intense discussions and reflections in teacher design teams result in teachers' enhanced awareness of own norms and values, yielding an altered, broader view on what "good teaching" and being "a good teacher" mean.

Various approaches have been employed around the world to develop science teachers' technology integration knowledge and skills. However the most commonly used approach is learning technology by design (Koehler et al. 2007) in which the learners become designers of technology-enhanced lessons, albeit for the duration of the course, not merely by learning about practice, but also embodying a process that is present in the construction of artifacts. Learning technology by design is based on the design team approach and was adopted by Alayyar et al. (2011), where pre-service teachers participated in a workshop and worked in design teams of 3–4 to design technology-enhanced science and mathematics lessons. Similarly in Agyei and Voogt (2012), pre-service teachers worked in groups of two to design technology-enhanced mathematics lessons and subsequently taught those lessons to peers through microteaching. According to Agyei and Voogt (2012) and Alayyar et al. (2011), teachers' collaborative lesson design in design teams offers effective learning experiences for developing knowledge and skills in integrating technology in teaching.

In Tanzania, teacher collaboration has been reported as an effective professional development strategy. Studies carried out in Tanzania at the level of secondary education (Kitta 2004; Tilya 2003) and university level (Kafyulilo, Fisser, and Voogt, 2011; Nihuka and Voogt 2011) have reported appealing results of teacher collaboration during professional development. For example in the study by Kitta (2004), peer collaboration was an important component of the professional development arrangement as teachers could support one another by using different learning strategies such as discussion and collaborative work. Tilya (2003) reported teacher learning of technology integration through sharing experiences during the microteaching of technology-enhanced science lessons. Nihuka and Voogt (2011) reported positive effects of design teams in which university teachers developed e-learning modules for the Open University.

3 The professional development arrangement

Based on the theoretical underpinnings, this study adopted TPACK as a framework for describing the knowledge required for teachers to effectively integrate technology in science teaching and also adopted teacher design teams as a professional development arrangement for developing teachers' technology integration knowledge and skills. The intervention program consisted of an introductory workshop, lesson design in design teams, lesson implementation in the classroom, and reflection on the designed and implemented lesson. Such an approach is also reported in Jimoyiannis (2010), Peker (2010) and Tondeur et al. (2012). Although most of the studies which used this approach were conducted with pre-service teachers, this study adopted the approach for in-service science teachers.

4 Research questions

The main research question in this study was what is the impact of teacher design teams as a professional development arrangement for developing in-service teachers' knowledge and skills in the integration of technology in science teaching? This main research question was divided into three sub-questions:

1. What are teachers' perceived technology integration knowledge and skills before and after the professional development arrangement?
2. What are the observed teacher practices with technology-enhanced science teaching before and after working in teacher design teams?
3. What are the teachers' perceptions towards collaborative lesson design in teacher design teams?

The study adopted an embedded single case design. Teacher design teams were taken as cases and individual teachers were the units of analysis (Yin 2003).

5 Methodology

5.1 The context of the study

The study was carried out in a public secondary school located in Dar es Salaam, Tanzania. The school has over 3,000 students and approximately 110 teachers. Of the 110 teachers, 24 teach science and mathematics subjects. The school had a computer lab with approximately 30 computers, of which 18 were not working. The computers were donated by a Swedish development agency (SIDA) and are mostly used for administration purposes, such as test preparation and record keeping, particularly for students' test results. Classroom did not have computers, but there were possibilities to bring students to the computer lab for a science lesson.

5.2 Participants

The study involved 12 of the 24 total in-service teachers who teach Physics, Chemistry and Biology, among which 6 were male and female. The sample comprised of teachers with ages between 26 and 42 years old, with majority (9) being not older than 35 years, and were all computer literate. Ten teachers were university graduates, and two teachers had diploma in teacher education. The school's science teachers were informed about the components of the professional development program, and those interested participated in the study voluntarily. Participant teachers teamed up according to the subjects of their specialization; thus three teams of four teachers were made. Each team worked collaboratively to design and teaches one technology-enhanced lesson. The lessons were taught through team teaching approach.

