

Changing Classroom Practice using a School-Based Professional Development Approach to Introducing Digital Resources in Zambia

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Abstract

This paper reports on the outcomes of a University of Cambridge Centre for Commonwealth Education (CCE) funded pilot project, which assessed the feasibility of supporting interactive forms of subject teaching in conjunction with providing Open Educational Resources (OER) to ICT- and internet-equipped primary schools in Zambia. The project worked with partners to identify and respond to the needs of school-based professional development adapted to the local context. The intervention focused on participatory, collaborative and inquiry-based pedagogies, both within the classroom and for teacher development. We worked over a four-month period with eight experienced teachers in three basic (primary) schools serving disadvantaged communities. All participants integrated OER into mathematics lessons and developed more interactive practices, including collaborative learning. Student engagement and understanding increased. An initial workshop, ongoing peer co-operation and researcher support were pivotal mechanisms. Constraints included lack of access to computers and students' lack of ICT and collaboration skills.

Keywords: ICT; Teacher Education; Sub-Saharan Africa; Pedagogy; Technology; Open Educational Resources; Interactive Teaching

1. Introduction

Primary schools (basic schools) in sub-Saharan Africa typically lack whole-class sets of teaching materials and in particular those supporting interactive and active learning. Teachers usually resort to using traditional *teacher-centred* methodologies such as *chalk and talk*, involving rote chanting or copying from the board. Any questioning tends to assume a linear ‘funnel pattern’ in which negotiation of meaning is eclipsed by routines for directly producing wanted actions and verbal responses (Bauersfeld, 1988). Such teaching methods foster superficial learning and do not encourage productive interaction among learners or with the materials. They do not offer the all-important opportunities for students to make their reasoning explicit or to engage in critical thinking and active knowledge construction. Successful attempts have been made to infuse teacher education programs with more interactive pedagogies, however classroom practice rarely reflects the new approaches. A substantial misalignment between professional development and classroom implementation has been noted in other contexts too (Yoon et al; 2007).

Our study focused on the education system of Zambia, rated one of the lowest-developed countries globally (150/169 on the 2010 Human Development Index). While the majority of schools there are not currently ICT-equipped or internet-enabled, access is increasing. Many teachers already use community internet cafés. The internet offers numerous educational resources that can potentially be adapted for learning in the Zambian classroom. In particular, Open Educational Resources (OER) are educational materials that are freely available to learners and educators under a licence that permits use, reuse, revision and distribution. In addition to this ‘legal freedom’, broader definitions of OER also recognise technical and cultural/pedagogical freedoms.¹ In principle this means that instructional materials, and guidance on how to use them, are readily available online. The assumption is often made that this alone is sufficient for teachers to discover these materials and integrate them into their classroom practice.

However, teachers lack skills in searching for digital resources (including OER) and for using ICT in the classroom (where available). More generally, they lack experience in creating appropriate inquiry-based learning environments. In this pilot project we worked with a number of teachers in three ICT-enabled schools, investigating how this gap could be bridged through a tailored continuing professional development (CPD) intervention. We used a workshop approach, developing, supporting and trialling uses of locally contextualised OER combined with new pedagogical approaches for teaching mathematics. In Volume II of this journal, Hennessy, Harrison & Wamakote (2010) drew on the recommendations of Unwin (2005), Commonwealth of Learning (2004) and Davis et al (2009) in identifying the characteristics of apparently successful teacher education programmes, suggesting that these:

- focus on pedagogy, rather than technology, promoting active, independent, inquiry-based and collaborative classroom learning, and exploiting the potential of ICT to support it;
- model interactive pedagogical approaches, including ongoing, collaborative and active learning opportunities for teachers;
- are culturally and locally contextualised, through being based in teachers' own schools and classrooms, incorporating tasks linked to participants' professional practices and the curriculum;
- infuse technology into an entire teacher education programme using blended solutions.

¹ see http://oerwiki.iiep-unesco.org/index.php?title=Access2OER/Conclusion_and_next_steps.

