THE EFFECTIVENESS OF AN OUTREACH PROGRAMME IN SCIENCE AND MATHEMATICS FOR DISADVANTAGED GRADE 12 STUDENTS IN SOUTH AFRICA

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This study was geared to address one aspect of a national strategic recommendation in South Africa by evaluating the effectiveness of a computer-based outreach programme. This outreach programme, which started in 1982, was in its twentieth year of existence in 2001 and provided support in mathematics and physical science to Grade 12 students and teachers from historically disadvantaged schools. This study examined the role that the outreach programmes played at two schools during 2001 and endeavoured to provide descriptions of the intended, implemented, perceived and achieved programmes for this year. Therefore, the purpose of this study was to investigate the effectiveness of this outreach programme in providing support to both teachers and students in the teaching and learning of mathematics and physical science. The findings of this study provide insight into the effective implementation of a computer-based outreach programme in disadvantaged schools and serve as baseline data for research into computer-assisted learning environments in the South African context. However, it should be noted that students at the Grade 12 level also wanted a continuation of teacher-centred teaching, even in the computer-assisted classes because of the perceived competencies of their teachers in helping them perform well in the matriculation examination in South Africa.

THE RESEARCH PROBLEM

In South Africa, there was, and still is, a dire need to support teachers and learners in mathematics and science at the secondary schools. The provision of extensive mathematics and science training would be an effective start in addressing the country’s economic and social problem. Learners studying science subjects such as physical science, biology and mathematics at the secondary level are the likely science, engineering and technology (SET) students for tertiary education. Naidoo (1996) argued that although it is at the tertiary level that the human resource capacity is developed, it is the quality of teaching and learning at the secondary level in mathematics and science that determines the numbers of the students that are trained in the SET fields. This need was especially true in the historically disadvantaged schools where long-existing imbalances were still prevalent. In the context of the national strategy to bring members of the historically disadvantaged communities into mainstream science and technology fields, it was considered imperative to develop interventions that could adequately address this need. The purpose of this study is to investigate the effectiveness of an outreach programme (intervention) in providing support to both teachers and students in the teaching and learning of mathematics and physical science. This study looked at the role that the outreach programme played in two schools during 2001 and endeavoured to document a thick description (Guba and Lincoln 1989) of the intended, implemented, perceived and achieved (Treagust 1987) programmes for this year. In addressing the purpose of this investigation, the following research questions were addressed:

1. What were the outreach programmes intended to achieve?
2. How were the computer-assisted lessons in the outreach programmes actually implemented, perceived and achieved?
3. How did students perceive their computer-assisted learning (CAL) classes?
4. What were the outcomes in mathematics and physical science as a result of the students’ participation in the outreach programmes?

THE OUTREACH PROGRAMME
A computer-based outreach programme was chosen for this evaluation study because it is probably one of the oldest, if indeed not the longest serving, outreach programme to disadvantaged students in South Africa. In the year 2001, it was in its twentieth year of existence. The mathematics/sciences matriculation outreach programme aimed at improving instruction in secondary school mathematics and the sciences. This programme extended the development of a computer-based educational programme that was designed to provide instruction in Grades 11 and 12 of the South African matriculation syllabi for biology, chemistry, mathematics and physics. The intended users included secondary school students, teachers, prospective university students and adults involved in self-improvement in order to prepare them for better employment opportunities (Mehl and Sinclair 1983).

The outreach programme has gone through various changes throughout its 20 years of existence in terms of format, target, structure, staff, and sponsors. In the year 2001, outreach off-campus activities centred primarily around the placing of Mini Computer Supported Education Centres (MICSECs) at selected schools because it had become too expensive to transport learners to the campus. Satellite computer centres (MICSECs) were set up at schools to serve learners and teachers. In the year 2001, a total of nine MICSECs were installed to serve a total of 50 high schools in different parts of the Western Cape. Each centre consisted of approximately 15 computer terminals with a server. The computers were dedicated for the use of physical science and mathematics only because the intention with the establishment of each centre was to serve Grade 12 mathematics and physical science students and teachers. The University of the Western Cape developed the physical science software and the coursework was based on the Physical Science Syllabus for Grades 8 to 12. The mathematics component, the CAMI software, which formed the basis of the activity, was developed in South Africa around the core Mathematics Syllabus to prepare students for university entrance. The course was divided into modules in accordance with subject matter, making remedial and enriching work easier (Ogunniyi and Isaacs 1998).

