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DEVELOPMENT OF A TECHNOLOGY INTEGRATED INTERVENTION IN TERTIARY EDUCATION

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Abstract. *It is expected of lecturers to integrate content knowledge with appropriate pedagogical approaches and select relevant technology to enhance student learning. However the selection of effective technology to support 21st-century learning in tertiary education could be time-consuming and complex since there is a plethora of technology available. The aim of this research was therefore to support lecturers by providing them with an evaluated technology-integrated intervention in fluid mechanics. Hence the objectives were to develop this technology-integrated intervention to support 21st-century learning for first-year physics students and to determine its effectiveness when presented by various lecturers. An exploratory case study research design guided the research. A design-thinking framework for technology-integrated lessons was used and included the Technological Pedagogical and Content Knowledge (TPACK) model. This research was done with two lecturers and 117 students from a University of Technology in South Africa. The data gathering tools comprised pre and post-tests, tutorials, observation schedules and questionnaires. Results indicated that student learning is affected by the way in which technology is used not only in schools, but also in tertiary education and that lecturer belief play a crucial role in the design process but also manifest when lecturers have to use a designed intervention.*

Key words: *21st-century learning, fluid mechanics, teacher beliefs, technology integrated lesson, tertiary education.*

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Introduction

There is a demand that lectures should integrate technology in tertiary education in order to deal with 21st-century competencies such as critical and creative thinking, communication, collaboration and conflict resolution. Therefore, the role of the lecturer is not only to have the required subject content knowledge and knowledge on how to teach, but additional knowledge to identify and to be familiar with transforming technologies into active tools for meaningful learning.

Technology provides lecturers with the "zone of possibility" (Dirken, 2009; Dirken & Mishra, 2010), but does not essentially determine how the technology is used. Although education has novel technological tools in the form of applications at its disposal, many of these applications are devoid of empirical, pedagogical underpinnings, which do not justify their employment (Salmon, 2002). Therefore, programmes need to be designed, especially in tertiary education, on how to best organise, represent and adapt the teaching of specific topics for improved learning when using technology.

Furthermore, students in tertiary education come from diverse backgrounds and cultures which add to the complexity of teaching. Issues of learners of diverse interests and abilities need to be attended to. Hence, lecturers do not only work "within the contextual, cultural and social limitations in the learning environment" (Park & Olivier, 2007, p. 6), they also need knowledge on how to use technology effectively (Shulman & Grossman, 1988).

Efforts have been made to develop interventions, such as Intel Teach (http://www.intel.com/education/teach/), that has reached over 6 000 000 teachers in 40 countries globally. These interventions attend to the needs in schools, but limited interventions are available for tertiary education. Studies done in tertiary education are mainly in teacher education (Voogt, Fisser, Pareja, Tondeur & van Braak, 2013) and not necessarily in teaching for an improved understanding of a specific topic in the science domain.

Limited interventions are found in the science faculties. One of the reasons could be that the emphasis of faculty members in the science departments at universities are more focused on content (what to teach) and less on pedagogy (how to teach). The integration of technology is therefore a further addition that they need to attend to. Consequently, it is expected of lecturers to integrate content knowledge with appropriate pedagogical approaches and select relevant technology so that their students understand the subject at stake (Voogt et al., 2013).

It is not easy to design lessons, but is regarded as an important competency required for the teaching profession (Laurilland, 2012). The design process comprises design thinking which is described as a reasoning process (Koh, Chai, Benjamin & Hong, 2015). Therefore, the reasoning process needs to be included as a strategy when designing technology-integrated lessons. This is in line with the concluding remarks of Koh et al. (2015) that the need to develop systems that support teachers' design of technology integrated lessons for various subject areas should be further explored.

The aim of this research was therefore to support lecturers by providing them with an evaluated technology-integrated intervention in fluid mechanics on tertiary level.

The research objectives are to:

i. develop a technology-integrated intervention in fluid mechanics to support 21st-century learning for first-year physics students;
ii. determine the effectiveness of the intervention, using the reflection in action process.

During the design and reflection process of this research, the lecturer's pedagogical reasoning was addressed and lessons were learned about supporting systems when integrating technology, which could be informative to a wider research community.