While our pilot programme was too small to address the last point effectively, the preceding points were very central. For instance, our participatory, hands-on workshop approach (described under 'Intervention') aimed to develop confidence with ICT and awareness of its potential. Following the initial workshop, much of the CPD intervention was executed by our UNZA-based senior researcher, an open- and distance-learning expert (the third author). He inducted the teachers and supported them in turn in their schools. There were opportunities for peer observation and structured reflection on practice, following O'Sullivan's (2002) finding that reflective approaches *per se* were less appropriate for under-qualified primary teachers in Namibia (who found it difficult to devise solutions to problems they identified). Thus we deliberately created support for introducing new technologies and ideas in situated classroom contexts, helping teachers see and explore how they could use the new approaches themselves (Ottenbreit-Leftwich et al; 2010) and how they could address any issues arising.

Another key tenet of our approach is a focus on embedding ICT in subject-based teaching rather than as a discrete, skills-based subject in school. As elaborated in the literature review conducted by Hennessy et al (2010, p.100), this responds to the call for 'ICT to be integrated throughout the curriculum, blending its use with other tools and resources to support student learning.' Indeed, changing the existing culture in this way is a key message for policymakers (Hennessy et al, 2010, p. 98).

Research into teacher learning (Glazer & Hannafin, 2006; Kong et al; 2007; Muijs & Lindsay, 2008) suggests that one-off workshops and system-wide approaches (cascade models, train-the-trainer) generally tend to be of limited relevance and value in sustaining transformation of practice. This may be aggravated by the challenging and highly individual circumstances in which sub-Saharan Africa (SSA) schools find themselves. Recent research indicates that a site-based CPD programme that draws on teachers' local networks is a promising approach. This encourages collegial learning and supports ongoing reflection on and reconceptualisation of one's own classroom practice and development of new insights into pedagogy (Polly & Hannafin, 2010; Wells, 2007; Zwart et al; 2007). This approach is detailed by Bowker et al (submitted) and our ongoing work applies it to a SSA context. A primary aim of the pilot project was to conduct the necessary research to build a solid foundation for further investigation over a longer period. Such work includes the creation of a CPD resource for in-service, as well as self-guided teacher use. The aim is to work towards lasting transformation in Zambian education but with anticipated relevance to a wide range of countries in sub-Saharan Africa.²

2. Initiative

Teachers were supported through workshops (at the beginning and end of the program), as well as weekly school visits, phone calls and emails. During these visits the teachers had an opportunity to discuss their experiences and jointly develop lesson ideas. The visits also served to gather research data. Teachers networked through a mailing list, sharing news, questions, digital resources and lesson plans. Further details are available in Section 3 below.

² For further information about the second phase of the OER4Schools project, current and forthcoming publications, see <http://www.educ.cam.ac.uk/centres/cce/initiatives/projects/ictzambia/>.

2.1 Participants

In collaboration with our partner iSchool³, three co-operative schools were identified that had internet connectivity and computers available to students. Across those schools we identified a group of nine teachers, as shown in Table 1, who were using computers to some extent and were willing to participate. (One teacher later dropped out owing to personal problems.) The schools all served deprived communities where unemployment rates were very high, parents struggled to pay the school fees, and many children were orphans or otherwise vulnerable. Two community schools (Chimwemwe Trust School and Aisha Project School) were located in high density housing compounds in the peri-urban area of Lusaka, with on-site access to electricity and the Internet. The third government school (Chalimbana Basic School), was located in a rural area of Lusaka province, about 50 km from Lusaka; it had electricity but no Internet and much larger classes.

Table 1 Participating teachers

School	Area	Name of Teacher	Sex	Grade(s) Taught	Qualifications	Teaching Experience
Chimwemwe	Peri-urban	Ivy	F	Grade 1	ECCED;*	1 year
		Eness	F	Grade 3	ECCED;	2 years
		Brian	M	Grade 7	Teachers Cert	6 years
Aisha	Peri-urban	Brighton	M	Grade 1/8	No qualification	9 months.
		Daniel	M	Grade 5	No qualification	ICT Coordinator 6 years
Chalimbana	Rural	Abel	M	Grade 6	Diploma, Teaching cert;	6 years
		Agness	F	Grade 2		9 years
		Sydney	M	Grade 8	Diploma, Teaching cert Diploma	13 years

* ECCED = Early Childhood Care, Education and Development.