It is against this background that this study was carried out to investigate the effectiveness of this outreach programme to serve the disadvantaged Grade 12 mathematics and physical science students in 2001, its twentieth year of existence.

A CONCEPTUAL FRAMEWORK FOR THE STUDY
A conceptual framework for educational evaluation originally conceptualised by Goodlad (1966, 1979), adopted by the International Association for the Evaluation of Education (Keeves 1972; Rosier and Keeves 1991) and further developed by Treagust (1987), van den Akker (1998) and Mills and Treagust (2002) forms the basis of this study. Subsequently, in order to investigate the effectiveness of the outreach programme for mathematics and physical science students, those representations described by Treagust (1987) and Mills and Treagust (2002) were used to form the framework of this study distinguishing between the intended, implemented, perceived and achieved programmes. In brief, the four aspects of the theoretical framework used as a template for this investigation are defined as the Intended Programme describing the original vision underlying the programme, in the form of the stated objectives or programme theory; the Implemented Programme including the actual instructional process as implemented; the Perceived Programme referring to the actual learning experiences as perceived and/or experienced by the learners; and the Achieved Programme highlighting the resulting learning outcomes of the learners after participating in the outreach programme.
METHODOLOGY

Centre A
The outreach programme established a MICSEC at this school towards the end of the year 2000. Twelve computer terminals and a server were housed in a classroom that could be extended to a second classroom should additional computer terminals become available. Physical science and mathematics software was preloaded on the computers. For the year 2001, there were three classes in Grade 12; three classes followed mathematics and two classes physical science. In total there were 64 mathematics students and 38 physical science students in Grade 12. The same teacher taught both mathematics and physical science to the Grade 12 students.

Centre B
The new school where Centre B was located was situated in a peri-urban area on the outskirts of Cape Town. In 2001, the school of Centre B had 1329 students with 37 teachers. In total, 80 students followed mathematics and 60 students followed physical science in Grade 12. The Mini Computer Supported Education Centre at Centre B was established in August 2000 and became fully operational from January 2001. The computer centre houses 15 computers and a server; mathematics and physical science software is loaded on the computers. Three teachers made use of the centre, two of who taught Grade 12 mathematics while the other teacher taught Physical Science.

The objectives of the outreach programme were compiled from documents and interviews. The implementation of the programme was observed through on-site visits to both Centres A and B. Sites were visited during two cycles of two months. The perception of learners of the contribution of the outreach programme was established through interviews and a learning environment instrument called the Computer-Assisted Learning Environment Questionnaire (CALEQ), which had both an actual and preferred version. The CALEQ consisted of six scales, namely Involvement (extent to which students have attentive interest, participate in discussions, perform additional work, and experience the CAL classes), Open-Endedness (extent to which an open ended approach is adopted in the CAL classes), Investigation (extent to which student is encouraged to engage in the learning process), Material Organisation (extent to which CAL classes are organized and computer hardware and software are adequate), Learning Assessment (extent to which the learner can assess his understanding of subject content) and Integration (extent to which the computer is included as a tool in daily teaching of mathematics and physical science). Each scale defined by eight items. At Centre A, seven students were interviewed individually as well as five groups of two to four students. At Centre B, nine individuals and five groups consisting of two to five students were interviewed. Responses provided in the questionnaire were used as a basis to guide the interviews.

FINDINGS AND DISCUSSION

What was the outreach programmes intended to achieve?
The author compiled the objectives after discussions with the Outreach Programme Manager and the teachers involved at each of the two MICSECs included in this study. Six composite statements represented these objectives as follows:

1. To assist teachers to incorporate computers as a tool in their daily task of teaching science and mathematics.
2. To improve the learning of science and mathematics by Grade 12 students.
3. To improve the achievements of students in mathematics and physical science in the external matriculation examination.
4. To serve as a resource centre that students can use in their own time.
5. To expose students to computers and their operation.
6. To provide skills to those sections of the South African population who through historical circumstances have been denied full access or chances of acquiring these skills.

