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The lack of adequately skilled and qualified teachers in developing nations, and the impact this has on the educational experiences of children within those nations constitutes an educational crisis comparable to the challenges global medicine faces with malaria or AIDS. The educational challenges, like many other aspects of development, are often most severe in rural areas (Mulkeen, 2005). It has been argued that such a challenge requires a new open-learning architecture for teacher professional development, situated in the context of the teachers daily practice, supported by the teachers peers, and accessing the full potential of new ICTs (Leach & Moon, 2006).

There is substantial activity and expenditure to provide 'computers' for schools in the global south, but this tends to conform to a pattern identified here as 'thinking as usual' about ICT; a pattern often framed by assumptions about the costs of various forms of ICT. However, little is really known about what constitutes 'appropriate' ICT for education in poor rural communities (InfoDev 2005); even less about ICT as a vehicle for teacher professional development in such contexts.

This paper applies a model of 'total costs of ownership' to a 'freely donated' ICT suite, and finds that the costs may well be much higher than alternative, more educationally empowering forms of ICT. Demonstrating that 'common-sense' assumptions about appropriate ICTs may not be correct, this paper seeks to clear the ground for establishing a framework for identifying appropriate ICTs for rural teacher and community development in the global south.

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Introduction: teachers, rurality, and ICT

It is internationally accepted that quality education, through the enhancement of human capital, lies at the heart of poverty eradication. In low-income countries, with each year of additional education, average earnings increase by 11%. In addition, people with literacy are best placed to start their own enterprises and increase wealth (UNESCO, 2005).

Yet more than 113 million children worldwide go without primary schooling and it is calculated that 18 million teachers are still needed if the Millennium Development Goals are to be met.

The scarcity of trained local personnel, including teachers, is greatest in the countryside (Mulkeen, 2005), in line with the trend that sees two thirds of the global poor concentrated in rural areas. Experienced practitioners largely avoid poor rural placements, or relocate to towns and cities as soon as they are able (Hedges, 2005).

The experience of poverty has been described as taking many different forms of 'un-freedom', of which financial poverty is but one (Sen, 1999). These multiple un-freedoms lead to a sense of 'stuckness' (Nelson Mandela Foundation, 2005) that incapacitates whole communities and those who live and work in them. Poor, rural communities need quality teaching that will successfully motivate and enable them to access information vital to their lives and livelihoods: about health, about the structure and services of public institutions; about their rights. They need to develop up to date knowledge and expertise and communication skills that enable political visibility and voice (Marker, 2002). Teachers in such communities should be shaping a new future

through their work: they are the multipliers, authority figures, agents of change in schools and the communities they serve (Milward-Oliver, 2005, p.136).

But all too often 'stuckness' also affects teacher initiative and sense of agency. It is not hard to see why: rural teachers have little by way of support and negligible opportunities for training in new knowledge and skills (Mulkeen, 2005). They are themselves trapped in the poverty of the communities they serve, facing an isolation that is at once physical, social and intellectual.

Such experiences limit rural teachers' abilities to engage in activities required for quality teaching: developing contemporary subject and pedagogic knowledge, planning skills, the ability to make informed choices, motivate learners and be creative (Demebele and Miaro II, 2003; Banks et al, 2005).

New, imaginative and ambitious solutions are required to address these problems. Influential commentators (UNESCO, 2002; Weigel, 2004; Selinger, & Gibson 2004; Unwin, 2005; Commission For Africa, 2005) agree that new ICT has a role to play. The Millennium Development Goals stress the need for access to ICT for development, and teachers are seen as key to the success and sustainability of ICT related educational strategies (Dufborg, 2005).

The dominant paradigm

Yet there is a dearth of research literature on ICT, education and international development. Where educational ICT innovations exist in developing contexts, they are largely based on a dominant paradigm of ICT for education. This paradigm defines the expectations and assumptions about *what* ICT for schools might mean and look like. This paradigm is constructed from a broad range of assumptions: for example, about the numbers and arrangement of equipment - but also about the affordances people hold about the ways such tools might be used; about the provenance of valued information and ideas; about appropriate classroom organisation and learning activities; about where, when and how learning shall take place.

