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Teaching teachers to teach physics to high school learners

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Abstract

To address the past inadequacies of high school teacher education in South Africa a course was taught to equip teachers with a basic understanding of Physics. This work discusses measures implemented in this module to increase cohort pass rates from around 40% to over 80%. The measures implemented include Problems Based Learning (PBL), technological learning (TL) and group learning (GL). This increased pass rate has a significant impact on throughput and also a far-wider reaching impact - that of improving the quality of education at high school level. In this work, we also highlight the difficulties faced by the students who are all in full-time employment with language barriers consequent of English being a second language. The methods employed while lecturing this cohort have been adopted by the cohort in their own classrooms with significant results noted. The study employs a mixed modal approach to quantify all data with qualitative responses.

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Keywords: PBL; technological learning; physics education; adult learners; high school

1. Introduction

The Apartheid regime in South Africa (1948-1994) resulted in the oppression of non-white citizens and severely curtailed their rights (Allen, 2005; Beck, 2000; Du Pre, 1994; Lacour-Gayet, 1977 & Geldenhuys, 1990). This significantly impacted all aspects of their lives and more especially the educational system suffered severe setbacks (Prew, 2009). The South African educational system, although significantly improved since the fall of apartheid, can best be described as a high-cost low-performance one (Prew, 2009 & Modisaotsile, 2012). It does not compare favorably to other educational systems in Africa or indeed worldwide with other educational systems in countries with a similar developing economies (Prew, 2009 & Modisaotsile, 2012).

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Year-on-year the enrolments at high schools increase but yet the exit level Grade 12 output continues to decline quite substantially (Modisaotsile, 2012). In fact the number of learners exiting the schooling system with adequate numeracy in mathematics and physical sciences has been steadily declining since democracy (Modisaotsile, 2012). Further the majority of learners who do pass Grade 12 are unable to access tertiary education at univeristies as they have failed to meet the minimum entry requirements of these institutions (Prew, 2009 & Modisaotsile, 2012).

The statistics show a far greater problem, that of a 50 % drop-out rate of learners from enrolment in Grade 1 to exiting in Grade 12 (Prew, 2009 & Modisaotsile, 2012). Part of this is a direct consequence of a shortage of teachers, underqualified teachers and poor teacher performance (Prew, 2009 & Modisaotsile, 2012). These issues permeate the classroom environment and result in poor learner performance due to questionable standards of the teachers and lack of learner discipline (Prew, 2009 & Modisaotsile, 2012). Inadequate resources and infrastructure further exacerbate the problem.

Closure of teacher training colleges and low levels of commitment to teacher training provided by higher educational institutions has worsened the crisis in an already dysfunctional educational system. Financial constraints for human capital development, resources and infrastructure development have also hampered the deployment of a quality educational offering by teachers to learners (Prew, 2009 & Modisaotsile, 2012). Prew (2009) suggested that the educational crisis in South Africa is further complicated by the low-erosion rate of teachers.

Being underqualified but holding positions within the educational sector make change for these teachers difficult (Prew, 2009). The problem intensifies when new teachers enter the foray at schools with these seasoned educators. The new recruits are often better qualified and skilled in modern educational methods. They meet vehement opposition from the seasoned teachers at the school and are thus unable to practice their modern teaching methods (Prew, 2009). This causes situations of immense conflict which ultimately results in many new teachers resigning and the rest following the rut of the seasoned educators and thus the cycle of inadequacy continues (Prew, 2009).

After democracy in 1994, a structured plan for educational development (SED) was implemented. This had however not achieved the outcomes it was anticipated to. A very disturbing position considering that 18.5 % of GDP was invested in education (Modisaotsile, 2012). Mji and Makato, 2006, showed the dismal failure of these initiatives to improve the results of leaners in the mathematical and physical sciences. Data shows that from early as Grade 6, most teachers have below basic levels of content knowledge (Spaull, 2013). A high proportion of the teachers were unable to answer content questions aimed at their learners (Spaull, 2013)

In 2004, ten years after the implementation of SED, two major initiatives were launched to replace SED. The first was the teacher developmental framework and the second was the review of teacher education programmes (TESA, 2005). The main thrust of these initiatives were to increase supply and demand of teachers and to improve the attraction of teachers into the profession. Included in this was the re-skilling (or improving qualifications) of teachers already in the system. These initiatives also paved the way for the design and delivery of initial teacher education programmes for the South African context and with the hope of changing the dismal landscape of education in the country (TESA, 2005).

As part of this strategic development of programmes, the University of KwaZulu-Natal's Faculty of Education launched the advanced certificate in education (ACE) to provide a quality teacher education programme for existing educators and those who wished to specialize in a particular subject area. The programme was designed to not only help teachers improve their subject content knowledge but to also gain some management and administration skills to help them develop for progression beyond simply teaching if they so desired.

