Why don’t learners achieve when using technology?

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Integrating technology in the classroom is not an easy process. Two different kinds of technologies were introduced to 214 Grade 10 physical science learners in order to understand kinematic graphs. Their TUG-K pre- and post test average were 34.5% and 39.3% respectively. Reasons for this underachievement had to be investigated because research indicates that learners are more motivated when their learning is supported by technology. It was decided to look at the multifaceted process when technology is introduced in the classroom. This paper analyses the dynamic equilibrium among three elements namely content, pedagogy and technology by illustrating what it means to use 2 different kinds of technologies in the teaching of graphs. This was illustrated by using the moving man and go motion indicating how complex the process is to choose the relevant technology, know what it can do and how to implement it for effective teaching. These findings hold implications for pre-service teaching and professional development.

Background

The availability of technology in everyday life such as banking, industries and telecommunications makes it impossible to ignore in schools. There is research evidence that learners are more motivated when their learning is supported by ICT (Newton & Rogers, 2001; Trey and Khan, 2008, Finkelstein, *et al.,* 2005). The South African Government is making efforts to integrate e-learning into the South African curriculum (DOE, 2003) and teachers have to implement it.

Two different kinds of technologies were introduced to 214 Grade 10 physical science learners in order to understand kinematic graphs. Their TUG-K pre- and post test average were 34.5% and 39.3% respectively. Reasons for this underachievement had to be investigated the multifaceted process when technology is introduced in the classroom were investigated.

Teaching is a highly complex activity that draws on many kinds of knowledge (Mishra & Koehler, 2006). However, teachers do not only need subject matter knowledge, they also have to know the order in which the topics should be presented, how to introduce them, what demonstrations to employ, what questions to ask, how to respond to specific student responses, what lab activities to adopt, how to assess what students learn and how to apply the subject matter to the world outside. In addition they also must know the major research in teaching and learning as well as the availability of learning resources, computer software, videotapes, books etc. (Tobin & McRobbie, 1999).

This paper analyses the dynamic equilibrium among three elements namely content, pedagogy and technology by illustrating what it means to use 2 different kinds of technologies in the teaching of graphs.

Introduction

Historically the knowledge base of teaching was on content knowledge of the teacher (Shulman, 1986; Veal & MaKinster, 1999) and on general pedagogical classroom practices (pedagogy knowledge) independent of subject matter (Ball & Mc Diarmid, 1999).

Content knowledge is the teachers understanding of the substantive structure of the subject (Shulman, 1987). Gess-Newsome, (1999b) did a review on the literature on secondary teachers' subject matter knowledge and beliefs and identified five categories of subject matter knowledge, namely conceptual knowledge, subject matter structure, context specific teaching orientations, nature of discipline and contextual influences on curricular implementation. The last two were excluded for the purpose of this paper. The most relevant findings are; the stronger conceptual knowledge the more detailed knowledge and more connections and relationships to other topics, experienced teachers are more likely to hold subject matter structures that are coherently structured and rich in relationships but may resist new content orientations. (CK and SMK are interlinked and no distinction was made between the two terms in this study).

Pedagogical knowledge (general) (PK) encompasses the broad principles on which the conduct of teaching is based, for example, approaches to classroom management (Shulman, 1987). PK consists of classroom organisation and management, instructional models and strategies, classroom communication and discourse as well as personal pedagogical knowledge which include teaching experience and personal beliefs and perceptions about teaching (Morine-Dershimer & Kent, 1999).

Teachers cannot only rely on their content knowledge and general pedagogical classroom practices; they also need knowledge about *how* the subject matter can be taught effectively and a term "pedagogical content knowledge" (PCK) was introduced   (Shulman, 1987). PCK is defined as " a special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding "(Shulman, 1987, p.8). At the heart of PCK is the manner in which subject matter is transformed for teaching (Mishra & Koehler, 2006)

Teacher knowledge

Grossman (1990) designed a model of teacher knowledge with four components; SMK, general pedagogical knowledge, PCK and knowledge of context. In this model PCK is presented as the central domain, which reciprocally interacts with the other domains. Magnusson, Krajcik and Borko (1999) argue for the uniqueness and importance of PCK within science education research and teacher preparation. They argue on the existence of PCK as a separate domain of knowledge including science curriculum, student understanding of specific science topics, assessment, instructional strategies for teaching science and orientations toward science teaching.

Opposed to this so-called transformative model, in which PCK is a transformation of different knowledge domains into a new domain ("a compound"), the integrative models do not present PCK as a knowledge domain on its own. In these models teaching is seen as an act of integrating knowledge of the subject, pedagogy and context ("a mixture") (Gess-Newsome and Lederman, 1999).