How were the Computer-Assisted Lessons in the Outreach Programme actually implemented?
The inclusion of the Mini-Computer Supported Education Centre in the daily teaching followed the different approaches for the two centres, even though the use of the computers is similar. At Centre A, one teacher taught both mathematics and physical science and could therefore use the centre on a daily basis. The teacher used the physical science and mathematics programmes as part of his teaching and would teach a particular topic including the introductory lessons on the programmes as part of his lesson after which students would work out problems on the computer. At Centre B, there were three teachers for Grade 12 mathematics and physical science, which caused a clash of timetables. To solve this problem the three teachers planned their annual timetable to allow for double periods during which time the centre could be used and so they took turns to use the computer centre. The computer programmes were mostly used for reinforcement for what was already taught in the class. The centre was therefore not used as a classroom in the strict sense of the word, but as an additional resource centre.

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<th>Table 1. Scale means and standard deviations for the actual and preferred versions of the CALEQ for Centres A and B.</th>
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<td><strong>Scale</strong></td>
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How did students perceive their computer-assisted learning (CAL) classes?
The perceptions of students were obtained from both interviews conducted with students and the actual and preferred versions of the CALEQ. The integration of computers at the two centres took on different formats, with Centre A having both formal (talk-and-chalk) and informal (computer-assisted) sessions in one teaching period. On the actual version of the CALEQ, the Integration scale of Centre A had a higher mean item score than Centre B (Table 1) which reflected a greater satisfaction of computer integration of their classroom by these students. However, students at Centre A indicated that they preferred less integration of the computers in physical science and mathematics classes, while students at Centre B
preferred more. Even though many students indicated during the interviews that they were positive about the integration of computers, some students felt that with the small number of computers that were actually available, they preferred that more teacher-centred classes be included. Their reason for this was that the computer classes catered for group learning instead of individual learning. Another group of students, especially at Centre A, did not want any more computer-assisted classes and claimed that they preferred the traditional teacher-centred method. This finding appears to contradict the purported effectiveness of computer-assisted learning that has been reported previously by other researchers over a number of decades (Bangerdowns et al. 1985; Barman 1993; Johnson 1995; Wainwright 1989).

The item mean scores for the Learning Assessment scale for Centre A and Centre B (Table 1, Figure 1) were similar at around 3.4 (between sometimes and often) for the actual version of the CALEQ. At both centres, the preferred scores for the Learning Assessment scales were higher, with students at Centre B indicating a greater preference for monitoring their own learning. This result is consistent with what was reported in the qualitative data. Students wanted more computers at their centres and also emphasised their individual needs to have a computer of their own in order to assess their own learning. The significance in the higher scores for this scale on the preferred level at Centre B could possibly be attributed to the fact that students, in most instances, only worked on computers once a week and expressed a desire to have enough computers to work on their own. At both centres, a number of students linked the monitoring of their learning to learning on their own. Students pointed out that the additional exercise they gained from working on the computers improved their problem-solving skills and the speed and accuracy with which they worked. This improvement in problem-solving supports the research findings of Yalcinalp, Geban, & Özkan (1995).

For the Involvement scale, the mean item scores (Table 1; Figure 1) for Centre A and Centre B for the actual version of the CALEQ were similar (3.41 and 3.37 for Centres A and B, respectively). In the preferred version of CALEQ, the mean item scores were higher than the actual version, but similar for both centres (3.60; 3.59) though these were not statistically significant. Most students were satisfied with the way that they were involved in computer-assisted classes and indicated that they readily participated in discussions with fellow students and with the teacher about the work on the computer.
The interviewed teachers reported that more students were willing to share their ideas and thoughts on topics that were based on the work from the computer but were reluctant to participate in the formal class. Students were encouraged by their teachers to interact with each other while answering questions on the computer. This interaction allowed greater involvement in the classroom tasks because students had to work in groups around the limited number of computers. Some students reported co-operative relationships with their peers, which were also encouraged by Bennett (1992) and Yalcinalp et al. (1995).