This work will only focus on the delivery of the Physics component of the ACE programme. Three modules were offered in the Physics component over a two year period. These modules were designed to align with the school syllabus as defined by the educational system at the time (NCS, 2003 & CAPS, 2010) so that the teachers gained sufficient subject content knowledge to effectively deliver lessons at school and thus help improve the skills and knowledge base of the learners. Teachers enrolled in the ACE programme had to pass all three Physics modules in order to graduate. The modules were structured on the distance learning concept and thus were offered part-time, over weekends and during the teachers school term breaks. The details of the module will be discussed in the following sections.

2. Research context

2.1. Outline of the module structure

The ACE Physics programme was split into three modules which collectively covered the Physics curriculum for learners from Grade 10 – 12. Table 1 lists these modules and enrolments over the research period. The enrolment numbers varied due to the number of centres were the contact sessions were offered. This work focusses entirely on the reaserchers class and not the other centres offering the same contact sessions. The distance learning concept (O' Lawrence, 2007) of the module dictated that only a minimal number of contact session were run. The distance learning method of instruction balances the need for full-time employees to acquire new skills without interrupting their working lives for extended periods of time and the need to reduce the cost of such education (O' Lawrence, 2007). These contact sessions were full-day programmes that ran for at least 8 hours in duration and were spread-out over a typical university semester (3 months) which translated to approximately a session once every three weeks. For the purposes of this study, we will present the results for the PHYSED1A 2010 and 2012 cohorts only.

Table 1. Structure of the ACE Physics programme.

Module Name	**Content**	**No. of contact sessions**	**No. of students registered in 2010/2011**	**No. of students registered in 2012/2013**
PHYSED1A	Mechanics and Elasticity	7	14	14
PHYSED2A	Electricity and Magnetism	7 (including 1 practical session)	14	11
PHYSED2B	Waves, Light & Sound and Nuclear physics	8 (including 1 practical session)	20	29

The students were provided with a study pack when they registered in the module which highlighted the dates of the contact sessions, the module outline of topics to be covered in each session, the assessment schedule together with the sections to be tested in each section and a comprehensive set of summarized notes. The summaries were based on the prescribed textbook: Physics principles with applications (Giancoli, 2010).

At the first session the teachers were acquainted with the structure of the module and the distance nature was again emphasized. A detailed work plan was then handed out to each teacher which prescribed the work that they would have to accomplish before the start of each of the subsequent contact sessions. They were also made away that the contact sessions were to be used to cover the more difficult concepts in depth and to focus on problem-solving techniques. This thus implied that they would need to cover the bulk of the work on their own before the session. The quantity of material that needed to be covered in each session was substantial and thus impossible to cover in detail in a single session.

The assessment was made clear at the start of each module and consisted of three tests approximately a month apart interspersed with written assignments that they could take home and complete either alone or in groups. The idea behind the assignments was again to promote the concept of problem solving techniques.

2.2. Research methodology

The effectiveness of a particular educational approach (in this case the ACE Physics programme) and its teaching effectiveness (as demonstrated by student knowledge of the subject matter and evidenced by performance in the assessments) needs to be determined (Chetty, 2014). The aim of this study was to determine the knowledge gained by the teachers in terms of factual knowledge, conceptual understanding and functional proficiency in physics to effectively teach their respective school classes.

A mixed model (qualitative and quantitative data sets) approach (Tashakkori & Tedllie, 2003, Creswell, 2003) was used in this study to garner information and thus answer the above research question. The quantitative data was obtained from the results of the formals assessments (tests) in the module and the qualitative data resulted from the interviews with the teachers (either individual feedback or group discussions). The research spanned four year duration (2010 – 2013) for two cohorts of teachers. The teachers had all been teaching the subject at high school level for a minimum of 4 years in both cohorts and the mean age of the cohorts was in the upper 30's. Various teaching mechanisms were employed to assist the teachers in understanding the material and thus improve their knowledge base. The assignment, test and exam results were used as measures to gauge the effectiveness of the academic interventions.

2.3. Researcher context

The researcher has a PhD in Physics and had been teaching for many years at University level. The 2010 cohort was the first adult class he had taught since joining the academic fraternity. In a mixed model study such as this one, the researcher plays an integral role in the research despite attempts to remain an impartial observer (Maxwell, 2005, White *et al.*, 1995) and as such the observations and interpretations of the researcher are represented in the qualitative part of the study (Creswell, 2003, Tashakkori & Tedlliw, 2003, Maxwell, 2005, White *et al.*, 1995).