William Carlsen, 1999 examined PCK using structural and post structural tools. He indicated that PCK is a form of teacher knowledge, and Figure 3 is one view of the domains of teacher knowledge.

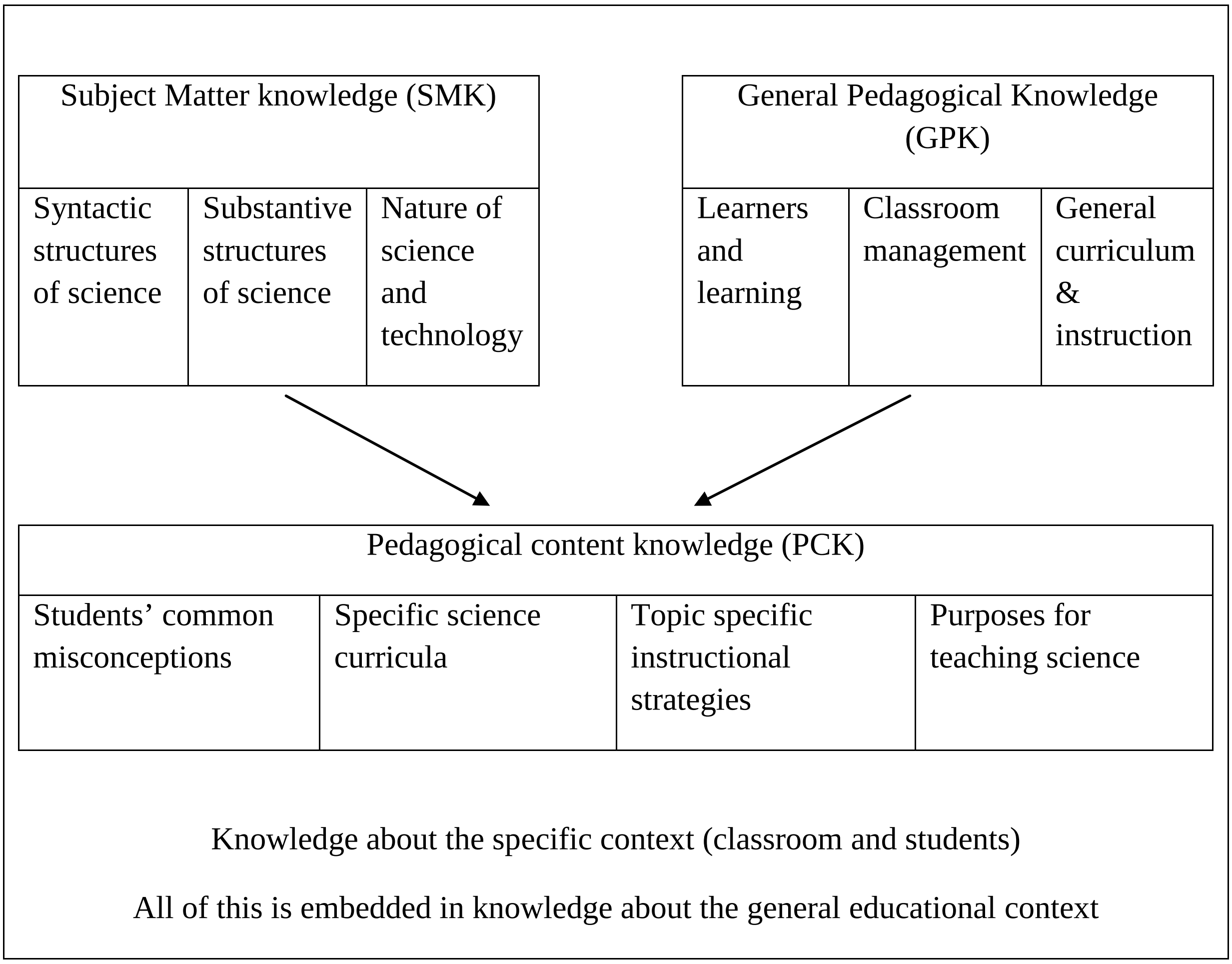

Figure 1: Domains of Teacher Knowledge (Carlsen, 1999)

Domains of teacher knowledge differ among the papers Shulman wrote or co-authored (Carlsen, 1999). However, the 7 identified knowledge bases needed for teaching namely, subject content knowledge, pedagogical content knowledge, pedagogical knowledge, curricular knowledge, knowledge of students, knowledge of context and knowledge of educational goals are commonly used (Shulman, 1987) and are also represented in figure 3.