2.2. Focus

This project identified mathematics as a key subject in the socio-economic development of Zambia. Most teachers interviewed expressed lack of interactive mathematics instructional materials and interactive pedagogical orientation. The research team developed a three-pillar intervention strategy to fill the identified gaps. As elaborated in the Introduction, the three guiding principles were to:

- (1) develop teachers' skills through a school-based professional development strategy (scenario-based) that introduced contemporary interactive teaching approaches,
- (2) integrate Open Educational Resources (OER) into classroom practice, and
- (3) leverage appropriate uses of Information and Communication Technologies (ICT).

³ iSchool (<http://www.ischool.zm>) is a project that delivers the Zambian National Curriculum to schools through interactive, blended e-learning with an end aim of enhancing the productivity of the Zambian workforce. This project has been running for 3 years, and has so far provided teachers in 20 community and government-funded primary schools with some form of ICT (usually a secure suite of desktop computers or a set of netbooks) and high-speed internet connections (most often free). It has also seen the development of a website of over 20,000 external links mapped to the Zambian National Curriculum and categorised via year groups. This has been very well received by the schools within the project and those that have accessed the site outside of the project.

The research methods involved recording classroom practice and assessing participants' reactions and learning, eliciting messages for embedding basic ICT and OER use in teacher education.

3. Intervention

The research team organised a five-day hands-on workshop to induct teachers in the use of interactive and collaborative pedagogy, source OER suitable for local contexts and integrating ICT into lessons. The workshop methodology modelled interactive pedagogy, emphasising group work and discussion at various levels. For instance, in some activities, groups did not report back to the whole class, but instead created a poster that was then shared with others. This encouraged discussion in smaller groups. We also explored concrete lesson ideas, such as exploring shapes through paper cutting, by conducting that lesson with workshop participants assuming the roles of students. The workshop itself was flexibly reshaped in response to teacher input, to emphasise teachers taking ownership of the workshop process, as well as offering some opportunities for peer observation. For instance, by teacher request, the last day of the workshop was partially held at one of the schools so that all teachers could observe the teaching practice at that school.

Our Zambian researcher subsequently provided extensive support for the teachers in developing the themes of the program. This was carried out over four months from January to April 2010, and included visits on a weekly basis (equivalent of 35 whole-day visits), frequent phone/Skype calls and emails. The visits served to support the teachers through discussion and joint development of lesson ideas. They also served to collect data (video, audio and observation notes of lessons) and video interviews with teachers and school directors.

Each of the eight participating teachers was given a netbook⁴ in order to be able to access OER, both on and offline. We encouraged participants to share experiences and consult each other in order to provide peer support too. An OER4schools community mailing list was set up to share digital resources, reflections, and lessons plans, as well as to ask questions and discuss difficulties. Teachers also communicated with each other through instant messaging, private emails and phone calls. A debriefing workshop was held in May 2010 and two teachers co-presented the findings with us at the annual e-Learning Africa Conference in Lusaka. They relayed experiences in coming to grips with the new approach and resources. A video clip of one teacher's impassioned account is available as part of our online video resources.⁵

4. Outcomes

Through the intervention, all of the eight participants showed a significant increase in the use of technology in the classroom, and began to create inquiry-based learning environments using ICT. At the beginning of the project the teachers' ICT skills were very basic; three had never used technology and none had used inquiry-based methods in the classroom. However, after four months all of the teachers demonstrated skills in using ICT in teaching and for communicating among themselves and with other stakeholders. Furthermore, they were able to search for OER related to curriculum goals, integrate them into lesson plans, and share interesting discoveries with other group members. Examples of resources used included online activities for addition and place value (for instance rewriting 2,4,3,5 as 2,000+400+30+5), an interactive application for measuring the

4 Netbooks are smaller (and initially significantly cheaper) than laptop computers, with reduced processing power, and smaller screens. Details about the machines used in this project are available at <http://oer.aptivate.org/wiki/OER4Schools/netbooks>.

5 See our video collection at <http://sms.cam.ac.uk/collection/1087359>

length of objects, a game in which fractions need to be paired with decimal values, as well as using documents (such as the NISTCOL Primary Teachers Diploma resources).⁶ Teachers were able to combine several OERs within a single lesson to form a set of coherent activities. Additionally, the teachers acquired typing skills, applied these to their schemes of work and weekly forecasts, and edited their lesson plans. They shared the resources with other teachers on the mailing lists and the colleagues at their respective schools.