5.3 Instruments

Six data collection instruments were used in this study: a questionnaire (TPACK survey), a reflection survey, an interview guide, a focus group discussion outline, a researchers' log book and an observation checklist. The use of different data collection approaches (teachers' self-reported data and observation data) was important for the triangulation purposes (Thurmond 2001).

5.3.1 TPACK survey

The TPACK survey was used to gather data on pre-service teachers' perceived knowledge and skills of integrating technology in science teaching before and after the professional development arrangement. The instrument was adopted from Schmidt et al. (2009) and Graham et al. (2009), and used a 5-point Likert scale: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree, and had an overall reliability of 0.93 Cronbach's alpha, which is very good according to De Vellis (2003). Examples of items and reliability for each TPACK component are presented in Table 1.

Table 1 Summary of the items and reliability in the TPACK survey instrument

TPACK constructs	Exemplary item	No. of items	Cronbach's α
Technological knowledge (TK)	I can use technology without problems	9	0.80
Pedagogical knowledge (PK)	I can use a wide range of teaching approaches	10	0.94
Content knowledge (CK)	I know about a lot of different approaches to solve biology/physics/chemistry problems	5	0.85
Pedagogical content knowledge (PCK)	I know how to select effective teaching approaches to guide students thinking and learning in biology/physics/chemistry	7	0.97
Technological content knowledge (TCK)	I can choose technology that enhances the content for a lesson I teach	9	0.94
Technological pedagogical knowledge (TPK)	I can use technologies to improve my teaching productivity	11	0.88
Technological pedagogical content knowledge (TPCK)	I can teach a lesson that combine science, technology and teaching approaches	16	0.97

5.3.2 Observation checklist

The observation checklist was used to assess teachers' practices with technology twice during lesson implementation. Items in the observation checklist were modified from Harris et al. (2010), Graham et al. (2009), and Tilya (2003) and had Three-point *scale*: 1=no, 2=no/yes, 3=yes. This instrument was administered before and during the intervention. Two teachers were observed before intervention and after intervention from each team. The observation checklist was rated by the researcher and an expert in science and educational technology. The inter-rater reliability (Cohen's κ) was calculated. The summary of the items and the inter-rater reliability are presented in Table 2.

5.3.3 Reflection questionnaire

The reflection questionnaire was administered at the end of the intervention to assess in-service teachers' opinions/attitudes towards learning of technology in teacher design teams. This questionnaire was adopted from Pineda et al. (2009) and some items were developed by the researchers to fit the research questions. The reflection questionnaire used a 5 point Likert scale: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5= strongly agree, and had an overall reliability of 0.88 Cronbach's alpha, which is very good according to De Vellis (2003).

5.3.4 Teacher interview

The interview guide was adopted from Handelzalts (2009) and Tilya (2003), and was used to assess teachers' experiences with design teams in developing technology integration knowledge and skills. The interview was administered at the end of the intervention. Examples of questions asked in the interview were, (1) How did you collaborate with other teachers to design and teach a technology-enhanced lesson? (2)

Table 2 Summary of items and inter-rater reliability for the observation checklist

Components	Exemplary item	No. of items	Cohen's κ
TK	[a]Technology selections are exemplary, given curriculum goal(s) and instructional strategies.	8	0.75
PK	[b]Teacher encourages learners to solve problems in their groups	7	0.74
PCK	[b]Teacher guides students' learning in order to get to the core of the content	5	0.86
TCK	[c]Teacher uses technology to allow students to observe processes that would otherwise be difficult to observe	5	0.67
TPK	[c]Teacher uses technology to interact and collaborate with students in the classroom	5	0.69
TPCK	[b]Teacher selects and uses technology applications to improve students' learning in the lesson s/he teaches	5	0.67

[a] Harris et al. (2010)

[b] Tilya (2003)

[c] Graham et al. (2009)

What technology integration knowledge and skills did you develop when collaborating in design teams? All interviews were coded by the first author of this article. To calculate inter-coder reliability, a random sample of four interviews out of 12 was coded by a second person who was involved in the study as an expert in science and educational technology. The inter-coder reliability was 0.80 Cohen Kappa, which according to Viera and Garrett (2005) indicates a substantial agreement.

