Pre-service teachers' competencies for technology integration: Insights from a mathematics-specific instructional technology course

Douglas D. Agyei
University of Cape Coast, School of Physical Sciences, Department of Mathematics & Statistics
Cape Coast, Ghana.
Email:d.d.agyei@utwente.nl

Joke M.Voogt
Department of Curriculum Design and Educational Innovation, Faculty of Behavioural Sciences,
University of Twente, Postbus 217,7500AE
Enschede, The Netherlands.
Email:j.m.voogt@utwente.nl

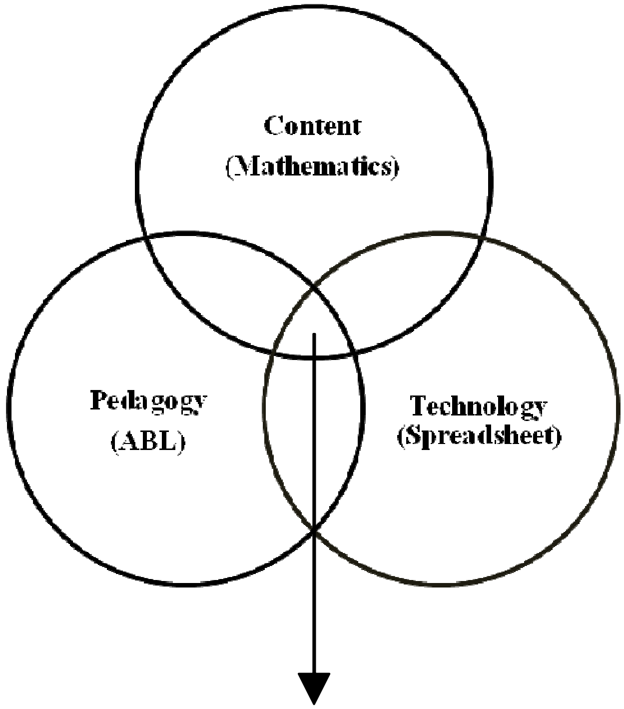
Abstract: A combination of various measures (self-report, learning outcomes and written reports) was employed to investigate 104 pre-service teachers' competencies in spreadsheet integration after enrolling in an Instructional Technology course. The pre-service teachers engaged in a "learning technology by design" approach in which they worked in design teams to develop spreadsheet-enhanced solutions to authentic mathematical problems. Their developed competencies were reported in their evolving lesson outcomes (TPACK evidence in the analysis of lesson plan product and observed instruction) and self-reported TPACK. The learning outcome provided specific information and concrete representations of what the pre-service teachers could actually do with technology as a result of their TPACK development. The study showed that, the teachers developed and improved their competencies in technology integration as a result of strategies used in the design of the technology integration course.

Introduction

In spite of positive impact of the use of technology on students' mathematics achievement (Beauchamp & Parkinson, 2008; Bottino & Robotti, 2007), evidence suggests that pre-service teachers do not feel prepared to effectively use technology in their classrooms (e.g. Kay 2006). Recent calls have indicated that to prepare pre-service teachers for effective technology integration, teacher education programs need to help them to build knowledge of good pedagogical practices, technical skills, and content knowledge, as well as how these concepts relate to one another (Koehler & Mishra, 2009). Kay (2006), indicated that there is no consolidated picture on how to effectively introduce technology to pre-service teachers to date. A comprehensive description and evaluation of strategies is a necessary step to guide researchers and educators. The purpose of this paper is to explore the impact of implementation strategies applied in designing mathematics-specific Instructional technology course on pre-service teachers' technology competencies. The study has been conducted in one of the major pre-service teacher preparation programs in Ghana; and although the government of Ghana has put in place support systems in schools to facilitate access to computers, lack of ICT infrastructure continues to be an issue in most mathematics classrooms. Schools lack common mathematical software (such as derive, graphic calculus, geometer's sketchpad etc) used for teaching mathematics (Agyei & Voogt 2011a, b).

The Mathematics-specific Instructional Technology Course Program

In this study TPACK has been used as a conceptual framework to determine pre-service teachers' knowledge and skill (and alongside a measure of their attitudes towards computer use as a learning tool) to examine the pre-service teachers' technology integration competencies as they design and enact activity-based lessons supported with technology in an Instructional Technology course. As shown in Figure 1, the technology (TK_{ss}) learned by the pre-service teachers were spreadsheet applications for mathematics. This general software is readily available and user friendly for mathematics teachers and students. The pedagogical knowledge (PK_{ABL}) examined in this study was Activity-Based Learning (ABL) pedagogical approach. The ABL approach was used to ensure that teaching and learning was based on hands-on activities.Content knowledge (CK_{maths}) was mathematics which was the pre-service teachers teaching subject area.