3. Results and discussion of teaching interventions

The first contact session in 2010 (the first adult class for the researcher) was pre-planned to follow the following order based on the researcher assumption that since the teachers had already been teaching the subject as part of their duties, they would understand the content (at least the basics):

1) Brief discussion of the course and plan for the subsequent sessions (20 mins)
2) Discussion of the basics of the section (2 hours)
3) Highlighting and emphasizing problem subject material and key points (3 hours)
4) Tutorial work and problem solving techniques discussion (2 hours)
5) Recap and summary (40 mins)

This did not happen. The class was completely un-prepared and not a single teacher had been through the material requisite as background for the contact session, even though they had been told to go through the material in advance. This highlighted the challenges with distance education for the first time to the researcher. To understand the reasons for the non-compliance with the instruction the following question was posed to the cohort:

Why did you not complete the assigned reading and tutorial work before the contact session?

The majority of the class indicated that a lack of time to focus on the material was the main reason for not having attempted the task. Family time and work commitments weighed heavily on the teacher and left little time for study. This is replicate of the study by Kerka (1986) were it was shown that no single factor prevented students in a distance learning programme from completing the work but rather that it was a myriad of life circumstances and individual attitudes that contributed to non-participation.

The teachers also indicated that they were unaware of what was required of them even though they had been through the instructions for contact sessions. Most were unable to dissect what "self-directed learning" required. Norman (1999), Attri (2012) and Keegan (1996) approached the idea of self-directed learning and highlighted the problems associated with it: to be successful in self-directed learning, the individual needs to be able to assess their weaknesses and to harness their strength's.

Further probing of the class of teachers revealed that while most taught the subject regularly, many had never had any formal training in the subject and relied solely on textbooks for their information. Further many could easily understand and explain applications of the subject matter but had very little understanding of the theory thereof and

thus could not understand their weaknesses or strengths. The successful distance learning student needs to have a number of characteristics such as tolerance for ambiguity, a need for autonomy, and an ability to be flexible (Threkeld & Brzoska, 1994). Inman and Kerwin (1999) found that distance learning requires students to be more focused, better time managers, and to be able to work independently and with group members, traits that many of the cohort had not encountered before.

Attri (2012) suggests that the development of the study guides must reflect the distance nature of the module. He also suggests that since materials are prepared for all the teachers in the modules, rural and urban teachers would dissect these differently. In the ACE Physics programme this was not considered an issue since the summaries had been designed to be of a distance nature and to encourage self-directed learning. At a particular level we have to attain similar learning experiences so the actual content for all teachers was the same but examples, activities and experiments were included in learning material according to their needs, learning experiences and expectations (Attri, 2012).

The course summaries included a large selection of question and answers for the teachers to gain experience with, the questions were arranged to test the basic assumptions (single concepts) and then to progressively get more difficult and to test multiple concepts. To assist the students to understand the requisite of the module, the researcher proceeded to explain to students the nature of self-directed learning and the need for completion of reading beforehand. Further to assist the teachers, the researcher allowed contact session venues to be open two hours earlier than start time to allow students to do some work before the session began. The students were then taught how to use the summaries and subsequent questions. The links with the textbook was emphasised. Teachers requested solutions to the problems to aid their studying and these were also provided.

The teachers were then assigned to groups based on their work and/or living proximity to each other to encourage group learning and peer motivation (Attri, 2012). They were also provided with email, telephone and facsimile details of the researcher to encourage communication with the researcher other than just during contact sessions (Attri, 2012). The students were asked to provide an email and/or cellphone number for the lecturer to provide feedback and to facilitate regular communication between the teacher and researcher. The researcher would after the first session send out emails or text messages to students on a weekly basis to remind them of the material they should have covered so far and the material still to cover. It would also remind them of upcoming deadlines and impending tests. The students were given an assignment to complete based on the work they had been expected to cover before the next contact session.

The second contact session for the 2010 cohort was in sharp contrast to the initial one, more than 75% of the class admitted to having managed to complete a significant portion of the material (>50% of content and tutorial questions completed). This was evidenced by the students submission of their attempts at the questions. The second contact session also heralded in the first test. The test was written at the start of the session. Figure 1 shows the results for the first test and assignment.

