LEARNING MATHEMATICS WITH TECHNOLOGY – A MEANINGFUL ENDEAVOUR INVOLVING 2ND YEAR EDUCATION STUDENTS

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ABSTRACT

The envisaged relationship between learning mathematics with technology and the achievement of student teachers at the University of Johannesburg (UJ) forms the focus of this research. Since the introduction of a new Faculty of Education programme for Grade 10-12 teachers in 2011, their mathematics lecturer faced several challenges. Most pertinent were inadequate foundational mathematical competency levels of students and their negative attitudes towards the curriculum.

In an effort to boost student attitudes, to enhance their intrinsic motivation and more frequent engagement with mathematical content, the second year lecturer integrated an extensive online support programme (Enhanced WebAssign) into the second semester module. The highly constructive effect of this intervention, monitored as research project, can be labelled as almost 'unlikely'. More encouraging attitudes, amplified confidence levels, a willingness to confront more complex mathematical content and a significant achievement surge, exemplifies this study as a meaningful mathematics learning with technology endeavour.

Keywords: Learning mathematics with technology, Attitudes towards mathematics, Improvement in mathematics performance, Teacher's factor in mathematics, Student engagement in mathematics

INTRODUCTION AND PURPOSE

A substantial amount of research has been conducted over the last two decades on determinants of students' achievement in mathematics, or the lack thereof (Afrassa & Keeves (1999), Akinsola, Tella & Tella (2007), Barkatsas, Gialamas & Kasimatis (2009), Mata, Monteiro & Peixoto (2012), Larwin (2010), Mohd & Mahmood (2011), among many others). Factors that have an influence on learning mathematics generally present themselves through a couple of related variables (Singh, Granville & Dika, 2002), of which student characteristics and behaviours, student attitudes, elements in the learning environment (e.g. class climate, group work, technology integration, assessment practices, etc.) and the role of the teacher (lecturer) are most pertinent.

Willett (1997) regards the measurement of change in mathematical achievement as a phenomenon that maps the heart of the educational enterprise. This paper thus focuses on the core of the higher education teaching and learning endeavour. Its purpose is to determine the influence of a technology-based learning-support strategy on the mathematical attitude, level of engagement and eventual achievement of a group of second year education students at a public South African higher education institution (HEI).

3. CONTEXT OF AND RATIONALE UNDERLYING THE RESEARCH

In 2011, the new four-year Further Education and Training (FET) programme for prospective Mathematics teachers of Grade 10 to 12 (or FET phase) learners kicked off at the University of Johannesburg (UJ). The first year has a precalculus emphasis, providing a basis for calculus in the second year. Differential calculus of one variable functions marks the first and applications of differentiation and integration the second semester of the second year, with the latter potentially more challenging.

During the first semester of 2012, the second year lecturer, despite having more than a decade of Mathematics teaching experience to Engineering and BSc students under her belt, faced unexpected complexities primarily relating to the following matters:

- the foundational mathematical knowledge and skills levels of the majority of the 78 students were vastly inadequate, to such an extent that their anticipated precalculus proficiencies were almost non-existent;
- student attitudes towards the first semester curriculum varied from apathy and dispiritedness to open rejection; and
- students had limited exposure to mathematics textbooks, which negatively influenced their willingness to regularly engage with the content.

The lecturer realised that this unsatisfactory state of affairs was increasingly constraining students' scope and quality of learning. Underachievement and non-accomplishment characterised assessment outcomes throughout the semester, with 36% of the students who eventually attained an end-of-semester mark in the 40 to 49% interval. The (June) examination results were even more concerning, generating a class average of 45%, with almost half (47%) of the marks being in the 30 to 49% interval. A supplementary examination was scheduled in July 2012, thereby affording students a 'second chance'. Fifty one (65%) of the 78 students eventually passed and thus gained access to the applications of calculus module in semester 2. However, the class average was still alarmingly low and the lecturer, who would also be facilitating this module, was doubtful whether the students were indeed adequately prepared to face the applied calculus challenges. She came to the realisation that a different approach, even an intervention, would be required. The implementation of the new second semester teaching and learning strategy, student experience thereof and its learning outcomes, form the focus of this paper.