Theoretical Framework

The design thinking framework to support 21st-century learning developed by Koh et al., (2015) was used as a theoretical framework. Design thinking entails the process when an act leads to creating improved products, services and experiences. This framework was used to guide the design of a technology-integrated intervention on fluid mechanics for first-year physics students to enhance learning.

The important properties of this framework are critical dimensions for 21st-century learning, the TPACK model and the design-thinking process.

Critical Dimensions for 21st-century Learning

The critical 21st-century dimensions that underpin the framework are cognitive, metacognitive, socio-cultural, productive and technological (Koh et al., 2015). In the cognitive domain it is expected of students to be critical and creative thinkers and be able to solve complex real-world problems. The metacognitive dimension was identified to ensure lifelong learning while the socio-cultural dimension is for students to develop competencies in communication, collaboration and conflict resolution. Productivity is an essential element for the 21st century where students need to develop productive and efficient work processes. Finally, technological competencies are imperative for students to be competitive in the future.

Technological Pedagogical and Content Knowledge (TPACK) Model

The TPACK model was developed by Mishra & Koehler (2006) and describes the knowledge base for teachers to effectively teach with technology. This model illustrates the complex interplay between three basic components that are essential when integrating technology for teaching, namely content knowledge (CK), pedagogical knowledge (PK) and technology knowledge (TK). TPACK involves knowing how to use technology effectively in the classroom where lecturers identify the learning outcomes and select the tools to use in order to achieve these outcomes, taking into consideration students' prior knowledge, difficult aspects of the topic, and how the technological tools could address learning problems (Misha & Koehler 2006, p. 134).

Although TPACK is a very complex concept (Graham, Borup & Smith, 2012) the TPACK model is included in the framework with the various components of the model described as working definitions:

- CK is the "amount and organisation of knowledge per se in the mind of the teacher" (Shulman 1986, p. 5).
- PK refers to the knowledge about the methods and processes of teaching and includes knowledge

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about classroom management, assessment, lesson plan development and student learning (Mishra & Koehler 2006:133).

- Pedagogical content knowledge (PCK) refers to knowledge that "goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" Shulman (1986, p. 9).
- TK is knowledge about various technologies, ranging from low-tech technologies, such as pencil and paper to digital technologies such as the internet, computer simulations, interactive whiteboards, discussion forums and software interventions. This knowledge entails knowing what each technology can offer.
- Technological content knowledge (TCK) is the knowledge of how technology can create new representations for specific content.
- Technological pedagogical knowledge (TPK) emphasises the existence, components and capabilities of various technologies as they are used in the settings of teaching and learning.
- TPACK is knowledge about using technology to implement teaching methods for various types of subject matter content.

Design Thinking Process

Three key activities of design thinking are development of frames and ideas, design, development and implementation of lesson materials and reflection in action. These activities occur without any prescribed order and for as many cycles as needed for sustained lesson improvement.

To develop frames and ideas the designers need to answer questions such as: What opportunities and constraints can be identified? Who are the students? What technological tools are available? What will the effect of the technological tools be?

When reflection in action occurs, designing, developing and implementing is part of the interactive process. Reflection in action is needed when lessons are created and refined (Koh, et al, 2015). The designer needs to reflect on possible mismatches between technology, pedagogy and content in the lesson design or mismatches between the lesson design and contextual factors, such as student profile, as well as effective learning. Interpersonal factors, such as support from peers and stakeholders and the impact of personal beliefs may also affect the design process.

Problem Statement

Lecturers need to align learning difficulties students might have with a specific topic and relevant technology to attend to these learning difficulties to improve learning. The selection of effective technology could be time-consuming and complex since there is a plethora of technology to choose from. However, many of these applications lack pedagogical underpinnings (Salmon, 2002). Technology-based resources as such are not sufficient for meaningful learning to occur. They are effective only when designed and used in a way that directly aligns with well-established learning principles (Wieman, Perkins & Adams 2008). There is therefore a need to provide assistance to lecturers to incorporate technology effectively in lessons in order to improve learning.

