Enhancing the mathematics capability of first-year information technology students at a University of Technology in South Africa

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Abstract

First-year IT students enrolled in the Higher Certificate in Information and Communication Technology programme at the UoT where this study was conducted are expected to have passed either Mathematics or Mathematics Literacy in their final matric examinations. However, the mathematics performance of many first-year IT freshmen enrolled in the HCINCT programme in 2015 was lower than the mathematical capabilities of current 11- to 12-year-old pupils attending Grade 6 in a South African primary school. This claim was based on the researcher's analysis of the students' pre-test and post-test scores. This study investigated the efficacy of the enhancement of the mathematics capability intervention programme known as the Higher Certificate in Information and Communication Technology. The main research question of the study was: What is the effect of the intervention programme on the mathematical knowledge of IT students upon entry into the HCINCT programme? The intervention was administered in 2015 to 147 information technology freshmen through class tutorials in the subject of Quantitative Techniques. Quantitative methods instruments were used to collect analyse and present data. To find answers to the main research question, hypotheses were constructed based on historical data. The null hypothesis (Ho) claimed that there was no statistically significant difference between the mean scores of the groups before and after the mathematics capability intervention (the treatment). A paired sampled t-test method befitted the nature of the hypotheses and the data collected. The descriptive statistics results suggested that there is a strong probability that the students' mathematical capabilities increased by chance.

Keywords: Enhancing, mathematics, capabilities, Higher education,

Introduction

The mandate to conduct this study was obtained by the researcher from the project sponsor in January 2015 (Alexander, 2013; DHET, 2013). From February 2015 to October 2015, 147 IT freshmen participated in voluntary class tutorials. The mathematics capability intervention was administered to the 147 students through the Quantitative Techniques (QT) class tutorials in the HCINCT programme of 2015. Quantitative Techniques is one of the three major courses in the HCINCT one-year programme run by the IT Department at the University of Technology (UoT) where this research was conducted. Class tutorials in QT were conducted to augment students' mathematical skills. The intervention differed from the usual teaching because the mathematics capability interventions content was based on the South African high school mathematics guidelines provided in the National Qualification Framework (NQF) level 4, while the ordinary teaching in the HCINCT programme was based on first year IT numerical skills curriculum pitched at NQF level 5 (South African Qualifications Authority,

2011). The students' mathematical skills were revealed as needing enhancement by the marks they attained in their Matric Mathematics results. These marks were confirmed to be weak according to an admissions proficiency scale used by the IT Department for acceptance of students.

In early February 2015 the researcher briefed the 147 HCINCT programme students about the voluntary mathematics capability intervention. Some students voluntarily took the pretest. The pre-test and the post-test were the same tests but the questions in the post-test were changed to avoid students familiarity with the questions. However, the topics covered in both tests were the same. The problem regarding throughput rates in IT programming courses rests in the mathematical skills of first-year IT students upon entry (Alexander, 2013). This is compounded by the level of mathematics education that students are taught at high school (Chisholm, 2005; Brandell, Hemmi & Thurnberg, 2008). Since high school mathematics education in South Africa is set at a lower standard compared with high school education in the same grades in other countries (Howie & Plomp, 2002; Fleisch, 2008). The UoT was concerned about the learner retention rates in computer programming courses (Andreae & Hoda, 2014; Ford, 2015; Nzama, 2015). Therefore, the Higher Certificate in Communication and Technology (HCINCT) programme was created to increase student throughput rates in the IT diploma programme, to improve the Quantitative Techniques (QT) course content, to allow certification to students that

want to leave on completion of the HCINCT programme, and to hand over the HCINCT programme to Technical Vocational Education and Training (TVET) colleges (DHET, 2013; Alexander, 2013). The research problem lies in extracting design guidelines for an intervention to enhance the mathematical capabilities of IT students upon which the desired IT programming skills can be scaffolded. Instructional and mathematics curriculum guidelines for adult education (Reynolds, Showalter & Wollet, 2014; Valenzuela, 2018) were followed to focus the mathematics intervention programme on the desired mathematical needs of the students in order to maximise time and human resources. This was due to the fact that the mathematics intervention programme was administered through the QT course, which had its own academic scope, time lines and expected deliverables. The QT tutorials were designed to provide students with practical experiences through interactive engagements using the World Wide Web so that their mathematical thinking skills would be challenged and developed in order for them to acquire the desired numerical skills (Chen, 2010).