5.3.5 Researcher's logbook

A researcher's logbook (Mclndoe and Hammond 2008) was maintained by the researcher throughout the study, from lesson preparation to classroom implementation of the designed science lessons. The logbook was comprised of notes that the researcher took during the professional development arrangement. This helped the researcher to keep a proper record of teacher behaviors and added to the information acquired through the other data collection instruments.

5.3.6 Focus group discussion

A focus group discussion was administered at the end of the intervention to assess teachers' attitudes towards teacher design teams as a professional development arrangement to develop technology integration knowledge and skills. Some of the questions in the focus group discussion were adopted from Handelzalts (2009), others were developed by the researcher to fit the context of this study and research questions. Examples of questions asked during the focus group discussion are (1) what are the main activities and issues that you have been able to accomplish through working in teams? (2) What do you consider to be the best features of effective collaboration in design teams? Two people, including the researcher, coded a randomly selected sample of one focus group discussion out of three, with an inter-coder reliability of 0.71 Cohen's Kappa, which indicates a substantial agreement (Viera and Garrett 2005).

5.4 Data analysis

Data from the TPACK survey, reflection questionnaire and the observation checklist were analyzed to compute descriptive statistics (means and standard deviations). The qualitative data from the interview and the focus group discussion were transcribed and translated from Kiswahili to English. The data from the interview and the focus group discussion were coded by using Atlas-ti software version 6.2. Both inductive and deductive coding approaches were used (Miles and Huberman 1994). In the inductive coding, coding schemes were generated from data while the deductive coding utilized coding schemes derived from the TPACK framework. Examples of the codes based on the deductive coding includes; TK, PK, CK, PCK, TPK, TCK, and TPCK (Koehler and Mishra 2009). Within these codes there were different "sub-codes" such as; students' activities, animations, video, PowerPoint slides, chemistry, physics, biology, etc. Examples of codes based on inductive coding include knowledge sharing, time, lesson design process, learning opportunities and team work.

Information recorded in the logbook was analyzed qualitatively using data reduction techniques. Major themes were identified and clustered (Miles and Huberman 1994).

6 Findings

6.1 In-service teachers' perceived technology integration knowledge and skills before and after the intervention

As shown from the data (Table 3), pre-intervention results showed high teachers' perceived CK, PK and PCK (M≈4.0) and average TK, TPK, TCK, and TPCK (M≈ 3.0). After the intervention, all TPACK components had mean values above 4.

During the interviews which were administered at the end of the intervention, teachers shared what they learned through their participation in the professional development program (Table 4).

As reported in Table 4, teachers learned various uses of technology such as animation, PowerPoint, and video in teaching some specific science topics; for example electrolysis in Chemistry, elasticity of materials in physics and first aid provision to a fainting person in biology (see next section for clarification). Teachers reported use of animation simplified the teaching of difficult topics such as electrolysis in chemistry. They argued that the use of animation made it easy to demonstration to students what occurs in the electrolytes at the positive and negative electrodes. For example a physics teacher stated, "I learned that the use of technology simplified the demonstration of some difficult topics such as electrolysis before engaging students into practical work". Additionally, one of the biology teachers said, "I used to teach through lecture method, but through this project, I learned how to use students' based activities and I realized that students' interests and attention to the lesson were enhanced" But a chemistry teacher said that, "I was not able to put colors on the drawing I made during the preparation of animation, my colleagues helped me to use the paint program to fill colors in the drawings," making clear that creating the animation was not always an easy task.