There was a marked increase in the use of interactive pedagogy including collaborative and cooperative approaches, as the learners were able to discover, discuss and present to other members. Teachers valued the uses of digital resources in helping the children to participate and learn actively. For example, one teacher commented:

‘When children learn using electronic media, we remember more of what we see, and therefore it's also an important part, to go from chalk and board, to students working on their own using the netbooks.’ (Brighton)

During this process of integrating ICT and new pedagogical approaches, the teachers demonstrated reflection on their own practice and its effectiveness, for the first time. For example, at the start of the project, they allowed group work and student discussion, perhaps to satisfy a formal requirement imposed by our workshop. However, with time the teachers started to evaluate this practice. When they noticed that group work was ineffective, they experimented with the size of the groups, coming to the conclusion that smaller groups (three or four students) help all children to be involved. One teacher noticed that some children still did not work well in groups, and asked for additional support in devising strategies to integrate those children. The teacher Ivy found that mixing talkative with quieter students, as well as those of different mathematical achievement levels, helped. The teacher participants Brian and Brighton successfully mixed those of different ICT-literacy levels, while Akabana reduced the number of groups in the class so that he was able to attend to all groups. These findings show that teachers were now going beyond the request to use group work towards actually developing skills in conducting group work that achieves learning outcomes.

The teachers also developed more insight into the children's learning processes. For instance, the teacher participant Agness commented that the children ‘are not empty tins’. Abel likewise stressed that teaching needs to start from what the students know, and then build up understanding bit by bit. In the following sections, we present key messages concerning classroom talk, questioning, sharing resources, technical issues and teacher aspirations.

4.1. Classroom talk and discussion

The teachers widely reported on their previous practice as ‘doing much of the talking’. The role of the students was to sit and listen, even if the children did not understand the subject matter. As an outcome of the intervention, the classroom practice changed to allow more space for the children to talk to each other, as reported by the teacher Eness:

‘Before the workshop I used to do much of the talking. Yes, [more] than the pupils. And I was like telling the pupils instead of involving them. Just after the workshop I've seen that I've changed. ... Not with telling them “No, these are what?” or “Today we will do this!”, “This thing means this!” [Now] it's up to the pupils to describe those things.’

⁶ The Google custom search used by the teachers, as well as lists of resources recommended to the teachers, are available on our wiki at http://oer.apptivate.org/wiki/OER4Schools/Maths_resources

The teacher Daniel valued children creating their own ideas, because they remember better:

‘I have created an environment of brainstorming, making the pupils brainstorm [by] themselves. I got the experience from [the workshop], I really like it ... I learned that, when you teach in a brainstorming manner, you let pupils create their own ideas, the memory stays longer than if you just teach examples - the old method of teaching.’

Teachers developed an understanding that allowing discussion would lead to more ‘noise’, which previously would have been unacceptable. The following quote from Brighton demonstrates this radical shift in their thinking:

‘[Now I] really use open-ended questions, encourage discussion – which we used to consider as noise, but now allow it. You may be teaching, and a pupil notices something, and starts talking to a friend, you have to allow them to do that. We encourage more discussions, more questions, [especially] “Why” and “How?”’

The idea of letting students interact with each other was quite new, as summarised succinctly by Brian, and elaborated by Brighton:

‘I didn't know that there was a system of interacting amongst learners. I thought it was teacher to learner.’ (Brian)

They are accustomed to always being given examples on the board. [Now] you... give them something to find on their own, which most of the time leaves a question, and they come back, and I tell them to work it out in groups. I don't care how, but they do really discuss and come up with answers. (Brighton)

The teachers were able to see the benefits of children talking to each other. For instance, Eness observed that getting children to explore ideas can lead to deeper engagement with concepts:

‘The topic that we did was the classification of animals. Yes, where they had to identify the vertebrates and the invertebrates. They did that in groups. They were like giving each other ideas. 'Cause after presenting the lesson I gave them homework. Then the following day, that's when the students started telling 'Uh Madam, in our community, we saw some animals, we saw some invertebrates, vertebrates.' They were able to classify the animals.’

4.2. *Questioning and dialogue*

The teachers appreciated the importance of an appropriate questioning strategy. This approach answers questions directly, but continues a supportive dialogue by asking questions to promote deeper thinking and understanding. They also acquired a basic understanding of open-ended questions, but needed help with generating appropriate ones. Teachers reported that they had had to learn to be patient, to not tell students answers directly, but to wait for the learners to think, and to allow them to try different strategies when solving a question. The following example illustrates a typical dialogic situation. In one of Eness's lessons, students were asked to find numbers that fulfil the equation: $\text{Box} + \text{Box} = 10$. Eness prompted the students as follows:

Eness: 'What should we do here?'
Student: 'Put numbers.'
Eness: 'What if I put 20? 20 is also a number.'
Student: '5'
Eness: 'Why did you say 5?'