Literature Review

The first literature review was used to navigate the landscape in the area of interest in order to learn from documented successful interventions (Higher Education Learning & Teaching Association of Southern Africa, 2009; Bozalek, Garraway, & McKenna, 2011; Siyepu, 2015; Rohlwink, 2015). Once this process was completed, the second literature review took place (Gustafsson, 2014; Cēdere & Gedrovics, 2014; Mickey-pabello, 2015; Cēdere, Jurgena, Helmane, Praulite & Tiltina-Kapele, 2015). The literature review is summed up into two categories: cognitive and scaffold. Many mathematics teachers use traditional strategies to transmit facts, skills, and values to students (Miller, 2010; Jao, 2017). Besides, traditional education settings use textbooks to support student learning while a systematic approach is followed for developing numerical skills. Despite that, Miller is against the idea of using traditional approaches alone. He suggests the use of transmission, transactional, and transformational educational strategies to transfer mathematics knowledge to students. Ball (1990) supports the previous authors by saying that traditional strategies emphasizes fluency in procedures, but do not help students to conceptualize their understanding of mathematical ideas.

Opposing views posit that cognitive development involves a shift towards abstraction and student's self-belief (Nath & Szücs, 2014; Bonilha, Hermann, kellerman & Lin, 2015; Barrouillet, 2015; Bonne & Johnston, 2016). Braithwaite, Goldstone, van der Maas, and Landis (2016) contest the notion of using abstraction for cognitive development by arguing that pupils' age and experience must be considered. However, some authors (Belfiore, Matrisciano & Rudas, 2010; Grenier-Boley, 2014, Pasiphol, Sujiva & Youngchim, 2015; Cēdere, Jurgena, Helmane, Praulite & Tiltina-Kapele, 2015; Cirino, Fuchs, Huston-Warren, & Tolar, 2016) say building mathematics capability includes focusing on executive function, cognitive function, cognitive interest, and using simple neural networks to stimulate verbal learning of mathematics. The different authors' views on how to enhance the mathematics capability of freshmen led to a dilemma that could be summarised in a research question that asked: What is the effect of the intervention programme on the mathematical knowledge of IT students upon entry into the HCINCT programme?

Methodology

The study used the quantitative methods approach for data collection, data analysis, data interpretation and data presentation **(**Sandelowski, 2000**;** Leech & Onwuegbuzie, 2009**;** Clark, Creswell & Vicki, 2011**;** Duan, Green, Hoagwood, Howirtz, Palinkas & Wisdom, 2013)**.** The researcher adopted a positivist paradigm to understand the nature of reality regarding the students' mathematical capabilities, explore if there are other realities and to understand what do other authors believe is the real problem (Burrell & Morgan, 1979; Stokes, 1997; Patton, 2002; Cronje, 2013). The conceptual framework for the investigation, the Iterative ADDIE (Berkowitz & O'Neil, 1979; Molenda, 2003; Gravemeijer, McKenney, Nieveen & van den Akker, 2006) was used to map out the processes that measured the mathematical attributes that were required to augment the students' mathematical competencies. Kolb's (2015) Experiential Learning Theory was used to administer the enhancement of mathematics capability intervention to the students' assessment scores retrieved from the pre- and post-test scores. Students' pre-test and post-test scores were evaluated to find answers to the main research question.

The Research Design

The instructional design approach that guided the construction, the implementation and the administration of the mathematics intervention was obtained from (Carey, L., Carey, J. O. & Dick, 2014) model. The Solomon, (1949)'s guidelines were used by the researcher to assign the students randomly into groups. While, Nelson & Thomas, 2001's guidelines were used by the researcher for the administration of the pre-test and the post-test IT students assessment scores. The researcher divided the students into four groups. This was done to test the efficacy of the intervention if any before and after the mathematics capability intervention was administered to the students in the HCINCT programme of 2015. A post-test was thereafter administered to determine whether or not the intervention had a significant effect on the students' performances. The data analysis was performed using the following four groups:

1. Experimental Group 1 (E1),

2. Control Group 1 (C1),

3. Experimental Group 2 (E2) and

4. Control Group 2 (C2).

E1 (n=37) was given a pre-test followed by the mathematics capability intervention (the treatment).

C1 (n=37) was given a pre-test and a post-test without the mathematics capability intervention (the treatment).

E2 (n=37) was not given a pre-test but received the mathematics capability intervention (the treatment) and a post-test.