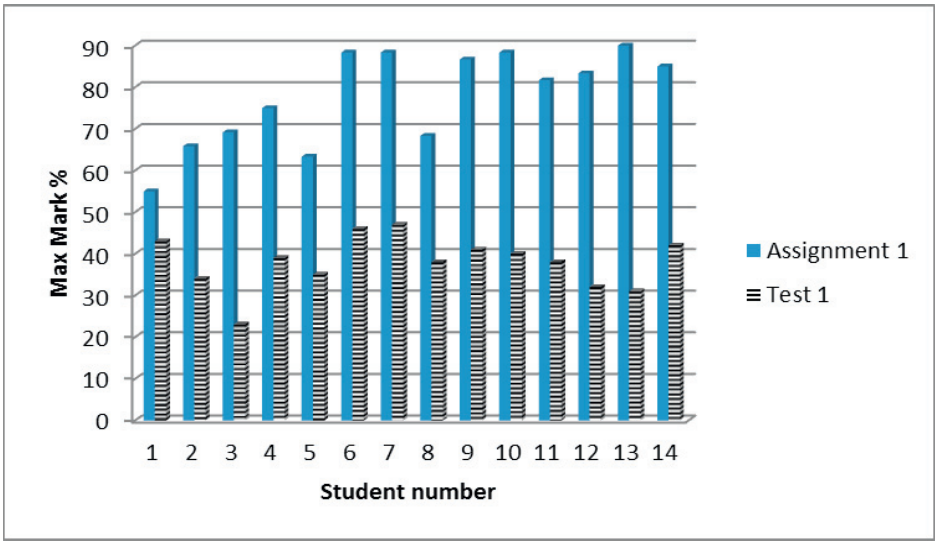

Fig. 1. First test and assignment results for the 2010 PHYSED1A module

It is very interesting to note that the students outperformed in the assignment than the test. The average mark for the assignment was 78% while the test average was just 38%. Quite shocking results considering that the test questions were based largely on concepts covered in the assignment and in a small percentage (<10 %) the questions in the test and assignment were repeated with mere numeral changes. Dissecting this further Figure 2 shows the assignment results plotted for all the students.

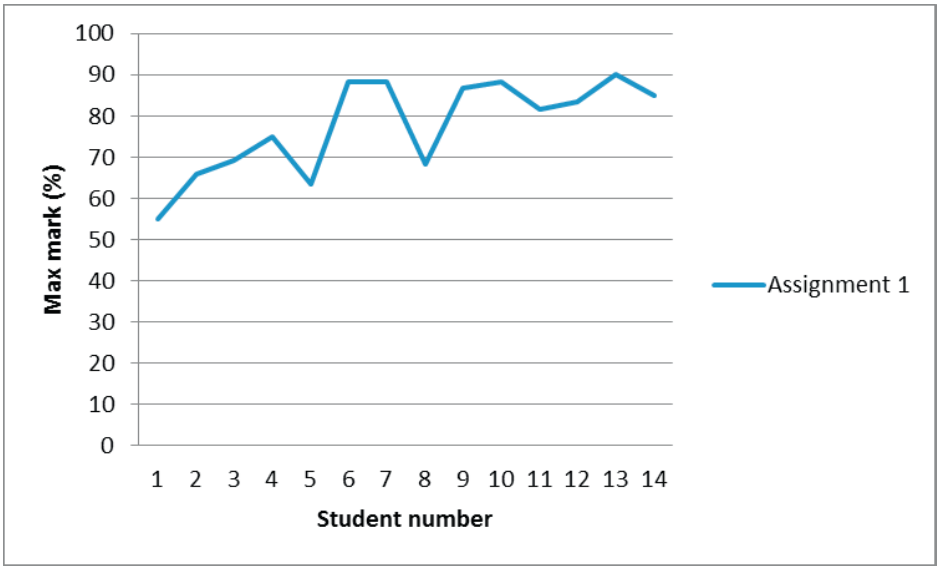

Fig. 2. First assignment results for the 2010 PHYSED1A module

It shows that for many students the marks were similar and with quite a few students having the same mark. It was determined further that the bulk of students with similar or exact marks for the assignment were in the same study groups. When the teachers' were questioned on this they indicated that they had all worked together and thus had similar solutions (or the same solutions). Clearly this highlighted a further problem in that students working in groups were reliant on the group for assistance with solving problems but had not mastered the technique and theoretical basis to do so on their own and without study materials. To remedy this the teachers were advised that although they could work in groups, they would need to submit their own work or face punishments for plagiarism and copying. Beaman (1998) highlighted assessment as one arm of deterrents to adult distance education. She indicated the need for assessments to be meaningful to the students and their lives otherwise thy felt it irrelevant and subsequently performed poorly.

The teachers were then questioned on their poor performance in the test through either individual interviews or group sessions to determine of Beamans (1998) comments had merit here. Their responses to various questions are detailed below.

What factor/s affected your performance in the test?

a) Time

Most of the students (>78%) of the class indicated that they found the time restrictions quite disturbing. They worked on the assignment at leisure and thus were ill prepared for the test conditions and fixed duration for the completion of the test. They spent disproportionate amount of time on long and short questions and in most cases did not finish the last question of the test. It was also noted that the students were unaware of how to relate the marks allocated to a question to a corresponding time allocation per question. Chetty (2014) showed that a similar

problem arose with first year university students. There seems to be a trend for assessments not to be rigidly adherent on time in the school system.