4. LITERATURE PERSPECTIVES: DETERMINANTS OF MATHEMATICS ACHIEVEMENT

3.1 Theoretical framework

A theoretical framework relates to the philosophical basis of the research, and forms the link between the theoretical and practical aspects of the inquiry (Bless, Higson-Smith & Kagee (2006) and Mertens (1998)). Such a framework on the one hand reveals the methodologies and methods which were utilised and on the other hand also justify their selection. The methodologies are meant to generate a satisfactory answer(s) to the research question. The justification relates to the researchers' assumptions and the theoretical perspectives which underpin the methodology used.

The main theoretical perspective and literature-based theory that underlies the inquiry is what Luckett (2006:78), building on Habermas's 1971- and Grundy's 1987-notion of learning that needs to focus on practical interest through various kinds of interactions, as well as Piaget's and Vygotsky's Constructivist theory of learning, regards as "curriculum-as-practice". In this paradigm, students' understanding, thinking and reflective processes are the central focus of any curriculum. It doesn't mean that stated learning outcomes aren't important, but "…rather that they are secondary to the learning processes of achieving them" (Luckett, 2006:80, underlining by the authors). The curriculum-as-practice paradigm places agency for learning in the hands of both teachers (lecturers) and learners (students) and emphasises the importance of the environment in which learning occurs. *Curriculum-as-practice* is thus the theoretical lens through which this specific study is viewed.

3.2 Affective determinants, especially the role of student attitude

Two decades ago, McLeod (1992) postulates that affective issues (attitudes, beliefs and emotions) play a central role in mathematics learning. Formal studies on student attitude towards mathematics are found in abundance in the literature (Mata, *et al* (2012) and Barkatsas, *et al* (2009)). Attitude, though considered by Hannula (2002) as a contentious and nebulous concept, is defined by various researchers. Maat and Zakaria (2010:17) describe it as "…someone's basic liking or disliking of a recognizable object". García-Santillán, Moreno-García, Carlos-Castro, Zamudio-Abdala & Garduño-Trejo (2012:9) quote definitions of student attitude towards a subject (discipline) like Mathematics or Statistics from:

- Auzmedi (1992) - "…aspects not directly observable but inferred, comprised of both beliefs as feelings and behavioural predispositions toward the targeted object";
- Gómez-Chacón (2000) - "evaluative bias (negative or positive) that determines the personal and behavioural intention" and
- Gal & Ginsburg (1994) - "the sum of all the emotions and feelings experienced during the learning phase of the studied subject".

They (García-Santillán, *et al*, 2012: 8-9) conclude their conceptual analysis by ascribing to the four interrelated dimensions of attitude originally configured by Schau, Stevens, Dauphinee and Del Vecchio (1995), namely the *affective* (positive or negative feelings and emotions), the *cognitive* (one's capacity for knowledge and skills); the *value* (usefulness and perceived relevance in life), and the *difficulty* (perceived level of complexity).

Student attitude is triggered by a situation rather than an emotion (McLeod, 1992) and can be regarded as a relatively stable conviction, which doesn't easily change over time. However Maat & Zakaria (2010) reckon that students' attitudes can be affected (and sort of 'destabilised') when they have to confront complex (difficult) mathematical challenges. The relationship between attitude and self-concept (including self-confidence) becomes more pertinent when students attempt mathematical 'problems'. Rangappa (in Larwin, 2010:132) reports on significant differences in the mathematics achievement of students with high, normal, and low self-concepts and makes the inference that students with high self-concepts perform better.

Authors involved in research on the intrinsic motivation of students (Middleton (1999); Fredricks, Blumenfeld & Paris (2004) and Mata, *et al* (2012), among others) consider this kind of motivation as the by-product of a positive attitude and as highly desirable for achievement in mathematics. Mata, *et al* (2012:7) summarises this phenomenon as follows: "…students learn more effectively when they are interested and when they enjoy what they are learning". Mohd & Mahmood (2011:1858) unequivocally state that students with a positive attitude towards mathematics will generally excel at it.