Technological Pedagogical Content Knowledge for spreadsheet-supported ABL in mathematics (TPACK)

Figure1: Framework of TPACK for this study

In the study, pre-service teachers' knowledge and skills which are needed to teach spreadsheet supported ABL lessons in mathematics was operationalised as their TPACK, and consists of the following specific knowledge and skills:

- Content knowledge (CK_{maths}): the knowledge about mathematical concepts.
- Pedagogical Knowledge *(PK_{ABL})*: knowledge and skills about applying ABL teaching strategies.
- Technological Knowledge (TK_{ss}): knowledge and skills about use of spreadsheet its affordances and constraints.
- Pedagogical content knowledge (PCK_{ABL}): the knowledge and skills of how to apply ABL to teach particular mathematics content.
- Technological content knowledge *(TCK_{ss}):* the knowledge and skills of representing mathematical concepts in a spreadsheet.
- Technological Pedagogical Knowledge *(TPK_{ABL}):* The knowledge and skills of how to use spreadsheets in ABL.
- Technological pedagogical content knowledge ($TPCK_{maths}$): the knowledge and skills of representing mathematical concepts with spreadsheet using *ABL*.

To understand and appropriately determine competencies to integrate technology into their lessons, pre-service teachers' attitudes towards technology is an important factor, alongside their knowledge and skills.

The 14-week course required pre-service teachers to attend one-two hours lectures and one-two hours laboratory sessions per week. Table 1 presents an overview of the Design Teams (DTs) activities in the IT program in relation to strategies for developing technology integration competencies.

Table 1: Outline of the Instructional technology course and strategies for technology integration

DT activities	Activity	Strategy	Integration competencies	Time frame

Introduction to technology-based possibilities of teaching mathematics	l/ls	Aligning theory and practice	$TPCK_{maths}$	4 weeks
Introduction to learning by design (collaboration)	l	Aligning theory and practice	-	
Introduction to computer skills(and spreadsheets in particular)	l/ls	Aligning theory and practice Collaborating with peers	TK_{ss}	
Introduction to TPACK concept	l	Aligning theory and practice	$TPCK_{maths}$	
Introduction to learner centred approaches (and ABL of teaching maths)	l	Aligning theory and practice	PK_{ABL} /PCK_{ABL}	
Introduction/demonstration of ABL supported by spreadsheet (exemplary material) and discussion	l/ls	Aligning theory and practice Modelling how to use technology	$TPCK_{maths}$	
Scouting spreadsheet techniques that support mathematics teaching	ls	Aligning theory and practice Collaborating with peers Learning technology by design Modelling how to use technology	TPK_{ABL}	5 weeks
Development of mathematics activities supported by spreadsheets and lesson development	ls	Aligning theory and practice Collaborating with peers Learning technology by design Modelling how to use technology	TCK_{ss}	
Teaching of activity-based lessons supported by spreadsheets to peers/researcher	ci	Aligning theory and practice Scaffolding authentic technology experience	$TPCK_{maths}$	5 weeks
Revision of the developed lesson materials based on feedback	ci/ls	Aligning theory and practice Learning technology by design	$TPCK_{maths}$	

l = lecture; ls = laboratory session; ci = classroom implementation

To complete their semester's long project, 104 pre-service mathematics teachers worked in DTs of four to identify mathematics topics (concept) from the SHS curriculum to be taught with technology, identified appropriate spreadsheet applications for the topic; designed and developed appropriate learning activities based on a learner-centred approach; incorporated activities in lesson and planned instructional strategy to be utilized in teaching their lessons accordingly. Eight teams presented their lessons in the middle of the course (6-7th week) and at the end to the peers and instructor. The lessons were taught in a classroom with a computer and a LCD projector available to the teacher. Based on their experiences and feedback these same teams and eight others presented their lessons at the end (12 -14th week) of the IT programme. The researcher's roles were mainly facilitative and demonstrative during the lecture sessions. It was more consultative during the lab sessions.

Instruments

Four different instruments were used in this study to assess TPACK development of the pre-service teachers. Table 2 gives a general overview of the different instruments used, the purpose and their stage of administration during the IT course.

Table 2: Overview of instruments and their stages of administration.

Instrument	**Construct**	**Measurement Type**	**TPACK data**		**Stage of Administration**		
			Source	Type	B	M	E
Lesson Plan Rubric	spreadsheet integration competence	Performance assessment	Team	Artefact		✓	✓
TPACK Observation Rubric	spreadsheet integration competence	Performance assessment	Team	Observable		✓	✓
Design Team	developing	Reports	Team	Artefact			✓

Reports	spreadsheet Integration Competence						
TPACK Survey	self-confidence of spreadsheet integration competence	Survey	Individual	Self-report	✓		✓
TAC Survey	self-belief of spreadsheet integration competence	Survey	Individual	Self-report	✓		✓

* B= Before, M = Mid, E= End of Instructional technology course

Findings

Lesson Plans

The results of the analysis for the teachers' lesson plan artefacts as presented at the end of the course by the two categories of teachers: teachers who taught their peers (further referred to as peer teachers (PTs)) and teachers without peer teaching experience (further referred to as teachers without peer teaching (NPT) are presented in Table 3.