Teachers' internal structure of knowledge cannot be known but can be expected to support a relationship to external representations (Hiebert & Carpenter, 1992). Therefore, Rollnick

(2010) represents a model that integrates teachers' internal knowledge domains to produce the visible product of integration of these domains in the classroom, referred to as manifestations including teacher beliefs as an underpinning factor influencing the teacher's knowledge domains. In her model the following domains of teacher knowledge is included; SMK, general pedagogical knowledge, knowledge of context, knowledge of students. Manifestations of teacher knowledge includes; representations, curricular saliency, explanations, interactions with students, topic specific strategies. In this study no distinction has been made between domains of teacher knowledge and its manifestations as seen in table 1.

Table 1 gives a summary of the discussed domains of teacher knowledge. The following domains have been combined into instructional strategies; subject matter structure, topic specific strategies and curricular saliency.

Knowledge domains and manifestations	**Shulman 1987**	**Grossman 1990**	**Magnusson, Krajcik & Borko (1999)**	**Carlsen (1999)**	**Rollnick 2010**
Subject matter	X	X		X	X
Student understanding	X	X	X	X	X
Orientations towards science teaching	X	X	X	X	X
Science curriculum	X	X	X	X	X
Assessment			X		X
Instructional strategies	X	X	X	X	X
Resource that can mediate learning /representations					X

Table 1: Summary of domains of teacher knowledge: five alternatives

Only the areas that were mutually indicated were used to analyse the data namely, student understanding, orientations towards science teaching, science curriculum and instructional strategies.

The third element in the dynamic equilibrium is technology.

Technology

A variety of technology (T) was and is still used in classrooms such as textbooks, wall charts, over head projectors etc. However, the more common usage of technology today refers to digital computers and computer software. The advantages of computers are enormous and cannot be ignored in the teaching and learning of science (Jimoyiannis & Komis, 2001). Although Shulman's approach still holds true, the requirements of learning and how to apply them to teaching has changed due to the availability of a range of new, primarily digital, technologies. The new technologies have transformed the nature of the classroom or have the possibility to do so. PCK as described by Shulman as "the most useful forms of (content) presentation...., the most powerful analogies, illustrations, examples, explanation and demonstrations – in a word, the ways of representing and formulating the subject that makes it comprehensible for others (1986b, p 9) has new meaning. What is happening in the classroom is the change from a drawing in a textbook or on the black board to an interactive simulation which makes analogies, demonstrations or explanations much more accessible. Teachers will have to do more than simply learn to use currently available tools, they also will have to learn new techniques and skills as current technologies become outdated (Mishra & Koehler, 2006).

Knowledge of technology is an important aspect of overall teacher knowledge and is viewed to be a separate set of knowledge and skills that has to be learned but also cannot be ignored because of its direct consequences to teaching.

In their framework for teacher knowledge Mishra & Koehler (2006) included technology to emphasis the connections, interactions, affordances and constraints between and among content, pedagogy and technology.

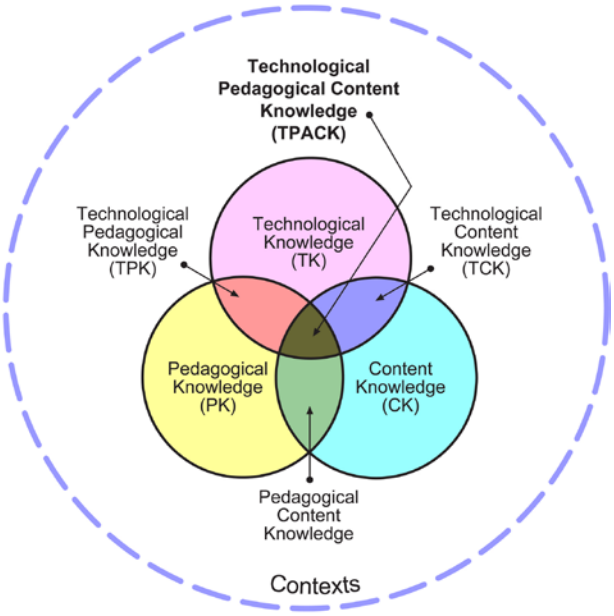

Figure 2: Pedagogical technological content knowledge. The three circles content pedagogy and technology overlap to lead to four more kinds of interrelated knowledge. (from http://tpack.org/)

Technology knowledge (TK) is knowledge about available technologies such as books, charts, software packages etc. This includes knowledge on how to operate particular technologies such as, how to use word, spread sheets, internet, install and remove software programs. Workshops will focus on acquisition of technical skills. However, because of the nature of technology it could be that these skills will not be necessary in future but the ability to learn and adapt to new technologies will still be imperative.