Research Methodology

Context

This research was done in the Department of Physics at the Tshwane University of Technology (TUT) in South Africa. For most of the programmes offered in the Faculty of Science Physics is a compulsory component in the first year and taught by lecturers from the physics department. South African students are from diverse backgrounds with 11 official languages but the language of education is usually English.

At TUT not all the classrooms are equipped with interactive whiteboards, although all the classes have white boards to replace the blackboards of the past. The lecturers use PowerPoint presentations since each lecture room is equipped with a data projector. The Physics Department invested in buying stickers, but they were only used by one lecturer who is part of this research.

Fluid mechanics was selected since it is prescribed in most undergraduate tertiary physics curricula. Bernoulli's principle and the equations of continuity can be applied to everyday life, for example, referring to the wings of an aircraft or any fluid flow. Students experience difficulties with these concepts, which could be due to a combination of the misapplication and oversimplification of Bernoulli's theorem and the Newtonian descriptions to explain the lift of a wing (Anderson & Eberhart, 2011).

Although this university is not equipped with the latest technology, it was decided to design an intervention with the available technology and use the design-thinking framework for technology integrated lessons to support 21st-century learning.

Research Design

Yin (1984) identifies three types of case studies in terms of their outcomes, namely exploratory, descriptive and explanatory. This research followed an exploratory case study research design that acts as a pilot and used and tested in larger experiments. Many types of data were used to look into this unique example of a social-technological and cultural context. A technology-integrated intervention was developed and presented in a tertiary level environment to understand ideas more clearly than simply presenting with abstract theories or principles (Cohen, Manion & Morrison, 2007).

Participants

The participants selected for this research were lecturers and students. For the pilot study the students were enrolled for the National Diploma in Analytical Chemistry (N = 44) and for the main study the students were enrolled for the National Diploma in Geology (extended programme) (N = 34) and National Diploma in Analytical Chemistry (extended programme) (N = 39). The two extended programme groups for the main study had the same selection criteria for admission; and the equivalence of these two groups was statistically confirmed (see pre-test results).

Two lecturers were identified to determine the effectiveness of the designed technology-integrated intervention presented by an external lecturer who was not involved in the design process. The first lecturer was part of the design process of the intervention and the presenter for the pilot study and the one group of the main study. She has a doctoral degree in science education with 20 years of experience in teaching physics. The second external lecturer was the presenter of the second group of the main study. He has a master's degree in physics and five years' teaching experience, much younger and more comfortable with the use of technology. The obvious differences between the two lecturers illustrate that developed teaching interventions need to cater for any lecturer, since this research follows an exploratory case study research design.

Research Instruments

The following research instruments were used to collect data for the main study:

Pre and post-test

Eleven similar multiple-choice questions followed by one fun question were used in the pre and post-test for the main study. In the post-test the students had to motivate their multiple-choice answers and a discussion question and a problem on Bernoulli's principle were added. The pre-test determined the statistical equivalence of the groups of the main study and the post-test determined the effectiveness of the interventions.

The test was set by a lecturer based on her years of experience in teaching fluid mechanics. Two experts, one with an MSc in physics and one with a PhD in physics, who have been involved in the field of physics education research for the past 20 years, validated the test. They agreed that the test adequately measured all the learning outcomes of the topic, and their comments and suggestions were implemented.

The post-test was given to both groups as part of their major semester test. The test paper was set and moderated in accordance with the university's policy. The moderator had to verify that the questions adequately measured all the learning outcomes. No comments or suggestions were made by the moderator.

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Tutorial

In the tutorial, the students had to solve two complex problems by using the equations of continuity and Bernoulli's principle and reflect on one of the videos that were shown during the intervention. They had to give a scientific explanation of what was happening in the video by means of an applicable diagram and equation.

Observation schedule

The 25-question observation schedule had been adopted from the Reformed Teaching Observation Protocol (RTOP) specifically for mathematics and science classrooms of schools, colleges and universities. This protocol had been developed over a period of two years and was chosen to use as a yardstick to determine whether reform in these three classrooms has actually taken place (Sawada, Piburn, Judson, Turley, Falconer, Benford & Bloom, 2002).