Core assumptions of the dominant paradigm:

- ICT = desktop computers
- locally networked (to share printers / internet / documents)
- 'office' specification (e.g. core activities around word processing, spreadsheets, document access and retrieval)
- 'multimedia' rare, but when present, the hardware and software is orientated to 'play' not 'make' multi-media content
- decisions on classroom organisation / classroom management are 'hardware led'
- learning with computers = individual or pair learning
- large numbers of machines (10-40) are required
- classrooms need to be organised around the security and infrastructure requirements of a large number of desktop computers
- a dedicated 'ICT classroom' is required
- 'horseshoe' or 'battery hen' model of classroom organisation is appropriate
- expectation narrowly defined around ICT skills
- office software: word-processing, spreadsheets, presentations
- learning 'about computers'
- accessing the internet / CDROM / DVDROM
- sending email

- emphasis on external knowledge and perspectives
- valorised knowledge is 'out there' on the internet or CDROMs (not in the learners, teachers or communities)
- focus on 'access' (e.g. not contribution, dialogue, participation)
- a 'tabula rasa' view of learning - external knowledge can be 'poured into pupils' through the computer, without needing to connect with or build upon their prior experiences and learning, and without socially or culturally relevant practices
- computers, physically and conceptually, remain 'within the school'; they are not accessible to the broader lives of the teachers, pupils and community.

Here I term this paradigm 'thinking as usual' about ICT.

The assumptions of the paradigm are so axiomatic that they are not usually stated explicitly within the literature; for example, Cawthera (2001) identifies three categories of ICT provision for schools in developing nations:

> Basic, using second-hand equipment, without training or support;
> Basic plus, using refurbished second-hand equipment , with some training or support; and
> Deluxe, using new equipment.

Between these categories there may be substantial variations in the numbers, age, cost and capabilities of ICT equipment, but all categories are still underpinned by the model of suites of desktop computers in a dedicated 'ICT classroom', being used largely for learning 'ICT' and 'office' skills.

The paradigm is not just conceptual, but also determines how ICT is practically implemented in schools, for example, in surveying the provision and use of ICTs in South African Schools for SAIDE, Cohen (2003) finds a stark contrast between the most and least ICT provisioned schools in the study, yet all conform to the dominant paradigm, and no mention of alternative possibilities is made in the report.

I suggest that 'thinking as usual' about education and ICT is characterised by a central malaise - that more thinking, money and effort is usually given to the ICT (equipment, infrastructure and skills training) than is given to the education the ICT is meant to support or enable; in other words, the learning is both led and constrained by the 'inevitable' model of ICT.

> "One of the enduring difficulties... is that educational planners and technology advocates think of the technology first and then investigate the educational applications of this technology only later." InfoDEV (2005)

Costs and the dominant paradigm

Studies that focus on implementing ICT in schools in developing countries tend to focus heavily on cost issues. Few studies take a broad definition of ICTs, for example, including radio and television (e.g. InfoDev 2005; Perraton & Creed, 2000); most focus on computers (e.g. Bakia 2002, Cawthera 2001, Moses 2004, Perraton & Lentell 2004), yet in each case, almost all consideration of 'the costs of computers' is based upon the often unstated assumptions of the dominant paradigm.

Sometimes arguments about cost are used to underpin the assumptions of the dominant paradigm. For example, the need for many machines, and the location of these in a single designated 'telecentre', has been argued as a way of spreading the cost of training teachers in ICT skills over as many computer users as possible by Cawthera (ibid).