C2 (n=36) received the post-test only. Total subjects = 147**.**

Data were checked to determine if they met assumptions for analysis using the paired samples t-test. The level of significance chosen was .05, which is the most common level of significance used by researchers (Bluman, 2015; Field, 2018). The critical values used were the t-test values gained from the IBM SPSS statistics 25 outputs. The reason for using the tvalues was to compare the means of the two groups in order to determine whether or not there was a significant difference between them. Paired t-test assumptions were tested to check the viability of the data for data analysis using a paired sample t-test statistical tool. Bluman, (2015) states that in a paired t-test, the dependant variable must be measured on a continuous scale and that

the data is measured at the interval or ratio level. The students' assessment scores were produced using the same assessment tool, and the instrument used produced continuous data represented through the students' assessment scores. In addition, one needs dependent observations (Field, 2018). In this instance, the students' pre-test scores were matched with the post-test scores so that for each participant, there were two scores. The paired t-test also assumes that the participants were randomly sampled from the population; this assumption was also met. The other assumption deals with the differences between the dependent variables, and these differences need to be approximately normally distributed. The differences must not contain any significant outliers (Raveendran et al., 2014). Figure 1 demonstrated that there were no outliers in the pre-test and in the post-test data obtained from the student's assessment scores.

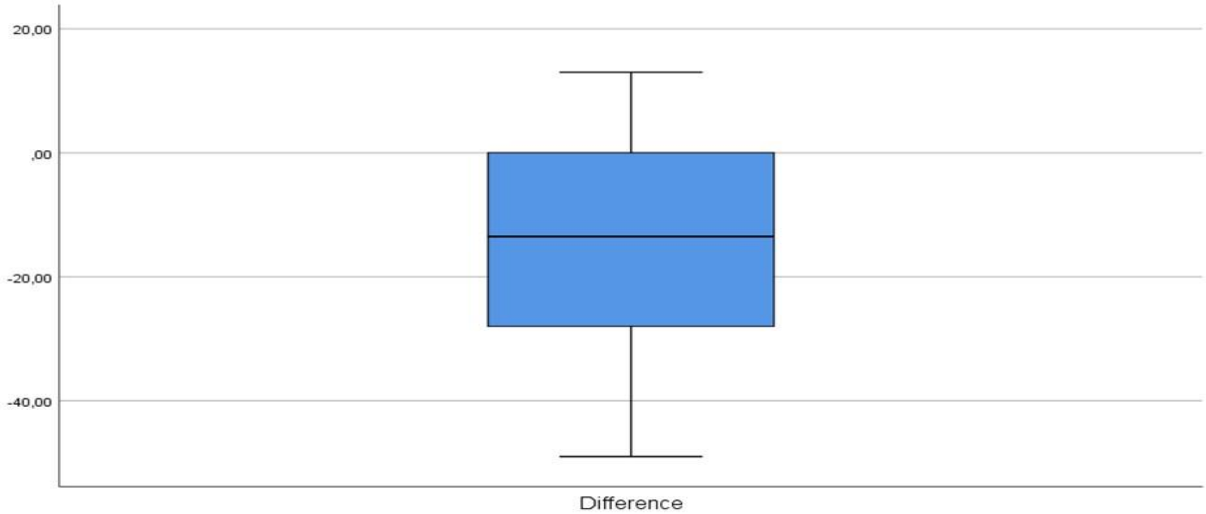

Figure 1: Pre-test and post-test students means scores

The box plot illustrated in Figure 1 shows that there are no outliers in the data distribution.

Based on the information obtained from the IT students' pre-test and post-test scores, the data meets the samples' paired t-test assumptions. The researcher assessed the normality of the scores for groups E1 and C1, the two groups that were administered a pre-test and a post-test.

Since each group had less than 50 subjects, the Shapiro-Wilk test was considered to be the best test for normality (Chen, Shapiro & Wilk, 1963; Shapiro & Wilk, 1965, Howell, 2013). Even though, the Kolmogorov-Smirnov test accommodates samples with N=50 and more (Kolmogorov, 1933; Smirnov, 1933; Birnbaum, 1952; Lilliefors, 1967; Riffenburgh, 2012). However, the Shapiro-Wilk method is more robust and is used by most researchers, especially when the sample size is less than 50 (Razali & Wah, 2011). The Shapiro-Wilk and the

Kolmogorov-Smirnov test are not parametric or non-parametric but are assessments that were used by the researcher to assess the normality of the sample to determine whether the data befitted assessment through parametric or a non-parametric test. A paired samples t-test which is a parametric test was used to assess the descriptive statistics (Raveendran, Gitanjal & Manikandan, 2014). The researcher assessed the descriptive statistics of groups E1 and C1 because these were the groups that took both the pre-tests and the post-tests. There was a noticeable difference between the mean values for E1 scores on the pre-test ($\bar{X}$ =41.27, SD=5.11) and the post-test ($\bar{X}$ =71.46, SD=12.06). The mean ($\bar{X}$) for the C1 pre-test ($\bar{X}$ =39.62, SD=6.3) was not noticeably different from the C1 post-test ($\bar{X}$ =39.16, SD=5.0). The researcher further assessed the differences between these two sample means using a paired samples t-test to assess statistically significant differences between the scores on the pre-test and the post-test measures for groups E1 and C1.