Questionnaire

In the questionnaire the lecturers reflected on their own practice. Three questions guided the teachers' reflection, namely:

Do you think the students enjoyed the class? Why or why not?

What would you change in the future when teaching fluid mechanics? Why?

What was your experience of teaching with technology?

Data Collection and Analysis

Data were collected from the two groups by writing pre and post-tests and submitting the tutorial. The pre-test was administered before the intervention commenced while the post-test was administered three weeks after the intervention and formed part of their summative assessment. The tutorial on fluid mechanics was administered as formative assessment and submitted one week after the teaching intervention.

During the observation of the interventions the observation schedules were completed by two observers. As part of the reflect-in-action process the lecturer also completed the observation schedule as well as a questionnaire.

Quantitative analysis

The scores of the pre and post-tests and tutorials were analysed quantitatively using the independent t-test to determine equivalence of the two groups and to determine whether the performance of the two groups were statistically significantly different.

Qualitative analysis

Six reflections were captured when analysing the observation schedules. During the analysis of the questionnaires it was envisaged to identify recurrent themes to get better insight into the questions asked. Since only two lecturers were part of the research, it was dealt with individually and no specific themes were identified.

Pedagogical reasoning of the intervention

Students will be expected to solve complex real-world problems in fluid dynamics and be able to communicate, discuss and resolve conflict situations to deal with the critical dimensions for 21st-century learning. To become lifelong learners, self-regulated learning is needed as well as encouragement to work effectively. Technology use can provide students with the necessary opportunities to work productively; therefore, they need to be exposed to various technologies to make informed choices.

To deal with the TPACK model, the CK comprised fluids in motion, equations of continuity and Bernoulli's equation. The PK dealed with language issues and student learning and the TK included how to use clickers, videos and PhET simulations and to create various representations as part of the TCK. The TPK determined when to use certain technology to facilitate understanding. For example, will it be better to show a specific video before using clicker questions or rather demonstrate fluids in motion using simulations first? TPACK involved knowing how to use technology effectively after deciding on the learning outcomes, the selection of tools, what students understand of fluids in motion and what learning difficulties they have. Will the use of these simulations, clicker questions and videos be able to attend to their learning difficulties?

During the design-thinking process the designer was aware of who the students were and what technological tools were available, but had to consider which of the various applicable videos would attend to and enhance learning the best.

Development of the intervention

The technology-integrated intervention was presented three times to different groups, and lasted two and a half hours each. The first intervention was presented to the pilot group where clicker questions, a video, simulations for the purpose of demonstration and problem solving were used. The intervention was observed and an observation schedule was completed by the researcher. After the presentation, the lecturer completed the same observation schedule as a reflection in action and a questionnaire to elicit her pedagogical reasoning when designing the technology-integrated intervention. The reflection-in-action process indicated necessary changes which included the best available technology to use to enhance teaching and learning. In her reflection the lecturer realised that the one video was too long and that shorter videos would be more effective. Furthermore, additional problems were added as activities during class time. The use of simulations would be more effective to add speed and pressure meters where the flow is actually taking place and a flux meter to illustrate the area and flow of the particles. The simulations of the equations of continuity and the Bernoulli principle were separated. Additional clicker questions were added and some refined to be clearer. The PowerPoint presentation was redeveloped to implement the changes.

The first main presentation was presented by the external lecturer. The learning outcomes of the intervention were discussed with the lecturer since he was not part of the designing process. Each of the two observers (the designer who acted as observer and the researcher) completed the observation schedule. After the presentation he was asked to complete the same schedule as a reflection in action as well as a questionnaire. The purpose of the questionnaire was to determine the challenges experienced during the lesson and recommendations to improve the intervention.

The second main presentation was presented by the designer-lecturer with no major changes in the presentation. This intervention was observed by two observers (the external lecturer and researcher) and an observation schedule was completed by both. Again an interview was conducted with the lecturer after the lecture and she was asked to complete the same schedule as a reflection in action. The purpose of this questionnaire was to tailor the intervention for future use. The development of the intervention is summarised in Table 1.

Table 1. Development of the intervention.