6.2 Observed teachers' practices before and after intervention

6.2.1 Notes from the researchers' log book

Physics teacher design team In the pre-intervention classroom, none of the physics teachers used technology in teaching; neither digital nor analog. All physics teachers

Table 3 Perceived technology integration knowledge and skills before and after the intervnetion (*N*=12)

TPACK components	Pre intervention M (SD)	Post intervention M (SD)
Technological knowledge	3.1 (0.43)	4.2 (0.42)
Pedagogical knowledge	4.0 (0.69)	4.6 (0.39)
Content knowledge	4.0 (0.56)	4.4 (0.61)
Pedagogical content knowledge	3.8 (0.66)	4.4 (0.61)
Technological pedagogical knowledge	3.1 (0.59)	4.2 (0.58)
Technological content knowledge	2.9 (0.67)	4.3 (0.56)
Technological pedagogical content knowledge	3.0 (0.83)	4.3 (0.55)

Scale: 1=strongly disagree, 2=disagree, 3=undecided, 4=agree and 5=strongly agree

Table 4 Interview results on technology integration knowledge and skills developed by teachers

Developed knowledge and skills		Physics				Chemistry				Biology			
		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
TK	Use of PowerPoint to design slides		x	x	x	x	x	x	x				
	Design of diagrams and animations with PowerPoint	x	x	x			x	x					
	Record videos by using a digital camera									x	x	x	x
	Use of internet to download materials								x				
PK	Use of learner centered teaching approaches						x			x			x
	Task based teaching							x					x
CK	Understanding Hooke's law of elasticity		x		x								
	Understanding electrolysis							x					
	Understanding biology topics taughts in different grade levels									x	x		
PCK	Methods to increase interaction between student-teacher and student-student when teaching physics or biology or chemistry lesson		x						x			x	x
TCK	Use of PowerPoint to present Hooke's law of elasticity			x	x								
	Use of PowerPoint to present a lesson about electrolysis						x	x					
TPK	Integration of students'practical work with animations	x		x			x						
	Application of PowerPoint in teaching and learning		x						x				
TPCK	Use of animation to demonstrate practical activities in physics				x								
	Use of animation to simplify the teaching of electrolysis topic						x		x				
	Use of video to teach about steps in first aid provision											x	x

lectured the class to teach, and students were only copying notes. During the intervention, the physics teachers designed a lesson about Hooke's law, in which they made an animation to demonstrate the extension of a spring in relation to weight. This animation was made with presentation software (MS PowerPoint), using custom animations in which they were able to add effects such as a motion path, the direction of the motion, emphasis etc. A still picture of the animation is presented in Fig. 1.

During classroom teaching of the technology-enhanced lesson, teachers used a video projector, a laptop computer, and a screen to present the lesson to 40 Form four students with ages between 15 and 16 years old.

Teachers began the lesson by asking the students to explain the characteristics of elastic materials and asked them to state Hooke's law. The animation was used to

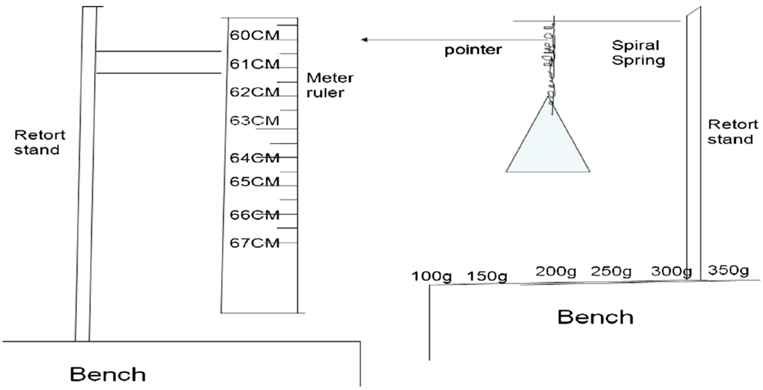

Fig. 1 A set up of the animation about Hooke's law to determine the elasticity of the material

demonstrate the extension of the spring against the weight. For every weight added, the spring extended downwards and the pointer read the distance in centimeters that the spring was extended. After the demonstration of Hooke's law through the animation, students were provided with paper worksheets which had data for length and weight and worked in groups of five to six to study the data and draw a graph of weight against extension.

Biology teacher design team Two teachers from the biology team were observed in the classroom prior to the intervention. One of the teachers taught a lesson about movement in animals and the other taught about growth (mitosis). Both teachers used a paper chart with pictures in their lessons. During the intervention, the biology teachers worked in a design team to design a lesson about first aid provision to a fainting person, via use of a video camera to film a role play. Students were organized and oriented on how to simulate the first aid provision procedures to a fainting person. The simulation was video recorded, and used for teaching. The designed technology-integrated biology lesson was taught to over 70 Form 1 students aged between 12 and 13 years old.