It can thus be concluded from the literature that students' attitudes related to their perceived mathematical ability is a prominent determinant (and a predictor) of their achievement. Understanding their students' attitudes towards mathematics will therefore serve teachers (lecturers) well in crafting and implementing an effective teaching and learning strategy.

3.3 The teacher (lecturer) factor as a determinant of mathematics learning

Lazarides & Ittel (2012) provides details on their study of more than 400 high school learners from ten schools in Berlin, regarding the perceived quality of their mathematics teachers. Almost half of the learners consider their mathematics teaching as meagre (almost miserable), with females who are more likely than males to have this perception. Their study confirms the solid relationship between such negative views of the so-called "teacher's factor" (Maat & Zakaria, 2010:16) and negative attitudes towards, low self-concept and a lack of interest in mathematics.

The noticeable contribution of the 'teachers' factor' to student learning of mathematics is increasingly on the international research agenda and has been established without doubt. A broad scan of the literature verifies that the factor can include a lecturer's personal qualities, beliefs, values, attitude, knowledge of mathematics, teaching-learning philosophy and methodology, devotion to her/his educational role, interest in and relationship with students, the establishment of a conducive environment and several other aspects.

Persons who conduct on-going research on the relationship between mathematics teaching and student learning, attitude, motivation and achievement (compare Dowker, Ashcraft & Krinzinger (2012), Mata, *et al* (2012), Maat & Zakaria (2010) and others) are almost in consensus when they highlight the following desirable features of an effective teacher's factor in action:

- shaping student expectations in respect of mathematics learning in a positive manner;
- setting "…meaningful tasks, which are somewhat but not excessively challenging" (Mata, et al, 2012:8);
- engaging students in regular mathematics learning and practicing, followed by frequent constructive feedback;
- creating teaching-learning situations that promote student motivation, attitude, ability, confidence, self-concept, interest and pleasure in respect of mathematics;
- establishing and maintaining a supportive and conducive teaching-learning environment and climate, characterised by a high level of clarity, effective management, structure, regular student-lecturer interaction and caring, observant and approachable teacher (lecturer) behaviour; and
- taking into consideration how students perceive and assess the effectiveness of teaching, their own learning and the nature of the teaching-learning environment, and constructively acting upon it.

In a study at two Malaysian Institutes (involving engineering technology students) to determine the possible relationship between the learning environment and the attitude of students towards mathematics, Maat & Zakaria (2010) confirm a moderately positive and significant relationship between the teacher's factor and students' attitude towards mathematics. Students who hold more positive perceptions of their teachers (lecturers) have a more constructive attitude towards mathematics. The substantial contribution of the 'teachers' factor' to student learning of mathematics clearly stems from the consulted literature and can't be emphasised sufficiently.

3.4 Learning mathematics with technology

Vast and widespread improvement in the availability and ease of use of technology, linked to the responsiveness and expectations of the younger generation of students stimulated the widespread use of Information and Communication Technology (ICT) in higher, but also in other forms of education. Many educational institutions are nowadays equipped with the latest technological facilities and networks. ICT adds a new dimension to teaching and learning by enabling teachers (lecturers) to do things that might not be possible within a traditional lecture room. While noting and welcoming the aforementioned, Czerniewicz, Ravjee & Mlitwa (2005:61) point to an increasingly common acknowledgement that "…ICTs cannot improve teaching and learning or effect change independently of the context of its application". The extent to which learning with technology generates effective and quality learning outcomes entirely depends on the nature of the learning environment and the value that the teacher (lecturer) adds.