Solution: The teachers were coached on time management for tests and exams. The students were provided with a clock in the classroom so that they always had a time reference. All examples were timed so that the students were aware of the time allocation to questions and the relevance of the mark allocation to the overall time allocation. All assessments set were time allocated so as to facilitate time management even outside the classroom. This was heavily based on the students self-directed learning outside the contact session but they had been provided with the tool to make time management possible. Chetty (2014) considered measures such as these and found them to be highly successful.

b) Language

A large fraction of the class (>82%) found the language used in the assessment not clear. Being second language English speakers (the language used in the module was English) the teachers found the language used in the tests confusing, difficult and hard to interpret. Chetty (2014) found such problem permeate the scientific world and should not be construed as barriers to education.

Solution: The students were coached on the language and grammar of test questions. Phrases such as “define”, “explain”, “justify” and “derive” were explained and further demonstrated in the contact sessions. The use of non-traditional words (as used in the textbook) in example questions, such as elevator and ferris wheel were replaced with South African equivalents such as lift and big-wheel. Questions were simplified so as to minimize the complications of language from hampering question solving (Chetty, 2014). In the technological ambit, the teachers were introduced to the use of online dictionary sources and mobile google via their cellphone web browsers. Valk, Rashid and Elder (2010) have emphasized the important role cellphones (mobile phones) play in improving educational outcomes.

The enhanced searching capabilities of search engines was also explained, demonstrated and used extensively during contact sessions to help students use this important tool in their own self-directed learning. For example, during a contact session, the researcher would ask students to find the value of a constant such as the speed of sound by using their cellphones, or to search for the meaning of a word that may be problematic to the teacher. Many of the teachers indicated that they had subsequently introduced the use of mobile internet into their own classrooms. In South African schools are under-resourced and internet and computers are non-standard in most school whereas most learners at schools own a wap enabled cellphone making such use common and practical.

c) Visual tangibility

Students cited the lack of demonstration of concepts impeded their understanding of the concept. Most were learners who preferred experiential learning as opposed to just textbook knowledge. O’Neil, Singh and Donohue (2004) showed the benefits of introducing e-learning programmes for higher education. Tarbin and Trevitt (2001) showed the success of online e-learning which made online learning a means of providing tangible visualization for the students.

Solution: PhET (PhET, 2014) simulation links were given to the students for their viewing in their self-study time. During contact sessions the researcher would introduce the students to the online learning possibilities such as PhET and leave them to further explore outside of the formal contact session. The MIT (MIT, 2014) open courseware site was also provided to the teachers, although the previous language barrier was highlighted and the students were asked to use with caution. The UC Berkley Physics (UC Berkley, 2014) demonstration site was also recommended.

d) Not having seen the questions before

Many of the students reported that they found the test difficult as they had not seen the questions before and thus the time constraint coupled with the unseen questions cost them marks.

Solution: The students were then made aware of the similarity of the test questions to the assignment questions. This again highlighted the problem that students completed the assignment in groups without really paying attention to the questions and thus they were unable to correlate the test questions to previous assignment questions and thus demystify the test questions. The students were then coached on the importance on the assignments and the need to answer them individually as well as to understand the principles, method and concepts of the assignment, class examples and tutorial questions.

e) Test run at the start of the contact session

The students believed that the test being administered at the start of the contact session disadvantaged the, they complained that there was no time to cover questions that they may have had regarding the material as well as for complicated theory or applications to be explained.

Solution: The test was moved to 2 hours after the start of the contact session. This allowed the students to ask questions and complete some revision before writing the test.

The problems faced by the students indicated the need for an educational reform to take place in the classroom. This reform was the introduction of Problem-Based Learning (PBL). PBL is a student-centered pedagogy in which students learn about a subject through the experience of problem solving (Hmelo-Silver, 2004). Students learn both thinking strategies and domain knowledge (Hmelo-Silver, 2004). The PBL format originated from the medical school of thought, and is now used in other schools of thought too. The goals of PBL are to help the students develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation (Hmelo-Silver, 2004).

In problem-based learning (PBL) courses, students work with classmates to solve complex and authentic problems that help develop content knowledge as well as problem-solving, reasoning, communication, and self-assessment skills (White, 2001). PBL is an effective method for improving students' problem-solving skills (Chetty, 2014, White, 2001). Students will make strong connections between concepts when they learn facts and skills by actively working with information rather than by passively receiving information (Gallagher, 1997; Resnick & Klopfer, 1989).

In the contact sessions the students were asked to work in their study groups to solve problems while making use of the technological learning tools such as mobile phones and e-learning. The groups were then asked to present their solutions and each group member was tasked with doing a small part of the presentation so that all members of the group had to work. This prompted the teachers to take responsibility for their own learning and work with information and link concepts with skills and facts, an integral part of the PBL method of instruction (Chetty, 2014).

This enhanced the teacher's self-confidence and further aided with their self-directed learning (White, 2001). The teachers were also asked to develop simple experiments that they could use to illustrate some basic concepts from the module itself. This was useful not only in increasing their own understanding of the topics but also helped them to improve their classroom delivery and thus positively impacting on teaching and learning of their own school learners. The contact sessions took the form of PBL sessions interlaced with salient theory discussions as necessary.