TPACK categories		TPACK activities for the interventions		
CK	TK, TPK, TCK	Pilot intervention changes	First main intervention	Second main intervention
Overview of fluids in motion	Clicker exercises to elicit prior knowledge of students and determine equivalence of the two groups	Increase the number of questions from 6 to 11.	At the end of the exercise, display results as distribution graphs for each question for students to evaluate their response. Although correct answers were given no explanation was given at that initial stage.	

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TPACK categories		TPACK activities for the interventions		
CK	**TK, TPK, TCK**	**Pilot intervention changes**	**First main intervention**	**Second main intervention**
Fluids in motion	Video on behaviour of fluids in motion	Include a short video (grade 6 level).	Show video with no discussion.	Show a physical model of an aeroplane and indicate the shape of the wings that will be dealt with in the video. Show video.
	PowerPoint	Include a slide to explain the properties of ideal fluids as they are used in the video to follow.	Explain properties of ideal fluids. Show slides of laminar versus turbulent flow.	
			Explain without using diagrams.	Use additional diagrams on the white board to explain fluid flow
Derivation of equation of continuity	Video	Include short video.	Play video without any interaction	Stop video and ask questions
	PowerPoint	Use less PowerPoint slides, additional to video.	Summarise mass and volume flow rate. Explain by writing equations on the board.	
			No emphasis on units.	Emphasis on units.
Equation of continuity	Simulation	Include first part of simulations at this stage	Simulations manipulated by the teacher	
			Simulate pressure as well, although not applicable at this stage	Simulate only speed and area with applicable gauges.
	Clicker question	Include problem solving activities.	Involve student to explain the last question on the board.	Emphasise square because the diameter is given, not area.
Introduction to Bernoulli	Video	Include a short video with practical applications of fluid motion – four phenomena.	No explanation	Explain highlights in video to follow.
	Video – how do aeroplanes fly	Include short video.	No explanation	Explain highlights in video to follow.
Derivation of Bernoulli's equation	Video – Derivation of Bernoulli's equation from energy principles	Include video	No initial explanation. Due to technology failure, the video was stopped and lecturer further explained on the board. The lecturer handled the situation very well	Explain highlights in video to follow. Start by asking questions on the conservation of energy. Ask students to write down the energy principle – repeat what was said in the video.
	PowerPoint	Use less PowerPoint slides and explanation on the white board, additional to video.	Present energy conservation as introduction and Bernoulli's equation as summary of the video.	
			No initial explanation, but after the interruption of the video due to technical errors, the lecturer emphasised KE and PE although not scientifically correct (referred to different terms of Bernoulli equation as energy and not pressure).	Explain again where equation comes from. Emphasise origin of kinetic and potential energy.

TPACK categories		TPACK activities for the interventions		
CK	**TK, TPK, TCK**	**Pilot intervention changes**	**First main intervention**	**Second main intervention**
Application of Bernoulli's equation	Simulation	Simulate only the second part at this stage.	Simulations manipulated by the teacher. Bernoulli's equation with different heights and diameters to investigate pressure	
	Video – application of Bernoulli's equation by problem-solving	No change.	No additional explanation. The video showed to the end. (In the video all units converted to atmospheric).	Explain highlights in video to follow. Stop video for students to do final calculations, using SI units of pressure.
	Clicker question	Increase one question to three.	Same three questions in both main interventions.	
Bernoulli in everyday life	Video – application	Include video	No explanation	Explain highlights in video to follow.

The effectiveness of the technology-integrated interventions presented by the designer and an external lecturer was determined by quantitative and qualitative results.

Results of Research

Quantitative Results

Pre-test results

The pre-test results were used to determine the equivalence of the two groups of the main study. An independent t- test was done $t(77) \approx 1.33$; p-value = 0.865. The means did not differ significantly at a 95% level of confidence, and did not suggest a statistically significant difference between students' understanding prior to teaching the two groups. The effect size was small (Cohen's D = 0.3).

Post-test results

The post-test results were used to determine the effectiveness of the two interventions. From the independent t-test $t\ (73) = 2.66$; p-value < 0.001 it was suggested that there was a significant difference between the two groups. The effect size was intermediate (Cohen's D = 0.62).