A video projector, laptop computer, and screen were used to present the lesson in the classroom. The lesson began with questions such as what would you do if your friend fainted in the classroom? This took the class to a short discussion of about 5 min. Then teachers asked the students to watch the video, and be able to answer questions that would follow. Teachers had developed some guiding questions for each stage of the video. The video began by showing a group of students having a discussion, then one of the students attempted to stand up and walk away from the group, but she fell down just when she stood up. At this point the teacher paused the video and asked students to discuss the first thing they would have done if they were in this situation. The same practice went on through the end of the video. Teachers concluded the lesson by asking the students to work in groups of five to six, to list the first aid provision procedures and explain what else could have done that was not presented in the video.

Chemistry teacher design team In the pre-intervention lesson, two teachers were observed in the classroom. One of the teachers demonstrated the explosion of sodium after contact with water. The other teacher used a lecture method. During the intervention, the chemistry team prepared an animation to demonstrate the electrolysis process.

They also used presentation software (MS PowerPoint) to make an animation of the movement of cations and anions in an electrolyte solution during electrolysis. The animation also demonstrated the evolution of oxygen gas and deposition of copper in the cathode and anode respectively.

The designed animation of electrolysis was taught to 42 Form three students aged between 14 and 15 years old. A laptop computer, screen, and video projector were used to teach the lesson. The lesson started with a discussion about electrolysis, what ions are available in the electrolyte solution, and what happens during the process of electrolysis. This was followed by the presentation of a step by step process of setting up an electrolyte circuit and the description of the process taking place during the electrolysis. This demonstration was followed by a practical work, which involved setting up an electrolyte circuit and observing the bubbles evolving from the electrolyte solution after connecting the battery. The lesson was concluded by asking students to work on the following assignment; "with the help of equations, explain the reactions taking place at cathode and anode".

6.2.2 Lessons observation

The lesson observations confirmed the findings of the logbook notes. Table 5 presents pre-intervention and post-intervention teaching. Pre-intervention results showed average teachers' PK and PCK (M≈2.0) and low TK, TPK, TCK, and TPACK (M≈1.0). After the intervention, all TPACK components were high, with mean values above 2.5.

6.3 Teachers' perceptions towards teacher design team

Having worked in design teams to design and teach technology-enhanced lessons, teachers were provided with a reflection questionnaire to assess their experience and perceptions towards working in teacher design teams (Table 6). Findings in Table 6 show that all components of the teacher design teams were ranked high, only time efficiency was perceived slightly lower than other components. Teachers reported in the focus group discussion that it was not clear on what to do and how to work in teams "*in the design team you are not sure of how long will the meeting take, you can plan to*

Table 5 Observed teaching with technology, before and after the intervention (N=6)

TPACK components	Pre intervention M (SD)	Post intervention M (SD)
Technology knowledge	1.2 (0.23)	2.6 (0.17)
Pedagogical knowledge	2.2 (0.35)	2.8 (0.08)
Pedagogical content knowledge	2.4 (0.34)	2.8 (0.08)
Technological content knoweldge	1.2 (0.40)	2.8 (0.15)
Technological pedagogical knowledge	1.2 (0.31)	2.6 (0.15)
Technological pedagogical content knowledge	1.4 (0.25)	2.7 (0.11)

These findings are reported in a three points Likert scale where 1=No, 2=Yes/No, 3=Yes

Table 6 Teachers' perceptions towards working in teacher design teams (N=12)

Components of the design teams	M	SD
Appreciation about the collaboration	4.6	0.38
Learning opportunities	4.8	0.32
Development of technology integration knowledge and skills	4.8	0.27
Opportunity for collaboration	4.7	0.37
Time efficiency	3.7	0.51

Scale: 1=strongly disagree, 2=disagree, 3=undecided, 4=agree and 5=strongly agree

spend 1 h, but you use up to 3 h" said a physics teacher. The biology teacher added that; "it was taking a long time to reach into agreement; I think this was caused by the novelty about technology integration. …even a small problem required a lot of time to discuss". She added that lack of agreement among team members caused some of them to be skeptical about the time to be spent in lesson design. Overall, teachers appreciated the opportunity to share knowledge, skills, abilities and experiences of technology integration in design teams. "*We shared experiences, ideas and we challenged each other during the design of the lesson … this made the work simpler. …all difficulties were easily sorted out in a team*" said a chemistry teacher.