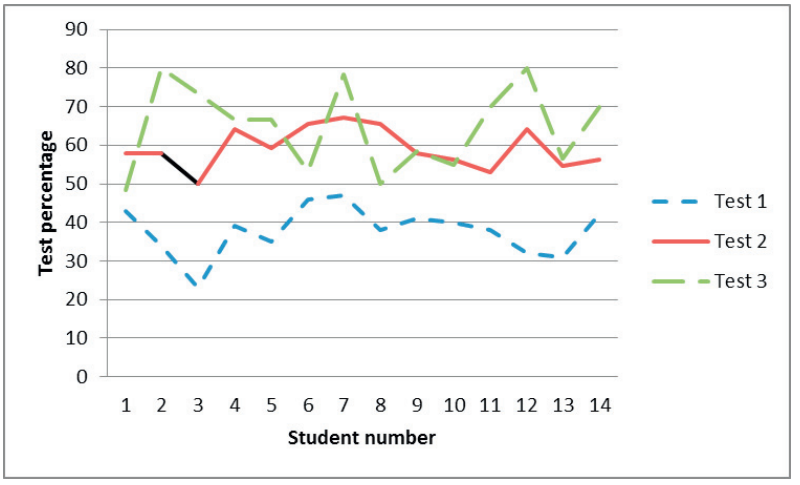

Fig. 3. All test results for the 2010 PHYSED1A module

Fig. 3 shows the results for test 2 and 3 in relation to test 1. There is a marked improvement in the test 2 and 3 results with test 3 being better than test 2. Clearly the interventions seemed to have worked to help improved test performance. Fig. 4 shows a strong correlation to the students' assignment and test marks, a stark contrast to the initial results. This shows more evidence of students having understood the material better and further highlights the improvement in their self-directed learning. A similar pattern between test 3 and assignment 3 results is shown in Fig. 5 which further enhances the results confirming the success of the interventions.

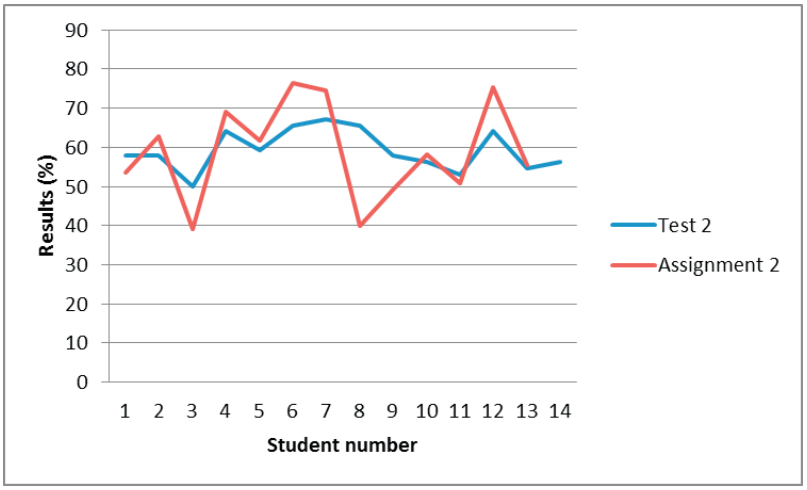

Fig. 4. Test 2 and Assignment 2 results for the 2010 PHYSED1A module

The strong correlation between Assignment 3 and Test 3 is shown in Fig. 5. It is interesting to note that the average for the test and assignment are quite similar at 73% and 65% respectively. Impressive given that Test 1 lagged behind Assignment 1 by almost 40%. When questioned after the assessments, the students commented that the use of technology, dictionaries and the PBL approach had helped them understand the work much better. They felt more confident and their results reflected this confidence.

The final test of success lays in the final exam results. The final exam was based on concepts covered in the tests and assignment but was mostly unseen applications of the respective theory. For example if in class the student was asked for the velocity in a certain problem, a similar concept was tested in the exam but now required the acceleration to be determined instead. Fig. 6 represents the final exam and class mark results for the cohort. There results shown that most of the students achieved final results that were fairly similar to their class mark results. The class mark is a combination of the students' test and assignment results.