Learning mathematics with technology requires that a number of important conditions be honoured. The following case study provides important evidence and guidance in this respect. Research by Barkatsas, *et al* (2009) to determine (among other aspects) the relationship between the mathematics confidence, assurance with technology (computers), attitude to learning mathematics with technology and achievement of 1068 Greek students, involves the Mathematics and Technology Attitudes Scale (MTAS) of Pierce, Stacey & Barkatsas (2007). The inventors of the MTAS define its five subscales as follows (Barkatsas, *et al* 2009:565–566):

- *Mathematics confidence:* Students' perception of their ability to achieve and their assertion that they can handle difficulties in mathematics.
- *Confidence with technology:* The extent to which students feel self-assured in operating technology, believe that they can deal with technological processes and techniques, are confident of feedback and answers provided via technological procedures, and in the case of possible errors are self-reliant in resolving problems.
- *Attitude to learning mathematics with technology:* The degree to which students believe that technology enhances mathematical learning by the provision of many examples, exercises and assessment opportunities.
- *Affective engagement:* Students' feelings about and attitudes towards mathematics.
- *Behavioural engagement:* Students' learning behaviours in respect of mathematics.

The project's outcomes encouraged Barkatsas, *et al* (2009:569-570) in drawing the following conclusions:

- *High to average* achieving students display mathematics confidence and constructive affective and behavioural engagement and generally view learning mathematics with technology very positively.
- Students with *exceptional* mathematics achievement exhibit all of the characteristics and behaviours of the high to average achieving group, but they do not believe that the use of technology will enable them to improve their performance.
- *Low* achieving students project negative attitudes toward mathematics, low levels of mathematics confidence and below-average affective and behavioural engagement. However, rather unexpectedly, these students despite their scanty achievement demonstrate confidence in using technology and a generally positive attitude to learning mathematics with technology.
- The two factors that highly associate a positive attitude to learning mathematics with technology are student confidence and their affective (attitudinal) engagement.

Based on the abovementioned far-reaching conclusions, Barkatsas, *et al* (2009:570) makes the following important observation: When properly used, technology may serve as an important tool for improving student proficiency in mathematics, as well as the learning environment.

3.5 Synthesis in respect of the theoretical framework

The following matters, highlighted by the abovementioned theoretical framework, have specific applicability in respect of this study:

- students' attitudes related to their perceived ability is an important determinant and predictor of their mathematics achievement;
- an understanding of students' attitudes towards mathematics will enable mathematics teachers (lecturers) to design and implement an appropriate teaching and learning strategy;
- students who have positive perceptions of mathematics teaching (and their mathematics teachers (lecturers)) have a more beneficial attitude towards mathematics;
- used appropriately, technology is an important tool for improving students' mathematical ability and to enhance the learning environment; and
- effective, dedicated and caring mathematics teachers (lecturers), who take note of and who attend to the four abovementioned aspects, make a substantial contribution to student learning of mathematics.

RESEARCH DESIGN AND METHODOLOGY

4.1 Research paradigm and methodology

Pragmatism (Tashakkori & Teddlie (2009); Creswell (2009)), is regarded as the relevant research paradigm underlying this inquiry. It firstly strongly builds on the curriculum-as-practice theoretical framework for the study (compare section 3.1). Secondly, because the research problem (What influence might a technology-based learning-support strategy have on the attitude, level of engagement and achievement of a group of second year mathematics education students?) is influenced by several determinants, Pragmatism opens the door to multiple methods.

A *mixed-methods* approach, which utilises both quantitative and qualitative data collection methods, which considers both subjective and objective knowledge and which focuses on 'what works' (Tashakkori & Teddlie, 2009), was therefore applied. A *parallel design* (Tashakkori & Creswell, 2007) was employed in two successive cycles in this inquiry, utilising a relationship of complementarity. The parallel quantitative and qualitative findings at the end of the first semester course (cycle 1), were used to devise a new teaching and learning strategy, which was implemented during the second semester's course (cycle 2). A follow-up parallel quantitative and qualitative data collection finally occurred at the end of cycle 2.

4.2 Sampling and unit of analysis

A purposive sampling method (Given, 2008) was adopted in both phases (Mathematics modules) of the study. Purposive sampling allowed the researchers to select both class groups (samples) according to the nature of the problem and the phenomenon being studied. The first phase unit of analysis, as indicated in section 2 of the paper, was a group of 78 pre-service Gr 10 to 12 Mathematics teachers, who enrolled for the first semester 'Calculus' module in their 2nd year (from February to June 2012) at UJ. The second phase unit of analysis was the (remaining) group of 51 students, who passed the aforementioned first semester module, and who enrolled for the second semester 'Application of Calculus' module (from July to November 2012).