Technology content knowledge (TCK) is about the manner in which technology and content are related. Teachers need to know not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology. For example by introducing simulations students can actually see how electrons are moving, if the bulbs are brighter or dimmer in series and parallel circuits etc.

Technology pedagogical knowledge (TPK) is about the existence, components and capabilities of various technologies as they are used in teaching and learning settings, and knowing how teaching might change as the result of using particular technologies. For example, to teach kinematics what would be the most effective: the go motion, simulations or trolley equipment?

In teaching, the productive integration of content, pedagogy and technology needs to be considered, not in isolation but within the complex relationships in the system.

Technological pedagogical content knowledge (TPCK) "requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students prior knowledge and theories of epistemology and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones". (Mishra & Koehler, 2006 p 1029).

Aim of the study

To illustrate the dynamic equilibrium among the three elements namely content, pedagogy and technology by using 2 different kinds of technologies in the teaching of kinematic graphs namely the go motion and moving man simulations.

Reason for the study

The topic kinematic graphs are part of the grade 10 physical science curriculum. Learners have consistent difficulties with the interpretation of kinematics graphs – i.e. graphs of position, velocity or acceleration versus time (Mc Dermott *et al*., 1987, van Zee & Mc Dermott, 1987 and Beichner, 1994). This topic provides a choice of technology to be used for example the ticker time experiments with trolleys, the go motion or moving man simulations.

The TUG-K pre- and post test average of 214 Grade 10 physical science learners were 34.5% and 39.3% respectively after being introduced to the go motion and moving man simulations. A go motion is used with a computer and allows immediate real-time data collection, provides graphical representation of the collected data and is not complicated. The moving man from Physics Education Technology (PhET) simulations is developed to understand kinematic graphs and is grounded in research on how students learn student conceptual difficulties and misconceptions, are highly interactive and provide animated feedback to the user. Reasons for this underachievement had to be investigated.

Method

Six teachers (5 male and 1 female) at one school in the Tshwane North District of the Gauteng region were approached to take part in this research and all voluntarily agreed. They attended a one hour workshop on the use of the go motion and moving man. The aim of the workshop was to provide the teachers with a variety of different strategies to understand kinematic graphs and to make sure they have confidence in using the technology themselves. They then introduced the go motion and moving man to their Grade 10 learners, and completed the experiments in the computer lab. The teachers were then interviewed individually for approximately one hour.

Results and analysis

To illustrate the equilibrium between the two elements content and pedagogy only the mutual components on teacher knowledge was used as summarised in Table 1. They are science curriculum, student understanding, instructional strategies and orientations towards science teaching. In the following two tables an analysis of the interviews with the teachers are presented. In the first table teachers with 4 and less year experience and the second table give data on the two teachers with more than 15 years experience.

Knowledge domains	**T1 (M)** **BEd FET 4**	**T2 (M)** **BEd FET 4**	**T3 (M)** **BEd GET 1**	**T4 (M)** **BSc Honours 4**
Student under-standing	Unclear - how to represent an actual movement Cannot use formula – don’t know how to use the area and gradient – use units	Interpreting graphs – get results and draw a graph	Cannot visualise the actual situation. 3 graphs – represent the same situation in 3 different pictures	Struggle understanding the basic shapes of graphs and how the same type motion has different shapes on the different sets of axes (s-t, v-t, a-t)
Instruc-tional strategies	Guide to explore – s-t graphs – draw conclusions with them	Relative to the world examples – Not particle acceleration. You put up a graph and you interpret it with discussions. There is a correlation with mathematics. We all have maths background – this is a good section to bring it together.	Walk in front of class and draw a graph on the board representing the movement I don’t have experience- learners don’t have the maths ability, cannot substitute variables and manipulate,	I first tried the mathematical approach (gradients, derivatives etc) but without a good grounding in mathematics that didn’t work; I then tried a practical approach of an object moving and tracking all the necessary information in a slow incremental way.

			convert a formula	
Orientation towards science teaching	Concept understanding – more than just answer questions - they have to learn more when they answer questions at home	You have to explore but you have to guide them. I want to teach them to reason and really understand. This is a bit different angle as the school. Don't what to teach formulas they must understand.	Essence see nature (what is really happening) and represent it More in curriculum – makes it difficult to finish the syllabus. My first year of teaching and is difficult	It is very important that they make links to practical contextual knowledge as well as have a visual basis during learning. It is a visual subject that requires understanding. If you understand the content, it becomes easy.

Table 2: Teachers with 4 and less years experience and their views on student understanding, instructional strategies of graphs and orientations towards science teaching.