Teachers from all teams acknowledged the opportunity for knowledge sharing and the quality of lesson they designed in teams. This is illustrated in a quote from the physics team "*we think the outcome of the lesson we made was a result of the discussions we had in the design teams. If it was not the design team probably we couldn't have made such a good lesson*". Additionally, the chemistry team had the following opinion regarding teacher design teams "team members had different ideas which were shared during the lesson design process. For example as a team we agreed about the animation we were going to make and students' activities related to the kind of animation we developed".

To make a design team more effective, teachers proposed features which they considered important for successful collaboration to design technology-enhanced lessons. These features were recommended as guidelines for future professional development programs that involved collaboration in design teams. Features which were most mentioned by teachers as important for effective collaboration and learning in design teams are presented in Table 7. The features proposed by teachers in Table 7 are based on what they experienced in their own teacher design teams and what they thought important for future improvement.

7 Discussion

This study examined whether learning technology by design in teacher design teams is an effective approach for in-service science teachers, in the specific context of secondary science education in Tanzania. Findings from this study suggest that teacher design teams are a promising professional development arrangement for developing teachers' technology integration knowledge and skills.

Table 7 Proposed features for effective collaboration in design teams

Features	Phy	Che	Bio
Teachers should set goals and agree on how to accomplish their goals	x	x	
Every team should have a team leader who will plan and lead the team meetings			x
If necessary, there should be a division of roles amongst team members	x		x
All teachers should be well informed of the task to be accomplished in the team		x	x
There should be a discussion to evaluate the potentiality of each idea raised up in the team			x
There should be an agreement on how and when to accomplish a given task	x	x	
There should be a common agreement on what to do, and how to do it; no one should dominate team decisions	x	x	x
There should be a good communication system between members of the group (most preferred phone calls).	x		
Everybody should be responsible for the agreed tasks to be accomplished	x	x	x

The findings presented in this study reflect what Jimoyiannis (2010) describes as TPASK, in which technology integration in science education is expected to change not only the presentation of the content, but also the learning process; shifting the emphasis from teacher-centred instruction to interactive teaching approaches. As depicted in Jimoyiannis (2010) about the competencies that teachers need to develop in order to integrate technology in science teaching; science teachers who participated in this study were able to organize scientific facts (electrolysis), theories (Hooke's law) and practices (first aid provision). Also, they were able to use multiple representations of scientific knowledge such as pictures, animations and videos to teach physics, chemistry or biology. Teachers who participated in this study were able to use PowerPoint program to model specific Physics and Chemistry topics. For example the chemistry team used PowerPoint to demonstrate the movement of ions in the electrolyte solution. This approach helped to expand the students' understanding of the process that takes place during electrolysis. They were also able to use PowerPoint to present virtual experiments such as Hooke' law, and used video to present first aid procedures. What teachers were able to demonstrate in this study also relates to what Koehler et al. (2007) and Niess et al. (2009) advocate about teacher professional development, arguing for the need to develop not only their knowledge of the content (science) and technology, but also the knowledge of instructional strategies and the representation of a particular science topics by using digital technologies.