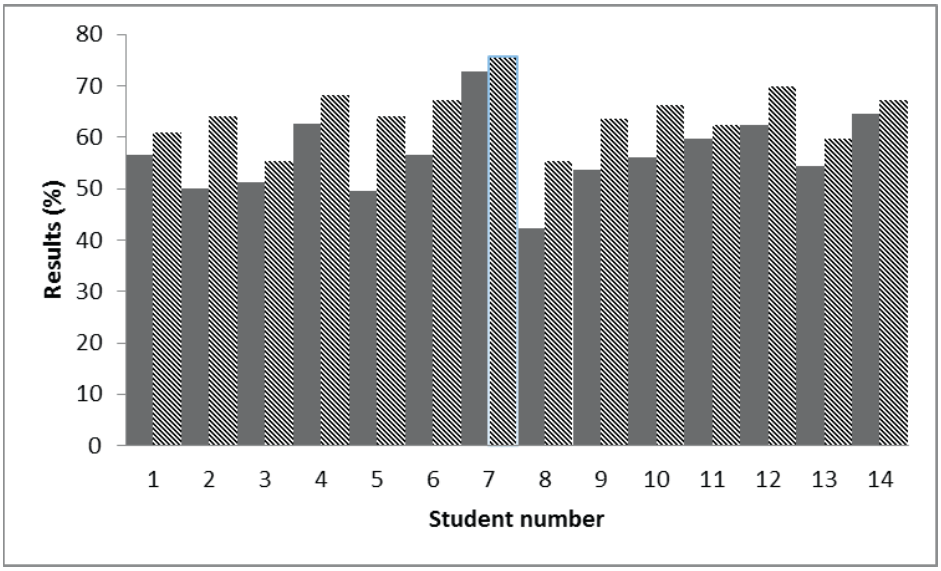

Fig. 5. Final exam and class mark results for the 2010 PHYSED1A module

Armed with the knowledge of the problems experienced in 2010, the researcher was able to start the module initially in 2012 using the same interventions as in 2010. The results for the initial assessments show a marked improvement when compared with those of 2010. It must be noted that the maximum marks for the tests and assignments remained constant for both cohorts which makes direct comparison possible. Further the content tested in each was the same. The 2010 cohort showed an average mark of 68% for the assignment and 56% for the test. This is a very different to that of the 2010 cohort and may be the direct result of the interventions in place.

Fig. 7 shows a comparison of the first test results for both cohorts and this clearly shows that the 2012 cohort performed better initially than the 2010 cohort which may in large part be attributed to the interventions learned from in 2010. Fig. 8 shoes the exam and class mark distribution of marks for the 2012 cohort. The discrepancy between the two is approximately 10% with the class mark being higher. This is indicative of the students having performed fairly well in the exams and displaying a strong understanding of the subject material.