Since the teachers have some classroom teaching experience and show a good understanding of their learners' areas of difficulty regarding graphs as well as the ability to develop teaching procedures it was the teacher with one year experience that revealed that he was unsure. The difficulty would appear to lie with his inexperience and could be his content knowledge because he is the only teacher that only had a BEd GET qualification. This assertion is supported by the fact that experienced teachers are more likely to hold subject matter structures that are coherently structured and rich in relationships (Gess-Newsome, 1999a) Conceptual understanding was underpinning their orientation towards science teaching except again for the beginning teacher who expressed his concern that he will not be able to finish the syllabus. Content specific orientations to teaching has an impact on classroom practice - if teachers are weak, they adopt orientations in embedded texts and curriculum guides (Gess-Newsome, 1999a).

Knowledge domains and manifestations	**T5 (M)** **HOD Physical Science 15**	**T6 (F)** **BPharm & HDE 24**
Student under-standing	Interpretation of graphs. v-t to a-t graph	Conceptual shapes st, vt, at – uniform velocity – 6 shapes –don't understand the shapes - can still manage. Don't know how to apply this in different situations
Instructional strategies	Repetition and examples Not necessary to do experiments explain on board – check and talk, marking tutorial.	Understand basic shapes – give exp – man walks – give intervals; come back and see motion. Table to and fro. From that draw graphs. Give motion, image – draw graph s-t, v-t and a-t; link the changes in

	No PowerPoint or smart boards	gradients and areas.
Orientations towards science teaching	Use examples that link to everyday life. Physical science is interesting, ask more questions. You do not teach all classes the same. Some have 40% and some high flyers. You adopt and treat them different.	Like kids a lot and science – what a pleasure

Table 3: Teachers with 15 and more years experience and their views on student understanding, instructional strategies of graphs and orientations towards science teaching.

Both teachers have extensive classroom teaching experience and show a good understanding of their learners' areas of difficulty regarding graphs as well as the ability to develop teaching strategies to address their problems however experienced teachers may resist new content orientations, returning to familiar patterns and procedures as seen with Teacher 5 (Gess-Newsome, 1999a). The two teachers with the highest qualifications (T4 and T6) both have more detailed knowledge and more connections and relationships (Gess-Newsome, 1999a)

To illustrate where technology fits into the equilibrium a brief summary is given in Table 4 to illustrate the interaction between TK, TCK and PCK if the go motion and moving man are used in the teaching of kinematic graphs.

Technology	**Technology knowledge**	**Technology content knowledge**	**Technology pedagogical knowledge**
Go motion	Go motion, Board Inclined plane, ball and computer	Real time graphs	Graphs are displayed after moving to and fro with body
Simulations moving man	Software installed either CD or internet and computer	Simulations easy to see	Graphs are displayed by setting the velocity, or acceleration

Table 4: The interaction between TK, TCK and PCK if the go motion and moving man are used in the teaching of kinematic graphs.

Integrating technology into teaching is not an easy process and is illustrated by discussing what a teacher needs to consider when the go motion is to be implemented in the teaching of kinematic graphs. The teacher needs to know that the different graphs (s-t, v-t and a-t) will be presented on the computer after real movement has taken place. It represents real time graphs but the curves are not always straight lines. Learners have the opportunity to work in pairs, see the difference in the graphs and could reshape their original hypotheses, test new hypotheses and display new results very easy and will have more time to analyse and interpret their data. In order to facilitate this process the computer lab has to be booked, the experiments have to be set up and software has to be downloaded on the computers. Worksheets need to be compiled to contribute to learning.

The moving man on the other hand also needs a computer lab, software to be downloaded and worksheets to be compiled. However, the different graphs (s-t, v-t and a-t) will be presented on the computer after manipulating the man by either moving him physically or changing his speed or acceleration and let him move backwards and forwards. These graphs represent perfect lines as seen in textbooks.

Teachers do not only need content and pedagogy they need to know what different technologies have to be used in such a way that it builds on existing knowledge and help redress the problems students face in interpreting kinematic graphs.

Therefore at the heart of teaching today it is not only the manner in which subject matter is transformed for teaching it is also how the technology for teaching is integrated.

Summary and conclusion

In their book "how people learn", Bransford et al, (2004) concluded "Outstanding teaching requires teachers to have a deep understanding of the subject matter and its structure, as well as an equally through understanding of the kinds of activities that help students understand the subject matter ..." (p.188)

In this paper the dynamic equilibrium among three elements namely content, pedagogy and technology was illustrated by using the moving man and go motion to show how complex the process is to choose the relevant technology, know what it can do and how to implement it for effective teaching. These findings could be the reason why learners do not achieve and hold implications for pre-service teaching and professional development.

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