Table 3: Descriptive statistics for end-TPACK mean score of Pre-service teachers' lesson plan artefact (n=8).

Lessons (with peer teaching)		Lessons (without peer teaching)	
Lessons	Lesson Plan score	Lessons	Lesson Plan score
Enlargement	15.30	Pie Chart	14.30
Statistics	16.70	Logarithmic Functions	15.30
Simultaneous Linear Equations	16.00	Linear Programming	14.30
Regular Polygons	17.00	Modular Arithmetic	14.00
Matrices	15.50	Quadratic Functions	13.00
Straight lines	16.50	Trigonometry	14.00
Plane Goemetry	16.00	Bearings	15.00
Linear Equations	18.00	Rotation	15.00
All lessons	16.38	All lessons	14.36

The results indicate relatively high TPACK score for lesson artefacts in which the teachers did a peer teaching as compared to artefacts in which no peer teaching was done. A non-parametric t-test confirmed significant ($P< .0001$) difference between the two lesson categories with a large ($d=1.52$) effect size. Feedback from peers and instructors which was directly related to their topics was a possible reason for improved scores of pre-service teachers who taught the peers in the first instance. Another possible reason was the authentic technology experiences as a result of the hands-on teaching try-out by these teachers.

Lesson Enactment

The critical factor of the evaluation posed a question of whether the pre-service teachers demonstrated TPACK in their lesson implementation. As was observed, the PTs used their lesson plans to guide class instruction using "interactive demonstration" in a spreadsheet environment. The use of the spreadsheet gave students greater opportunities to verify results and consider general rules, make links between spreadsheet formula, algebraic functions and graphs, analyse and explore number patterns and graphs within a shorter time. The PTs during their first teaching try-out (mid of the IT course) in particular, found lots of difficulty using the spreadsheet to develop mathematical concepts well to support their students 'understanding. For instance it was difficult to illustrate that as the absolute value of m increases the graph of $y = mx + k$ become steeper and vice –versa in the lesson on

Linear Equations. Apparently, what was difficult for the students was to connect the resulting changes in the graph (which is wider or steeper?) to changes in the numerically values (teachers displayed graph after graph on the same spreadsheet when the parameters were altered). Such similar difficulties were encountered in the other lessons as well. The corresponding subsequent lessons implemented at the end (second teaching try-out) of the IT course were less of a struggle. For instance on *Linear equations*, the teacher was able to present the concepts better by demonstrating the different graphs with corresponding changing values of the parameters on the same spreadsheet. The results suggest that the teachers' knowledge and skill developed and improved as the IT course progressed and was further observed in the significant difference ($p<0.0001$, $d=7.9$) in respondents' overall mid ($M=36.11$, $SD=0.753$) and end ($M=42.39$, $SD=0.834$) lesson mean scores. The improved observed lessons suggest that the results and insights (peer assessment and feedback) learned from the first teaching try-out as well as authentic technology experienced gained from the teaching might have served as necessary inputs for the teachers in revising and implementing their designs in the second try-out.

Pre-service Teachers' Perceived Technology Integration Competencies

Table 4 reports on the differences between post-test mean scores of the TPACK components for both categories of teachers (PT and NPT). The results showed that significant differences existed in mean scores in all constructs in favour of the teachers who did a teaching try-out with peers. It appears the peer teaching experience in which the teachers engaged themselves in additional planning and preparation informed their knowledge and skill and this was pronounced in spreadsheet-related constructs: TK_{ss} ($d=0.79$), TPK_{ABL} ($d=0.80$), TCK_{ABL} (0.67) and $TPCK_{maths}$(0.90) which required teachers to revise the role of the spreadsheet in their designs for successful implementation.