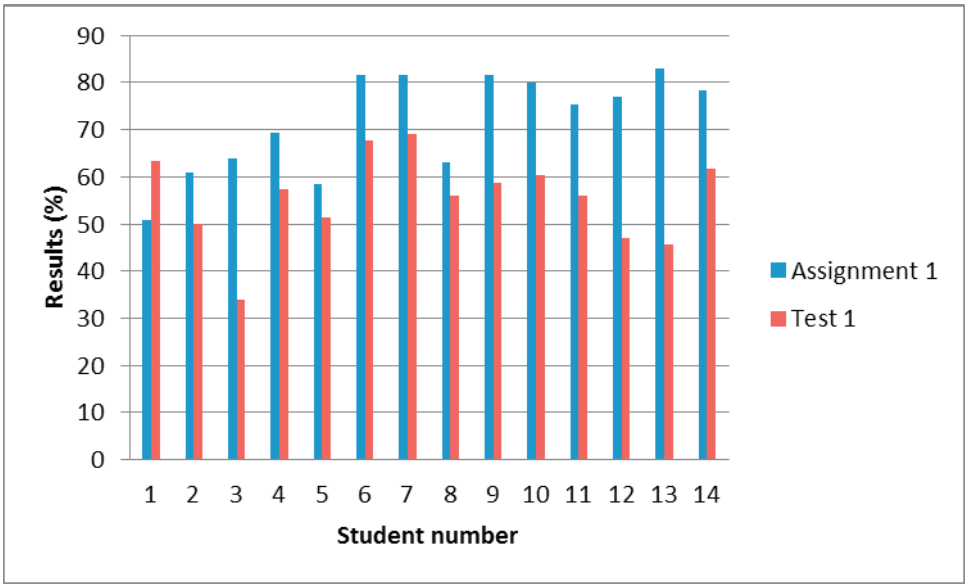

Fig. 6. Test 1 and Assignment 1 results for the 2012 PHYSED1A module

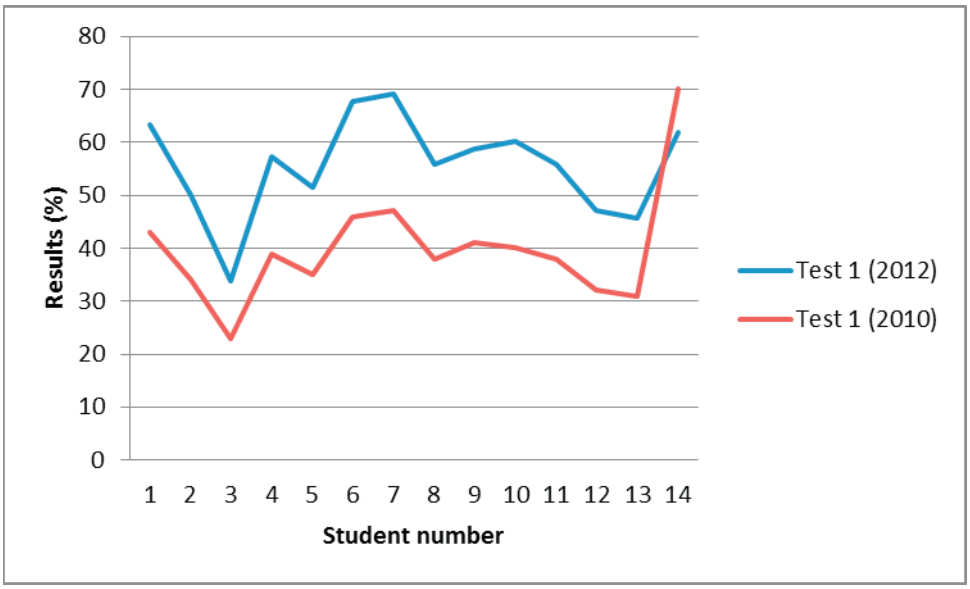

Fig. 7. Test 1 results for the 2010 and 2012 PHYSED1A module

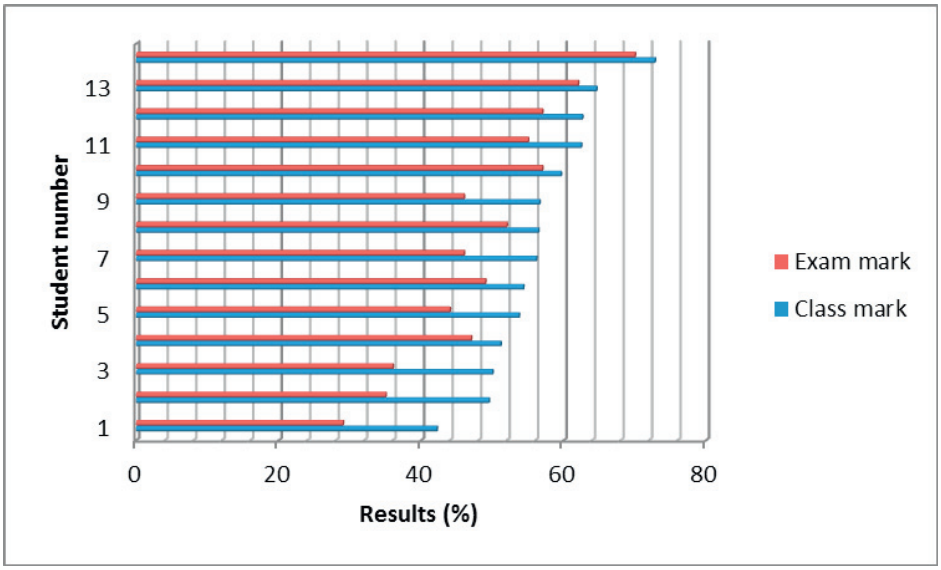

Fig. 8. Final exam and class mark results for the 2012 PHYSED1A module

4. Conclusion

The results of this work have shown that the use of PBL, Group learning and technological learning have helped to significantly improve the retention and knowledge of teachers learning Physics. This then translates to better and more knowledgeable teachers educating the learners in our public schooling system. This will greatly improve the quality of learners who exit the high school system. This study has been limited to adult learners being taught via distance education but it is in no way restricted to this. The methods employed will be of benefit to all educational scenarios.

We showed that the results of the teachers increased significantly when they were allowed to work in groups as prescribed by the PBL method. Further the use of technology helped reduce the anxiety of teachers as they had resources on hand to attempt their prescribed work. Further the communication between the researcher and the teachers helped improve the results since the teachers were able to query problems and resolve them once they arose rather than waiting for the contact session by which time the problem may have been forgotten altogether.

The social problems of funding, food security and health related aspects have not been discussed in this work. Their impact on the teacher performance may be significant however the researcher is not equipped to deal with the psychological ramification of these. It is not possible to delve into these problems without offering some counselling or emotional assistance.

These results do open the way for further research into the PBL method of instruction and its context with adult learners. It definitely in this study help improve the self-directed learning of the cohorts and thus improved results and throughput. Ultimately increased throughput is important however the tangibles of this throughput are qualified teachers who can make a marked difference in improving standards of school education.

Technological learning and mobile learning in developing countries such as South Africa are becoming more and more necessary especially in the increase of distance educational offerings. Meeting the need to improve education in the country will only be possible if the current cohorts of teachers are helped to improve their qualifications. Given the full-time nature of the employment, distance education makes educational sense.

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