This contrasts with previous teaching practice, where teachers immediately provided feedback (characterising answers as 'right' or 'wrong'), rather than generating further questions to draw students out, as well as to understand students' reasoning underlying their answers. The teachers appreciated that more classroom dialogue meant additional flexibility, being more responsive to students' ideas, and allowing for their own suggestions on informative websites. This is shown by Brian's statement:

'Sometimes, like in a lesson, when it comes to improvisation, I find that the pupils themselves will give you an idea. So you change automatically, seeing, 'let me also include this new thing which I've learnt from the pupil. That's one of the things. So there, like the questioning part, you try to get some challenge there now, so that maybe ... you can alter your plans, if your plans are more advanced, or maybe at least you can add more.'

However, although teachers incorporated some inquiry-based methods into teaching, they did easily relapse into the traditional teaching methods. Nevertheless, the usual closed questioning represented a shift forward from a lack of any questioning of students or taking into account their prior knowledge. This is illustrated by the examples above, where Eness continues to probe students, rather than just stating whether the student has been right or wrong.

4.3. Practical work

The teachers were quick to incorporate practical work into their lessons. To a large extent, using everyday objects is already part of the teaching practice, but often this may not necessarily be in the context of group work or interactive exercises. A popular task is to use measurement, and the teacher Brian used group-based measurement activities in a very engaging way. After an introduction to various ways of measuring, children were asked to measure the environment around them, including the classroom and themselves. However, teachers clearly need more support in taking such ideas further, for instance in terms of what to do with the measurements, such as to collate and compare tasks, for which a computer is ideally suited. Instead, computers are sometimes used to simply repeat real-world activities. For example, following Brian's practical measurement, the students went to the computer suite to perform very simple and prescribed measurement tasks using a web application that displayed a basic onscreen ruler to measure lengths of objects. The teachers classed this as an interactive activity. We note that 'interactivity' is often synonymous with 'computer-based', regardless of whether the computer-based activity actually models interactive pedagogy or not. Similarly, the OER emerging from internet searches were often simply closed quiz-type activities. There is no direct link between interactivity and OER so a degree of selectivity is crucial.

4.4. *Sharing ideas and difficulties*

All teachers appreciated the value of sharing teaching ideas. Some teachers formed peer groups (e.g. between two teachers of similar ages) and observed each other's classes. Teachers were also keen to share with colleagues outside of the study. Other teachers from the same schools also observed lessons:

‘... other teachers from the school were interested to see what was going on in my class and how the children were learning ...’ (Eness)

At Aisha Project School, an enthusiastic colleague had been inducted and supported by two teachers, including one of the teacher participants Daniel:

I share the ideas that I grasped, most of the times I invite [maths] teachers to come and observe my lesson... At times I even request to come and teach a subject that they had taught, then I teach in their class as well, then in the presence of the teacher, so that they can see the methodologies that I knew, which are skilful... There's one teacher we normally share [ideas] with, Mr N... Most of the time, I normally check on his lesson plan so that I could advise on what interactive games he can apply to his lesson.’

Somewhat unusually for a project in this context, the teachers also became very willing to share difficulties and ask for help. This is shown in the following posting the mailing list:

‘Am having problems with a Grade 1 class teaching in an interactive way cause they are too quiet and most of the time it's teacher to pupil interactivity and I find myself doing 75% of the talking. What do I do?’ (Ivy)

Brighton played a particularly important role within the mailing group, both responding to others' postings and suggesting digital resources:

‘In the quest to find something to use as a resource to help me teach the addition of numbers up to 30, for my grade one class, I stumbled upon this resource which proved to be helpful... The good thing is that it covers all primary subjects. Check it out and hope you find it useful as I did. The address is www.primaryresources.co.uk/maths’

Brighton also helpfully assumed the role of observer and reporter upon others' practices, capitalising on his own advanced ICT skills to do so:

‘I am currently listening to [Eness] teach in her class via Skype, it's fun and interactive; the pupils are doing some explaining to the teacher's questions. Attached here are photos of [Daniel] teaching a lesson that [I have] just come from observing, the pupils are using the netbooks for their lesson's reference. The arrangement of the class enables pupils to interact and hold group discussions.’