Tutorial results

The tutorial results were used in the same way as the post-tests. However, there was a time difference since the post-test was written three weeks after the intervention while the tutorial had to be submitted one week after the intervention. From an independent t-test $t\ (81) = 4.48$; p-value $<.0001$ it was suggested that the means differed significantly. The effect size was large (Cohen's D = 0.988).

Qualitative Results

Observation schedule results

The observation schedule results are summarised in Table 2. For each of the 25 questions the following codes were used:

O_{11} : Observer 1 for first main intervention
O_{21} : Observer 2 for first main intervention

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L_1 : Lecturer of first main intervention
O_{12} : Observer 1 for second main intervention
O_{22} : Observer 2 for second main intervention
L_2 : Lecturer for second main intervention

Table 2. Observation schedule- reformed teaching observation protocol.

	Associated activity/content during intervention	Well Done	Done	Not Done
I. Lesson Design and Implementation				
1. Students' prior knowledge	Use clicker questions	O_{12} L_2 O_{11} L_1	O_{22} O_{21}	
2. Engage students	Interactive activities	O_{12} L_1	O_{22} L_2 O_{21} O_{11}	
3. Student exploration	Real-life situations	O_{12} O_{11}	L_2 O_{21} L_1 O_{22}	
4. Need alternative modes of investigation	Present experiments	O_{12} L_2 O_{11} L_1	O_{21} O_{22}	
5. Direction of the lesson from students	Could be more student -centred		O_{12} L_2 O_{11}	O_{22} O_{21} L_1
II. Content: *Propositional Knowledge*				
6. Lesson involved fundamental concepts	Energy	O_{12} O_{22} L_2 O_{21} O_{11} L_1		
7. Promoted conceptual understanding.	Different representations	O_{22} L_2 O_{11} L_1	O_{12} O_{21}	
8. The teacher had good subject matter content	Good qualified	O_{12} O_{22} L_2 L_1	O_{21} O_{11}	
9. Elements of abstraction (symbolic representations) were encouraged	Shown in simulations	O_{12} O_{22} L_2 O_{11}	O_{21} L_1	
10. Connections with other content disciplines.	Better connections needed	O_{22} L_2 O_{11}	O_{12} O_{21} L_1	
II. Content: *Procedural Knowledge*				
11. Students used a variety of means (models, drawings) to represent phenomena.	Diagrams, calculations simulations	O_{12} O_{22} L_2 O_{11}	L_1	
12. Students made predictions, estimations.	Pre-test and clicker questions	O_{22} L_1	O_{12} L_2 O_{11}	
13. Students were actively engaged in thought-provoking activities.	Problems need to be solved	O_{12} L_2 O_{11} L_1	O_{22}	
14. Students were reflective about their learning	Clicker feedback	O_{12}	O_{22} L_1 L_2 O_{11}	
15. Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	Need more time for student discussion and feedback		O_{12} O_{22} L_1	L_2 O_{11}
III. Classroom Culture: *Communicative Interactions*				
16. Students need to communicate their ideas	Collaborations	O_{12} O_{22} L_1	O_{21} L_2 O_{11}	
17. The teacher's questions triggered divergent modes of thinking.	Providing different examples	O_{12} O_{22} L_2 O_{11} L_1	O_{21}	
18. High proportion of student talk	Spontaneous		O_{12} O_{22} L_2 O_{21} O_{11} L_1	
19. Student questions determined the direction of classroom discourse.	Ask more questions and be guided by student response		O_{12} O_{22} L_2 O_{21} O_{11} L_1	
20. Climate of respect for what others had to say.	Provide time for feedback	O_{12} O_{22} L_2 O_{11}	O_{21} L_1	

	Associated activity/content during intervention	Well Done	Done	Not Done
III. Classroom Culture: ***Student/Teacher Relationships***				
21. Active participation of students.	Opportunities provided	O_{12} L_2 O_{11} L_1	O_{22} O_{21}	
22. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	Need to do more		O_{12} O_{11} L_1 L_2 O_{22}	O_{21}
23. Teacher patient with students.	Good class atmosphere	O_{12} O_{22} O_{21} O_{11} L_1	L_2	
24. The teacher works to support and enhance student investigations.	Use different representations	O_{12} O_{22} O_{11}	L_2 O_{21} L_1	
25. The metaphor "teacher as listener" was characteristic	Need a more student-centred approach	O_{12} O_{21} L_1	O_{22}	L_2 O_{11}

Questionnaire results

The following comments were extracted from the questionnaires where the two lecturers reflected on their own practice. Lecturer 1 is the external lecturer and Lecturer 2 is the designer lecturer:

Did you think the students enjoyed the class? Why or why not?