Table 4: Mean score responses for end-TPACK Subscales of lessons with (and without) teaching try-out (N=104)

Factor	PT *Mean (SD)*	NPT *Mean (SD)*	P	Effect size
TK_{ss}	4.13 (0.30)	4.41(0.40)	0.005*	0.79
CK_{maths}	4.44 (0.58)	4.52 (0.40)	0.049*	0.15
PK_{ABL}	4.33 (0.32)	4.50(0.43)	0.027*	0.45
PCK_{ABL}	4.36(0.46)	4.48(0.55)	0.031*	0.24
TCK_{ABL}	4.10 (0.31)	4.34(0.40)	0.008*	0.67
TPK_{ABL}	4.21 (0.29)	4.45(0.31)	0.001*	0.80
$TPCK_{maths}$	4.15(0.28)	4.43(0.34)	0.001*	0.90

* *Significant at the 0.05 level*

Comparing the teachers attitudes towards computer use, similar results were observed in dimensions regarding teachers' lack of anxiety: peer teaching ($M=4.22$, $SD = 0.583$), without peer teaching ($M=4.05$, $SD = 0.588$) and instructional productivity: peer teaching ($M=4.22$, $SD = 0.583$) without peer teaching ($M=4.05$, $SD = 0.588$). The differences were significant: lack of anxiety ($p=0.041$, $d=0.29$) and instructional productivity ($p=0.049$, $d=0.19$).

The Contribution of the Instructional Technology Course to Pre-service Teachers' Technology Integration Competencies Learning

Table 5 enumerated various reasons that contributed to teachers 'development of technology integration competencies.

Table 5: Pre-service teachers perceived usefulness of the strategies in IT course (N=26)

Strategy	NPT (N=18) (100%)	PT (N=8) (100%)
Importance of Collaborative Design Team strategy in lesson design	17(94.4%)	8 (100%)
Usefulness of Learning technology by doing approach in developing competencies	15 (83.3%)	7 (87.5%)
Effectiveness of mixture of theory during lectures and practical during labs	16 (88.8%)	8 (100%)

Teaching try-out usefulness with technology	8 (44.4%)	8 (100%)
Usefulness of feedback from peers and instructors in lesson revision	13 (72.2%)	8 (100%)
Use of exemplary materials in enhancing technology competencies	18 (100%)	8 (100%)
Use of demonstration by the lecturer was a good example and gave practical insight of what to design	16 (88.8%)	8 (100%)

Despite appreciating the importance of the strategies in the IT course and the role they played in enhancing their TPACK, the teachers admitted encountering some challenges in the instructional design process. They reported having difficulty in applying their own abilities in an unknown skill domain as novice teachers in technology use. As a result most teams might have adopted strict use of the exemplary materials which could explain the relatively high values reported (NPT=16; PT=8).The following problematic and difficult areas they had experienced during the design of their lesson were also reported: designing authentic learning activities for their chosen topics (NPT=11; PT=4) as well as selecting and matching appropriate integrating spreadsheet tools and relevant resources in designing mathematics learning activities (NPT=13; PT=6).

Conclusions

This paper employed different strategies in training pre-service teachers (in an IT course) to integrate technology into their future classrooms. Researchers learned that prior to the technology course experience; pre-service teachers were limited in their competencies in integrating spreadsheet in teaching their mathematics-specific content. After the teachers' participation in the semesters' IT course, their technology integration competencies improved as were reported in their self reported and learning outcome TPACK measures. In spite of drawbacks, findings of the study showed that the use of content representations and mathematic-specific strategies seems to be one that was central to developing pre-service teachers' TPACK. The study contends that in designing a subject-specific teacher education program to prepare pre-service teachers in Ghana (or similar context) to integrate technology in teaching, program designers should deliberately create experiences in which: i. conceptual or theoretical information would be linked to practice so that pre-service teachers can understand the reason behind using technology; ii. collaborative design (in which pre-service teachers work with peers) should be a useful support for teachers' to develop their competencies; iii. scaffolds and authentic technology experience such as teaching tryouts should be included; such an activity has the tendency to reduce pre-service teachers anxieties about computers thereby increasing their enthusiasm to use them in instruction; iv opportunities where teacher can learning technology by design should be created; and v. modeling how to use technology should be an integral component; using demonstrations and exemplary materials are options, but caution should be taken to ensure that exemplary materials provide meaningful and effective technology examples.

References

Agyei, D.D., & Voogt, J.(2011a). ICT use in the teaching of mathematics: Implications for professional development of pre-service teachers in Ghana. Education and Information Technologies,16(4),423-439.

Agyei, D. D., & Voogt, J. M. (2011). Exploring the potential of the will, skill, tool model in Ghana: predicting prospective and practicing teachers' use of technology. Computers & Education, 56, 91–100.

Beauchamp, G., & Parkinson, J. (2008). Pupils' attitudes towards school science as they transfer from an ict-rich primary school to a secondary school with fewer ict resources: Does ICT matter? *Education Information Technology, 13,* 103-118.

Bottino, R. M. & Robotti, E. (2007). Transforming classroom teaching and learning through technology: Analysis of a case study. *Educational Technology & Society,* 10(4), 174-186.

Kay, R. H. (2006). Evaluating strategies used to incorporate technology into pre-service education: a review of the literature. Journal of Research on Technology in Education, 38,383–408.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? Contemporary Issues in Technology and Teacher Education, 9(1), 60–70.