A further analysis was performed to determine whether or not the means of the 4 post-test groups were significantly different from one another. A one-way between groups ANOVA was performed. There was a significant effect between the mathematical knowledge scores of the 4 post-test scores (E1, C1, E2, and C2): ($F (3,143) = 160.108$, $p < .001$). Post hoc comparisons using the Tukey HSD test indicated that the mean score for the E1 group (M = 71.46, SD=12.06) was significantly different than the C1 group (M = 39.16, SD=4.96) and the C2 group (M = 38.96, SD = 4.67). However, the E1 group did not significantly differ from the E2 group. The E2 group (M = 72.59, SD=11.84) was significantly different than the C1 group (M = 39.16, SD=4.96) and the C2 group (M = 38.96, SD = 4.67). The two control groups, C1 and C2 did not differ from one another.

Since there was a question of normality for the C1- Pre Test group as determined by the Shapiro ($p< .05$), a Kruskal-Wallis test was conducted comparing the results of the Post-Test for all 4 groups: E1, E2, C1, C2. A significant result was found ($H(3) = 109.848$, $p < .001$), indicating that at least two of the groups differed from each other (See Summary Table below). Follow-up pairwise comparisons indicated results identical to the ANOVA. The E1 group was significantly different than the C1 group (H(1) = 54.831, p < .001*)* and the C2 group (H(1) = 54.155, p < .001). However, the E1 group did not significantly differ from the E2 group (H(1) = 0.288, p > .05). The E2 group was significantly different than the C1 group (H(1) = 54.928,

p < .001*)* and the C2 group (H(1) = 54.173, p < .001). The two control groups, C1 and C2 did not differ from one another (H(1) = 0.040, p > .05).

Table 1: Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PostTest is the same across categories of Group.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Results

The results of the two paired samples t-tests indicated that there were significant differences between the scores of the E1 pre-test ($\bar{X}$ =41.27, SD=5.11) and the post-test measures ($\bar{X}$ =71.46, SD=12.06): t (36) = -22.936, p<.001 (two-tailed). The mean increase in scores was -30.189 with a 95% confidence interval ranging from -32.859 to -27.520. The eta squared statistic (.94) indicated a large effect size. For Group C1, there were no significant differences between the scores of the pre-test ($\bar{X}$ =39.62, SD=6.3) and the post-test measures ($\bar{X}$ =39.16, SD=5.0): t (36)=.723, p>.05. The null hypothesis (Ho) claimed that there was no statistically significant difference between the mean scores of the groups before and after the mathematics capability intervention (the treatment).

The results of the analyses indicated that the variables were normally distributed. The results of the voluntary pre-tests that were administered to some of the research participants (Experiment Group 1 (E1) and Control Group (C1)) before they assumed their studies in the

HCINCT programme of 2015 also confirmed that the students' mathematical skills were below the level of proficiency needed to embark on their chosen studies. Descriptive statistics results suggested that there is a strong probability that the students' mathematical capabilities increased by chance. In conclusion, the researcher reached the conclusion that there are significant differences between the pre-test and post-test scores for Group E1. Figure 2 demonstrates the mean mathematical knowledge scores for the pre-test and the post-test administered to students in Group E1 and indicates the differences in the student assessment scores of this group.