4.3 Data collection and analyses

Qualitative data

Towards the end of the first semester, individual student feedback on their lived course experiences was collected via a semi-structured open-ended questionnaire. Individual feedback per category was consolidated and then analysed via the constant comparative qualitative research methodology (Jacobs and Du Toit, 2006:305-306), as a directed form of content analysis (Hsieh and Shannon, 2005:1281). Appropriate student views, by quoting their direct words are integrated into all categories of feedback in support of the findings.

Quantitative data

To compare the students' first and second semester marks, a paired-samples t-test, including Pearson's product moment correlation coefficients, were conducted on the two pairs of first and second semester examination and final module marks, for the 51 students who enrolled for both modules. The SPSS statistical package was used to conduct the analyses.

4.4 Trustworthiness, validity and reliability

Strategies to maintain the *trustworthiness* of the qualitative aspects of the study included selected measures of the four constructs credibility, transferability, dependability and confirmability, originally cited by Lincoln and Guba (1985). A thorough description of the nature of teaching and learning during the first and second semester courses is seen to enhance transferability. A dense description of the methodology employed through the constant comparative and directed content analysis methods is seen to promote dependability and rigour. The credibility of the research is strived for through a proper interrogation of the analyses and findings and records of these have been kept for further referral.

In respect of *validity* of the quantitative aspects of the study, the paired t-test is regarded as valid. The differences between the paired tests marks is approximately normally distributed (Kolmogorov-Smirnof $z = .729$ and $.738$, with $p = .663$ and $.647$ for the two sets of examination and final marks respectively). Additional *reliability* and internal consistency measures (e.g. Cronbach's alpha) were not regarded as necessary, due to the robust nature of the paired t-test.

4.5 Ethical considerations

In order to maintain the concept of individual confidentiality, participants were assured that any information divulged via the questionnaires are recorded in an anonymous manner. Participants were also informed that their participation and involvement were voluntary and at any time, should they feel uncomfortable, they had the right to withdraw from the study without prejudice to them. Written consent was also obtained from all participants via the questionnaires, in order to utilise their views and module marks (anonymously).

5. THE 'NEW' TECHNOLOGY-BASED TEACHING AND LEARNING STRATEGY

The original (first semester's) teaching and learning approach basically comprised of formal lectures and tutorial classes, the latter supporting students with homework and reinforcing their knowledge and skills. Continuous formative assessment, involving weekly class and tutorial tests, combined with three summative assessment opportunities, two semester tests and an end of semester integrated capstone examination.

Towards the end of the first semester, individual student feedback on their lived course experiences was collected via a semi-structured open-ended questionnaire. Consolidated patterns of feedback are summarised below in a number of categories. Appropriate student quotes are integrated into all categories to support or strengthen findings.

Relevance and complexity of the content and the textbook

In general students indicated that the course content is not relevant to pre-service teacher education. Many students experienced the content challenging and commented that they require lots of practise to master it. This had a potentially negative influence on their general attitudes towards the module. Students also experienced difficulty in handling the prescribed textbook –

- "*The content is very challenging … I don't understand*".
- "*We are doing some engineering stuff, it is not necessary*".
- "*I am disappointed*".
- "*Sometimes I feel like I am overloaded*".
- "*Mathematics is about calculations not some kind of theory and you have to bring your textbook to class, textbooks are meant for self-study where you can practice and view your answers there, but you have to come with it during the lectures, because the lecturer keeps on referring to it and she expects us to go through some of the definitions in the textbook while the class is in progress*".

Tutorial classes as an integral component of the teaching and learning strategy

Students reported that they benefitted from tutorial classes as these classes provided an opportunity to discuss homework questions and reinforced new content that was presented during the formal lectures, as preparation for assessments –

- "*Homework is crucial and they help us*".
- "*The tutorial classes are informative and of great help*".
- "*I think they are often important when we are doing content that are more difficult which needs more explanation to be understood*".