Lecturer 1: *" They enjoyed both classes; They were disciplined for 2 ½ hours and were willing to stay longer; Students were active in their minds and were interested during the whole session.*

Lecturer 2: *"Yes, the students show interest in the clicker technology which was used in class. That can be seen from their reaction when the display on the clicker screens changes from its initial display. The students show some understanding of what was presented on the video. This was seen when they were confident to attempt the question on the board."*

What would you change in the future when teaching Bernoulli? Why?

Lecturer 1: *"Make use of less videos. The videos were an overdose; Give more opportunity for discussions and reflection; For this, the time was not enough".*

Lecturer 2: *"A clear video showing the derivation of the Bernoulli's equation will be the first step. Video will be followed by examples showing its animations, calculations and applications; The video I used gave more information at a small period of time, and this might cause confusion to students who are slow in class. As a lecturer using technology in class, you don't have to repeat what has already covered on the video".*

What was your experience of teaching with technology?

Lecturer 1: *"Technology enhanced learning and student attention. This is the way they learn; The choice of videos is important, because there are so many available. And there are "mistakes" in the videos – handwriting (v, V P ρ); use of the = sign in the derivation of equation of continuity; A video should not replace the lecturer (eg the derivation of Bernoulli equation), if it is not necessary. (In case of an inexperienced lecturer, a video would be the better option!; Clickers should be used in all classes. Time is wasted, because students are not familiar with clickers".*

Lecturer 2: *"It was not such an easy excise, because I'm used to do the explanations on my own. I was trying to avoid repeating what was already said on the video. I also give you a chance to be able to move around to see different activities the students are engaged in. Some students had a chance to ask questions while the video is playing".*

Discussion

Quantitative Results

The results of the pre-test indicated that the two main groups taught by the two different lecturers were statistically equivalent. The tutorial and post-test results were used for formative and summative evaluation of student learning and to compare students' understanding following the designed interventions for the two groups. This evaluation did not analyse the learning of individual students, but measured the extent to which learning has taken place. There was a significant difference in the means of the post-test results and tutorial for the students in the second main intervention with an intermediate and large effect size respectively. The analysis of the results verify that the way a lecturer uses technology tools to represent and make meaning of the content knowledge has an impact on learning. Therefore, the quality of technology needs to be ensured not only in schools (Lei & Zhao, 2007), but also at a tertiary level.

Qualitative Results

What was captured in the analysis of the observation schedule corresponded with the lecturers' reflections on their own practices through the questionnaires.

The *Observation Schedule* section Lesson Design and Implementation indicates that the "*direction of the lesson from students"* was not determined by ideas originating from students. This could be because the sequence had been decided on before the lecture and therefore the students were not able to give input about what they wanted to know. For the section Content, with sub-sections Propositional Knowledge and Procedural Knowledge, all the criteria were met except *"Intellectual rigor, constructive criticism, and the challenging of ideas were valued".* This area needs improvement as it is also seen as a critical dimension and forms part of the cognitive dimension. With regard to "*students were reflective about their learning"* there was agreement between the lecturers and observers and this is in the metacognitive dimension, one of the critical dimensions for 21st-century learning. For the section Classroom Culture with sub-sections Communicative Interaction and Student/Teacher Relationships, there was agreement that the section "*students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence"* needs to be improved. This was met in the second main intervention, but needs to be emphasised since there is a need for creative thinkers who are able to solve complex real-world problems. This area is also seen as a critical dimension and forms part of the socio-cultural dimension. There was not a unilateral agreement amongst the observers and lecturers that the section "*the metaphor "teacher as listener" was characteristic*" was achieved and one of the reasons could be that both lecturers followed a hybrid of a teacher and student centred approach. The classroom was not only dominated by the lecturer, because the students had collaborative, co-operating and communicating opportunities, although limited.