Changes in teachers' technology integration knowledge and skills was contributed by several factors which Jimoyiannis (2010) describe them as components of the science TPASK curriculum. According to Jimoyiannis, teachers can develop lesson materials through practical training, learning by doing, collaboration, classroom presentation, and discussion. Similarly, this study was organized into a workshop (TPACK training), collaboration in design teams, classroom implementation of the designed lessons, and reflection with peers based on the feedback from students and practical experiences with technology. Findings revealed that, through collaboration in design teams, teachers learned from each other and from their practices as they designed and implemented the technology-enhanced science lessons within their context. As argued in Voogt et al. (2011), teacher learning can be effective if it is situated in a meaningful context, with teachers actively engaged in their own learning process and collaborating with their peers (cf. Putnam and Borko 2000; Whitcomb et al. 2009). In this study teachers used the available resources within their school context and actively engaged in a collaborative design and implementation of technology-enhanced lessons. Through collaboration, teachers reminded each other about the concepts of technology integration they learned from the workshop at the beginning of the professional development program. They also learned new science concepts from their peers through sharing of experiences about technology, pedagogy and content as applied in the teaching and learning process.

The findings of this study can be of great importance for professional development initiatives aimed at developing science teachers' technology integration knowledge and skills in Tanzania. Since 2002 the government of Tanzania, in cooperation with international development agencies, has invested a considerable amount of money in the purchase of technological tools for schools and teacher training colleges, and training of in-service and pre-service teachers on technology integration in science and mathematics teaching (URT 2009). Despite all these efforts, a recent study by Swarts and Wachira (2010), reported a low uptake of technology for instruction, despite the availability of technology in schools. This study demonstrated that Teacher Design Teams might be a more successful approach to prepare teachers for the use of technology in their teaching.

Although teacher design teams as a teacher professional development strategy is not common in Tanzania, collaboration for social issues is inherently a Tanzanian culture. Tanzania's first president, Julius Nyerere (1922–1999) implemented the Ujamaa system in 1967 as a way to organize social care and education in Tanzania's local communities, and although the Ujamaa system does not exist anymore, collectivism is still an important cultural characteristic of Tanzania (The Hofstede Centre nd.). Collaboration is a routine in the schools, but it is mostly focused on activities other than academic. Teachers collaborate in social affairs but not in the teaching. Introduction of design teams was an expansion of the areas of collaboration within the school.

8 Conclusion

The findings of this study indicate that teacher design teams are a promising professional development strategy for developing teachers' technology integration knowledge and skills. However, teacher design teams could be more effective if there could be substantial support to guide teachers' collaboration in teams and the design of technology integrated science lessons. Teachers didn't exactly know how to go about the collaboration in the design teams. This made it difficult for them to organize themselves in design team meetings. According to Bakah (2011), working in design teams is always challenging to teachers in terms of agreement and time planning. Thus, they need guidelines to guide their decisions. Teachers also experienced difficulties in the design of technology-enhanced lessons as they had no exemplary lessons which could help them in getting a clear picture of the goal of their learning (van den Akker 1988; Voogt et al. 2009). Additionally, the lesson design process was difficult for some teachers as they experienced challenges in working with technology, e.g., they encountered difficulties with the design of animations, and the editing of videos. There were also difficulties in choosing the adequate student activities which can be supported by technology. In a follow-up study we will implement a support system to help teachers to design technology-enhanced lessons. This support system will consist of

1. Expert-for enhancement of teachers' technological and pedagogical knowledge and skills, we propose the availability of the expert who can help teachers to overcome the challenges of technology during the lesson design and lesson implementation process.
2. Online learning materials-during the design of technology-enhanced lessons, teachers used presentation software to make animations for their lessons. This process was difficult and time consuming to teachers. Therefore we propose the adoption of ready-made science learning materials which are available online, example online animations, videos and pictures.
3. Exemplary lessons-we propose the exemplary lessons to provide a starting point for teachers' lesson design in design teams. Exemplary lessons can help teachers in getting a clear picture of the goal of their learning, provide them with the necessary background information and support them while practicing what they learned from the workshop (Voogt et al. 2009).
4. Collaboration guidelines-In this study we also recommend collaboration guidelines that can be developed in line with features for effective collaboration which are proposed by teachers in this study.

Moreover, this study presents some promising results of the teachers' collaboration in design teams in developing technology integration knowledge and skills. However, the findings presented in this study are based on one school with a specific technology infrastructure and involved only 12 science teachers. Other schools might have a different technology infrastructure or different possibilities for working in design teams. It is therefore recommended to further explore the potential of teacher design teams for teachers' professional development to integrate technology in science teaching in Tanzania.

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