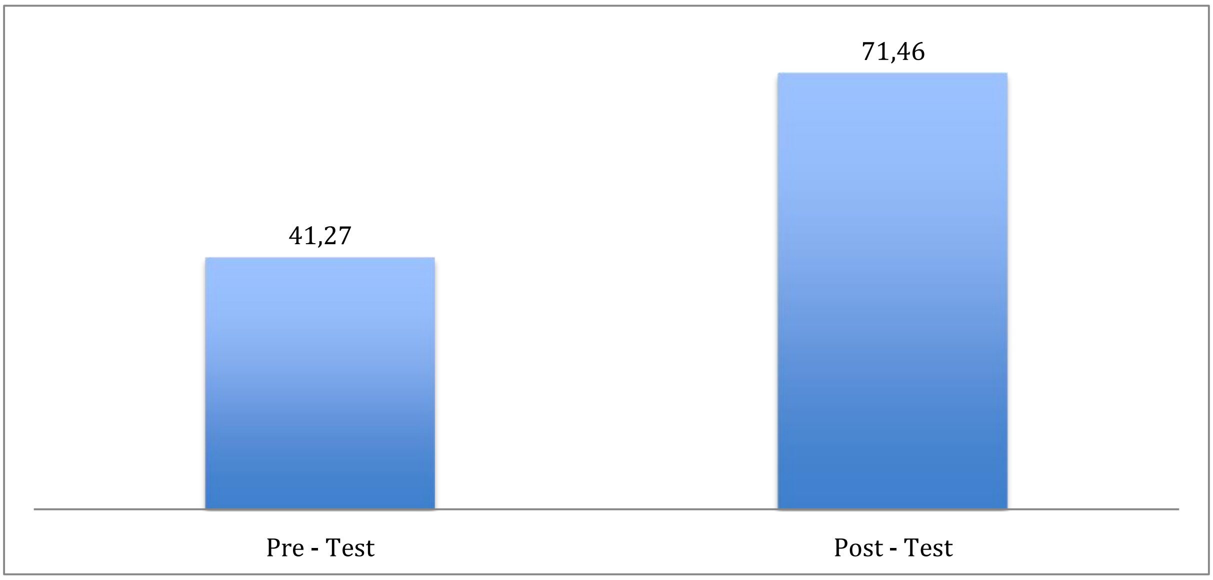

Figure 2: Mean Mathematical Knowledge score for the Experimental Group 1 (E1)

The post-test scores of the IT students in Group E1 demonstrate an increase in the students' mathematical knowledge. The answer is that the mathematics capability intervention had no effect on the students' mathematical knowledge upon entry into the HCINCT programme. Even though, the students' post-test scores in groups E1 and C3 increased, the inferential statistics results suggested that there is a strong probability that the students' mathematical capabilities increased by chance.

Discussion

The researcher claimed that the descriptive statistics results suggested that there is a strong probability that the students' mathematical capabilities increased by chance. Many students in the HCINCT programme of 2015 lacked the foundational arithmetic skills that were needed to scaffold upon their IT programming skills needed for their IT national diploma a year after they had completed their HCINCT programming. The mathematics performance of many first-year

IT freshmen enrolled in the HCINCT programme of 2015 was lower than the mathematical capabilities of current 11-to 12 year-old pupils attending grading 6 in a South African primary school. To illustrate the missing knowledge the researcher has extracted two problems that were given to the HCINCT students of 2015. In question 1.3 we were asked to

find the missing numerator for the denominator 12 in $5\frac{1}{4} = \frac{?}{12}$

While, in question 1.4 we were asked to solve: $\frac{(6+1)(5-(-14))}{-7}$

The majority of the students could not solve these problems. There are operational arithmetic rules within rules that one has to follow when solving mathematical problems where Bracket, Over, Division, Multiplication, Addition and Subtraction (BODMAS) or Parentheses/Brackets, Exponents, Multiplication/Division, Addition/Subtraction (PEMDAS) rules are to be re-adjusted depending on what the problem presents.

Recommendations

Future mathematics and/or IT orientated courses at the UoT where this study was conducted could be aligned to the market and global trends to expose students more to global market demands. Outdated course materials could be removed from the syllabus to allow for new and contextualised learning materials. The QT class materials could incorporate tutorials that introduce partakers to aspects of artificial intelligence (and its subsets machine and deep learning), data mining and cyber security. To allow UoT graduates job opportunities in areas that are needed most at this present time.

Conclusion

In the end, the researcher rejects the null hypothesis (H_o) that claimed that there was no statistically significant difference between the mean scores of the groups before the mathematics capability intervention (the treatment). There was a significant effect between the mathematical knowledge scores of the 4 post-test scores. Even though, only 36 of 147 (n = 147) students achieved the 65 aggregate score needed to be guaranteed a space in the three-year IT National diploma at the UoT where this study was conducted the following year. The majority of the students from the HCINCT 2015 programme acquired an overall mean 50 score for all 11 courses offered in the HCINCT programme. However, these students had failed two or three subjects. Hence, these failed courses had to be repeated in the following year.

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