In the *Questionnaire* feedback the external lecturer indicated that "*It was not such an easy exercise, because I'm used to do the explanations on my own".* This can be regarded as one of the disadvantages of a rigid pre-set intervention. It could be that he also wanted to change the intervention based on ideas from students or wanted to change the teaching sequence. This could also be why he indicated that he wanted more interaction with the students as indicated in the observation schedule when reflecting on his own practice (see section on Content with subsection Procedural Knowledge 14 & 15). The designer lecturer used the same sequence and technological tools, but changed the way in which the first main intervention was taught. However, she also indicated that she would "*Make use of less videos. The videos were an overdose. Give more opportunity for discussions and reflection".* This was also noted in the observation schedule when she reflected on her own practice (see Procedural Knowledge 13 & 15). The difference between these two interventions was also noted in the way the videos were used. For example, she would highlight certain aspects in the video in advance. She would also indicate that "*there are "mistakes" in the videos – handwriting (v, V P ρ); use of the = sign in the derivation of equation of continuity".* She alerted her students to these mistakes before showing the videos and repeated what was said in the video. The external lecturer did not see a reason to do this since he indicated the following: "*As a lecturer using technology in class, you don't have to repeat what has already been covered in the video".* Hence, this lecturer's personal belief affected the way in which he used the technology.

It was evident from the analysis of the data that the way in which a lecturer uses technology tools to represent and make meaning of the content knowledge has an impact on the effectiveness of the intervention. However, the designer plays a critical role in the design process when intervention materials are developed and implemented. Consequently, if another lecturer has to implement an already designed intervention and his/her personal beliefs are not in line with the design decisions, it would impact on the learning of the students. This was revealed in the external lecturer's reflection and the post-test and tutorial results.

Teacher/lecturer beliefs are therefore critical in any design process. There is a correlation between teacher beliefs and their actual behaviour when using technology (Kriek & Stols, 2010), but this research shows that it is also critical when implementing an already designed technology integrated intervention.

Critical Dimensions for the 21st Century

The critical dimensions for the 21st century were in some ways addressed. On the cognitive level the focus is from learning to thinking (Thompson, 2011). The challenge lies in designing interventions to include intellectual rigor. The metacognition dimension was partly incorporated where students were expected to answer clicker questions and compare their responses to a graphical representation of the student feedback. The socio-cultural dimension was dealt with when students were provided with opportunities to communicate and discuss their answers to problems with one another and conflicting situations occurred. The productive and technological dimensions were partly addressed when it was expected of students to keep to due dates, when submitting tutorials, however productive and efficient work processes were not developed as well as the lack of technological competencies. Students were not exposed to the use of different technological devices over and above the use of clickers

Limitations of the Research

There are several limitations to the present research. Firstly, there were a small number of participants. Only two lecturers and 117 students took part in the research. Secondly, only one university was used because both the lecturers were lecturing at this university. Thirdly, although the technology-integrated intervention was developed, it was done with the available technology at the university and no new technology was purchased.

Conclusions

The contribution of this research was to present an evaluated technology-integrated intervention in fluid mechanics and the results indicated that student learning is affected by the way in which technology is used not only in schools but also in tertiary education.

Lecturer beliefs play a crucial role in the design process, but also manifest when lecturers have to use a designed intervention. As design thinking is not an easy process as reflected in the design and redesign process, a database could be provided specifying which videos and simulations are relevant to a specific topic and highlight content, advantages and disadvantages. The flexibility of what to use as well as the lecturer's competency in using the technological tool that relates with his/her belief then rests with the lecturer.

It is crucial to deal with the critical dimensions of the 21st century. Explicit opportunities must be provided when designing interventions for students in order to develop critical and creative thinking by providing complex real-life problems. In addition, it should be expected of students to solve these problems in groups, using technological tools in a specific time frame to deal with social-cultural, productivity and technological dimensions.

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