Course structure and support

A well-structured course environment with online support, which also provides required administrative information, is a key component of a more optimal student learning experience. Most students reported positively on the use of the electronic learning environment (Edulink) provided by the UJ –

- "*Edulink is my best friend*".
- "*Without the information that we always get on Edulink, I am not sure if things would be as smooth as they are if we never had Edulink. And it is easy to use, it makes things simple*".
- "*I think it is a great learning environment*".

In an effort to address the abovementioned feedback, to boost student attitudes and motivation and especially to encourage more regular engagement with mathematical content, an extensive online support programme (Enhanced WebAssign from Cengage Learning) supported the lecturer in the implementation of the second semester's teaching and learning strategy. WebAssign (Stewart, 2012: xv) is an online homework system that:

- supports the lecturer to deliver, collect, grade and record homework or assignments via the Internet;
- enables students (individually or in groups) to get instant feedback in respect of their efforts and possible misconceptions (multiple attempts at solving problems are possible), based on carefully selected and scaffolded questions; and
- features video solutions, multiple online questions and online eBook support as integral components.

The new teaching and learning strategy of the second semester basically comprised of formal lectures, tutorial classes, continuous formative assessment (weekly class tests), similar to the first semester's strategy, combined with three summative assessment opportunities. The foremost difference in the teaching and learning strategy between the first and second semester was the inclusion of online homework tasks. These tasks were frequently scheduled and covered individual content areas as well as the integration of content. The graded tasks forced students to work continuously and were included as one of the formal continuous assessment opportunities in the second semester.

The influence and learning-related outcomes of the new teaching-learning strategy was formally monitored by a two-fold empirical investigation, of which the methodology and findings are outlined in the next section. The first part of the investigation focuses on student perceptions and lived experiences in respect of the new strategy and the second part on the 'real' learning outcomes, as portrayed by student achievement.

6. EMPIRICAL INTERROGATION OF THE NEW TECHNOLOGY-ENRICHED TEACHING AND LEARNING STRATEGY

6.1 Qualitative research findings: Student perceptions and experiences

In the penultimate week of contact sessions during the second semester, individual student feedback on their lived course experiences was again collected via a semi-structured open-ended questionnaire. Main categories of feedback, incorporating directly quoted student views, are summarised in the following sub-sections.

Student experience of WebAssign

An overwhelming positive reaction was reported by the majority of students. The use of WebAssign as technology tool was relevant, appealing, contributed to their education as mathematics teachers, enhanced their mastery of content and built their mathematical confidence –

- "*Exposed me to technology that I could apply in my classroom as a teacher*".
- "*I tried a question until it is correct*".
- "*It also helped to boost my self-confidence*".
- "*It makes you challenge yourself*".
- "*WebAssign help me to understand some of the problems I had when I was practicing mathematics, because it allowed me to try some of the problems similar to those I was practicing*".

The course content and textbook

In complete contradiction to their first semester views, most students reported that they require calculus skills in order to be effective mathematics teachers. Although the content was still seen as challenging, it was now viewed as a necessary preparation for the future, rather than a current obstacle. In addition, students reported positively on the utilisation, integration and relevance of the textbook –

- "*It is important for a teacher to be on a higher mathematics level than school children*".
- "*Calculus skills provide ways to exploring mathematics with ease and they are also enjoyable*".
- "*The book is good and helpful. We need to have an advanced knowledge*".
- "*I love the book*".

Students' approach to learning mathematics

Students prefer learning mathematics in groups and/or individually via different methods. The majority of students were positive about the use of different practice opportunities including class discussions, homework questions and different technology tools –

- "*It is better to study mathematics in groups but you have to study alone so that you can see how responsible you are. Using WebAssign homework tasks are the best way of practicing mathematics*".
- "*In the classroom with a lot of practical examples, and by the use of different technological programs*".

- “*Give more practice opportunities. More class where learners can interact with the teacher and she can explain some work in more detail and in the simplest way. That is how I study the best*”.
- “*Using WebAssign is a better way for me or doing homework tasks*”.

The most important conclusion drawn from the student feedback was their positive response to the use of WebAssign as teaching and learning enrichment mechanism, which motivated them to engage more frequently and enabled them to eventually master the challenging calculus content.