The scores for the Investigation and Material Organisation scales at Centre B showed a different trend compared to that at Centre A (Figure 1). The scores at Centre B (Table 1) indicated lower levels of these two scales for the actual version of the CALEQ (3.33 for Investigation; 3.32 for Material Organisation), and then even lower scores for the preferred version (3.20; 3.24) though these were not statistically significant. However, the trend of these results indicated that students at Centre B preferred less investigative activities and less organisation in the computer centre. Indeed, many students at Centre B indicated that they did not like to work out problems with the teacher standing behind their backs looking over their shoulder. Some students considered it as distracting “I cannot think so fast when Mr. U is looking over my shoulder” and suggested that they preferred to call the teacher when he was needed. Also, students indicated that they preferred the situation where the teacher worked out the problems on the board and then they could just follow what the teacher was doing, instead of struggling with problems on their own. Students indicated that they wanted to work on the computers as individuals that could imply that they preferred a less structured approach in the computer centre.

Three distinct views were obtained from the transcripts. The first view, which formed the majority viewpoint, was held by students who considered the computer-assisted lessons as being supportive because they found their interactions in the classroom conducive to learning. Students with this view wanted the group interactions, and preferred to discuss the problems with one another, and where needed, called for the assistance of the teacher. Students indicated that they learned from one another by providing assistance to one another when attempting to answer questions on the computer. The second view was held by students who wanted computer-assisted learning but believed that the current situation was not catering for their individual learning needs. These students were not sure whether the inclusion of computers in their daily lessons made any difference in their learning, as they considered the teacher having a greater effect and actually preferred a more teacher-dominated lesson. The impression gained from the interviews was of many students not being convinced that using the computers would guarantee them success in the final examination. The third view, which represented the minority view, was held by a few students who wanted their lessons without computers. This view was more strongly expressed by a group of students at Centre A (three students), and to a lesser degree at Centre B (one student), but also came to the fore when student perceptions of their computer-assisted learning environment were measured. These students indicated that computers played no part in their passing of examinations from the lower grades up to Grade 12 and suggested that the teachers should continue with the teacher-centred lessons to which they had become accustomed.

**What were the outcomes in mathematics and physical science as a result of the students’ participation in the outreach programmes?**

**Teacher support**

Teachers indicated that they could use the computer centre for revision and reinforcement purposes by planning exercise sessions for students. In situations where there was a shortage of textbooks (Centre A) or when learning material was insufficient, the computers provided an alternative resource because teachers could refer students to the relevant sections on the computer. Teachers pointed out that many students entered Grade 12 with tremendous academic deficits in mathematics and physical science and the teachers used computer-assisted classes to try and address some of these deficits. Teachers were also of the opinion that allowing students to work on the computer freed up some of their teaching time so that they could spend time with students who were weaker than others in the tests and examinations.
Learner support
Teachers indicated that through their interactions with the computers, students were identifying the gaps in their own learning. When teachers enquired about the solution of a problem, students were able to point out at which step of a problem they did not understand and then asked the teacher to explain a particular step in a problem. Students were therefore monitoring their own learning. Teachers indicated that a great deal of student learning took place as a result of the interactions that occurred among students when they discussed and debated answers to questions. This point was supported by a number of students during interviews as well.

Achievement
The achievement of students was measured in terms of the numbers of students that passed physical science and mathematics examinations; this phenomenon was also the issue that attracted the outreach programme to these particular schools. At both centres, the percentage of students that passed the examination in physical science in 2001 increased by more than 20% after the implementation of the outreach programme. The mathematics outcomes were less dramatic where a 10% increase in Centre A and 5% increase in Centre B in the number of students passing the examinations were reported.

Resources
The outreach programme indicated, as one of its objectives, the availability of the MICSECs as a resource for a number of schools in the region to use. Unfortunately, due to the limited number of computer terminals at the two centres, this was not always possible.

Computer literacy and skills
The computers of the outreach programme were reserved for the use of mathematics and physical science activities only and, therefore, there was no structured computer literacy programme associated with them. However, the exposure that students got from working on computers for the first time, from switching-on the computers, learning how to select different programmes, to typing in answers in different formats provided them with some skills to operate computers even though this also limited their cognitively active time in the lessons.

REFERENCES