To sum up, it was pleasing that the teachers developed their own supportive peer community, including colleagues from outside of the project as well. We hope to build on this in the next phase of the project, encouraging and facilitating wider support networks so that teachers can take more ownership of their professional development.

4.5. *Technical issues*

One considerable obstacle to using digital resources is the time it takes for a teacher to load a particular resource on all computers used in the classroom. Typically, the teacher must visit each computer, assisting students in loading the resource (e.g. within a web browser). There is a clear need here for a classroom management system that is able to initiate the launching of a particular resource across all computers. Another issue is that resources are usually displayed in a web browser. Toolbars can take up a very substantial part of the screen, leaving only half of a small netbook screen for the activity. Teachers also reported the need for using resources offline (when the internet fails), and how it was difficult to save online resources for offline use (which might break certain interactive features). Lessons were also interrupted by frequent loss of power. While this may not affect a set of netbooks used in class, it does affect connectivity and interrupts the use of online resources. There were also problems regarding accurate reporting, related to a cultural reluctance to impart 'bad news'. For example, teachers sometimes indicated that there were no problems with the netbooks, when their own netbook was in fact not working (or the charger had been lost).

4.6. *Teacher perspectives on change*

All teachers were very enthusiastic about the project and its impact on their own professional development. The experience of the initial workshop, which was the first CPD experience for some, had a significant impact:

‘Just right from the workshop when I came back to class I improved my communication skills with pupils... that has really greatly improved in my teaching. Yes, I obtained this skill from the workshop.’ (Daniel)

The teachers were very enthusiastic about their changed role, and voiced a number of classroom aspirations. Teachers aspired to give learners a stake in how the lesson develops. Rather than make the students go through a pre-arranged lesson, they tried to be flexible. The teachers reported that they were learning from the students (including mathematical ideas), and that the subjective enjoyment of teaching and learning for both teacher and students had increased. One teacher commented, ‘I have become a new teacher,’ and many also reported that before engagement with the project, teaching methods were not always appreciated by the students. The increased degree of interactivity and ICT use made the lessons more enjoyable by students:

‘Before the project, the teaching methods weren't appreciated by the students... They could really see that I had difficulties incorporating ideas, it was so easy after the project, mostly we'd be discussing, they'd really come to understand what we were doing in class. Really easy to teach the pupils, with interactivity you don't do all the talking.’

The teachers participating in this study expressed the wish to form peer groups across schools or within the region that could support teachers in using ICT, and wanted to arrange school-based workshops. Teachers also thought that other colleagues within a school should be involved, and spontaneously broadened their new approaches to other subjects.

Another example of embracing changing practice by creating learning-centred environments through integration of technology and inquiry-based pedagogies was exhibited by Agness. After participating in the project, she, like all the other teachers, enthusiastically remarked on the positive impacts of her experience with ICT in the classroom. She explained that the technology offered her

the chance to explore a variety of interactive methods such as small group work. She argued that through group work the learners were able to express themselves, This assisted her to identify misconceptions as the students' thinking became more visible, compared to the 'chalk and talk' methods that she was used to prior to the project. The principles of the project thereby promoted increased interaction between the teacher and the learners; between learners; and between learners and instructional materials.

Overall the teachers perceived a direct impact of their changed teaching styles (incorporating OER and ICT), including through reduced absenteeism and improved student punctuality. It also seems that the parents were well aware of the program, and appreciated the additional opportunities for their children:

'[The project] is valuable, because the world we are in now is a world of technology, so it is very important that the project we had should not stop, it should continue or spread to the whole country. To my part, at Chalimabana Basic School, it made even the pupils reduce where absenteeism is concerned, because they saw it is very important and interesting to them.' (Agness)

Brighton expressed the outcomes for himself as follows:

'Learnt to be a consultative teacher, free to discuss with other teachers, share resources and ideas, so that the classroom becomes a learning environment, where knowledge can be manufactured [i.e. constructed rather than transmitted], where you utilise the ideas that students come up with their own knowledge, improving the country. I am just so proud to have been part of the project.'