6.2 Quantitative research outcomes at the end of semester 2

Where underachievement mostly characterised learning outcomes in the first semester module, the complete opposite happened in the more challenging second semester module. Just four of the 51 students (7.8%) obtained a less than 50% semester mark, the November examination generated a 86% pass ratio and an average student mark of 65.6%, with exactly a third of the students obtaining a distinction (75%+) in the end of the year examination.

A paired-samples t-test, including Pearson’s product moment correlation coefficients, was conducted on the two pairs of first and second semester examination and final module marks. Tables 1, 2, and 3 below summarise the respective paired samples t-test statistics, correlations and test findings.

TABLE 1: PAIRED SAMPLE STATISTICS

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Mathematics 2A (Exam)	47.94	51	14.680	2.056
	Mathematics 2B (Exam)	65.61	51	16.966	2.376
Pair 2	Mathematics 2A (Final)	52.86	51	13.188	1.847
	Mathematics 2B (Final)	68.06	51	13.873	1.943

TABLE 2: PAIRED SAMPLE CORRELATIONS

		N	Correlation	Sig.
Pair 1	Mathematics 2A (Exam) and Mathematics 2B (Exam)	51	.678	.000
Pair 2	Mathematics 2A (Final) and Mathematics 2B (Final)	51	.784	.000

TABLE 3: PAIRED SAMPLE TEST DIFFERENCES

				99% Conf Interval of the Difference				
	Mean	**Std. Deviation**	**Std Error Mean**	**Lower**	**Upper**	**t**	**Df**	**Sig. (2-tailed)**
Pair 1: Maths 2A (Exam) and Maths 2B (Exam)	-17.667	12.678	1.802	-22.492	-12.842	-9.805	50	.000
Pair 2: Maths 2A (Final) and Maths 2B (Final)	-15.196	8.911	1.248	-18.537	-11.855	-12.179	50	.000

The paired-samples t-test and Pearson's correlational findings confirmed that the learning outcomes in the form of students' examination marks in the second semester module differ significantly (M = 65.61, SD = 16.966), from learning outcomes presented by marks in the first semester examination (M = 47.94, SD = 14.680), t (50) = -9.805, $p < 0.001$, d = -1.114. This was also the case in respect of students' final marks in the second semester module (M = 68.08, SD = 13.873) in comparison to their final marks in the first semester module (M = 52.86, SD = 13.188), t (50) = -12.179, $p < 0.001$, d = -1.123. The two Cohen's d effect size values above (respectively -1.11 and -1.12) in addition suggested a very high practical significance of these findings.

6.3 Empirical synthesis

Based upon students' positive lived experiences and their significantly (statistically and practically) increased performance in the second semester module, the influence of the new teaching and learning strategy on student learning in mathematics is regarded as substantial.

7. IN CONCLUSION

The purpose of the study was to determine the influence of a technology-enriched learning-support strategy on the attitude, level of engagement and eventual achievement of a group of second year students and mathematics teachers-in-training at the University of Johannesburg. More positive student attitudes and a growth in their mathematics confidence levels, which enabled the students to deal with more challengeable content, were perhaps the most pertinent dividend stemming from the research. The marked and significant increase in student achievement led the researchers to believe that the study meaningfully contributed to learning in mathematics.

The authors don't regard the abovementioned outcomes as accidental or by chance. Through a revised teaching and learning strategy, which incorporated carefully planned online learning support, students were encouraged to more regularly engage with the mathematical content. Besides the expectation of frequent practice in respect of each content area, integration of areas was often applied and assessed. Because they could gradually witness and experience the growth in their mathematical ability, the confidence and attitudes of the students were boosted, which led to an increase in their engagement and which in turn enhanced their performance. The whole course experience eventually turned out to be an academic and personal highlight in the short career of these mathematics teachers in the making.

The authors discovered, and confirmed, that a supportive, passionate and knowledgeable teacher on the one hand; in combination with user-friendly, interactive information technology on the other hand, are key determinants of a conducive learning environment for Mathematics teachers in training. These students did indeed learn Mathematics more effectively via technology, which is in itself a meaningful research endeavour.

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