Besides the professional changes, the project also benefited the teachers personally. It afforded the opportunity to learn how to communicate by email and how to use the internet. In a similar way, netbook ownership meant that the teachers were approached for help on ICT-based tasks within their communities, which elevated their standing.

5. Conclusions

The research findings show that all eight participant teachers portrayed significant increases in their use of digital tools and resources and integration of OER into the mathematics learning environment. Our intervention additionally provoked a marked rise in the use of interactive, collaborative approaches, with learners able to explore, discuss and present to peers, including acceptance of 'noise' and more practical work. While the pattern of progression towards interactive pedagogy is not likely to be a linear trajectory, teachers shifted towards open-ended questioning to some degree, allowing children to engage with ideas more freely. Consequently, pupils benefited from the project as teachers became able to innovate and share resources, acting as catalysts for actively constructing knowledge. The findings indicate that integration of ICT, inquiry approaches and digital resources can empower teachers and learners with 21st century skills required for education and socio-economic development of the country.

Our findings suggest that successful teacher education programmes should focus on pedagogy rather than technology. For example, if ICT tools and resources are introduced without guidance, they are simply used to replace 'talk and chalk', with the lesson otherwise unchanged. The emphasis on inquiry is of primary importance. Open-ended questioning needs to be coupled with genuinely open tasks. Moreover, there is a tendency to teach ICT as a discrete subject. This is because most students exhibited low ICT literacy levels, which were viewed by the teachers as an

impediment. In reality the computing skills needed within subject teaching do not require an underlying understanding of computers. The teachers in some cases started teaching 'parts of a computer' instead of the lesson content. Most teachers did realise, however, that students were able to gain sufficient operational knowledge of the computers quite quickly.

While the focus on pedagogy is important, access to technology is also an important motivating factor for teachers and students. It can therefore play a significant role in facilitating the introduction of new pedagogies and in moving towards inquiry-based learning. It is of course not just the technologies alone that are motivating. Combined with connectivity, technology enables communication. This applies particularly in situations where teachers find themselves posted to areas with few other amenities, such as no running water or electricity.

We concur that it is important for programmes to model interactive pedagogical approaches, including ongoing, collaborative and active learning opportunities for teachers, as embodied in our hands-on workshops, as well as school-based learning opportunities and research support. Our program could have benefited from a second one-week workshop if resources had permitted. This would provide an opportunity for practical demonstrations by participants, as well as helping to clarify concepts further. Developing, sharing and critiquing concrete lesson plans that implement interactive teaching are absolutely essential. Indeed, the lack of related theory to practice seems to be a substantial and widespread problem in current Zambian teacher education. The mailing list proved very useful, however, and teachers later commented that more use of such a facility would help colleagues. Teachers also remained enthusiastic throughout and beyond the project. Shifting towards new pedagogies proved possible within a short time, even with limited resources.

We conclude with the following recommendations:

1. Ongoing support is needed that heeds teachers' everyday realities and professional capabilities. This could help them to continue to implement inquiry-based approaches fully and to develop the requisite reflective skills to underpin and evaluate these. An action research approach may be most appropriate here (O'Sullivan, 2002).
2. To create environments that will improve learning outcomes in Zambia, it is vital to provide more, longer-term, contextualised CPD opportunities and associated resources. This means taking a whole school approach – and ultimately developing an educational partnership based on school clustering (Kong et al; 2007), in reorienting teachers (and school curriculum leaders) towards interactive learning approaches, both with and without technology. This is the focus of our next research and development phase.
3. Teacher education colleges could review their curricula and embed the design and development of flexible and blended-learning approaches that promote inquiry. Particular emphasis should be placed both on developing skills for finding and adapting a wider range of OER, and on providing concrete pointers for classroom engagement and experimentation. Teachers can thereby implement such learning approaches in practice, reflecting and receiving feedback.

The participating teachers, school administrators and other teacher educators have recommended that inquiry-based teaching should be taken to scale. This will allow the induction of all teachers in the use of ICT, OER and interactive pedagogies that encourage learners to use critical thinking and to negotiate meaning. Multi-lateral partnerships between leading Zambian teacher education providers, together with government and partner support, would be effective in implementing such programs in sustainable ways. We would encourage institutions to consider the approaches advanced in the pilot project to leverage the use of ICT in the classroom.

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7 <http://www.nistcol.ac.zm/>

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