SchoolNet Africa has often championed by proxy the assumption that schools must use suites of desktop computers, through it's support for 'refurbished' or thin client computers - which rules out laptop or mobile computers (which are not available as refurbs) and flexibly organised computers (which cannot be permanently tethered dumb terminals). This is largely argued on the basis of costs, rather than any pedagogic imperative:

> "The biggest factor in the popularity of using refurbs [desktops] in African schools is that they have been perceived to be significantly cheaper than new computers and therefore more affordable." (SchoolNet Africa, 2004)

However, the reality is that little is really known about the true costs of ICTs in education and even less is known about cost effectiveness - this is universally true, but especially so in the context of low and medium developed countries (InfoDev 2005).

Towards an understanding of Total Cost of Ownership

InfoDev (ibid.) note that the Total Costs of Ownership (TCO) of ICTs are typically underestimated, and sometimes grossly so, but quite what is meant by the TCO?

The essence of TCO is simple - it is the entire cost of buying, using and eventually disposing of / replacing your equipment, over a particular period of time. However, there is no single accepted way of calculating TCO.

A thorough literature review of TCO studies in relation to ICT (Scrimshaw 2002) revealed almost as many methodologies as studies (135), with important distinctions between studies that take the individual institution as a unit of study and those that range wider; those that consider only monetary costs, or those that include other kinds of costs (such as teachers personal time for learning new skills). All the studies in this review were drawn from UK and USA institutions.

Writing for the international development context, Moses helpfully provides a number of 'ball-park' costs for considering TCO for ICT in the context of schools, which are broadly inline with the studies reviewed by Scrimshaw, suggesting the following as a guide to annually recurring costs:

- **Maintainance**: 15% of the original purchase price of hardware and software (ideally 20%);
- **Supplies**: 8-10% of original purchase price, for printer ink, floppy disks and CD-ROMs etc.;
- **Electricity**: 10 cents per kilowatt hour, with computers running 1,600 hours (8 hours a day, for 200 days a year), with 400W being a typical desktop power consumption.

Two other significant (non-annual) costs being identified as:

- **Professional development** (cast in the limited sense of training people to use the computers, as opposed to developing professional teaching practices with ICTs).

Retrofitting (the cost of modifying buildings, space, electrical wiring and network connections to make a computer useful).

Retrofitting is a much more significant issue when thinking as usual, as a computer suite is dominated by the computer equipment, and it's associated wiring, benches, power supplies, cooling, window shades and security. Moses makes no estimate of the cost of retrofitting, as there are too many variables to allow any general figure to be put forward; we will simply point out that the cost is likely to be significant for a computers suite, but negligible by comparison, when modest numbers of mobile technologies (laptops and hand held computers) are being used in a conventional classroom, as the room requires little or no modification

In this paper, I will apply this model to a typical educational ICT scenario conforming to the dominant paradigm, and then to a radically different scenario which does not adhere to any of the dominant paradigms assumptions.

Assumptions in applying the TCO model to the dominant paradigm

Equipment:
For 'thinking as usual' I have assumed a suite of 20 computers, as this seems typical of the numbers of computers donors have provided to schools. I have not included the costs of a printer, as it introduces too many variables and assumptions, and the costs could be added or removed equally to any comparisons without changing the outcomes.

Ongoing costs:
It is important to note that ongoing costs apply, even if the equipment was donated, subsequent costs are calculated as if the school had bought similar new computers.

For maintenance, this actually significantly *under reports* the costs for the refurbished equipment, as "...the costs of maintaining the refurb might be ten times as high as the cost of maintaining the new PC, and the new PC might last twice as long" (SchoolNet 2004). The differential against refurbished computers should be higher still, as new machines should have warranty for at least the first year or two of use. However, because no such quantitative studies have been carried out in the context of rural schools in developing nations, there is no way to precisely quantify how much higher the weightings should be for refurbished computers; for that reason, and because I do not want to be seen to be applying factors arbitrarily, I have left the weightings for maintenance costs the same for the refurbished computers and the new ICTs.

For electricity, I have kept Moses' assumptions of a full days use, throughout the school year, with desktops using 400w, and a nominal cost of 10c / KWh.

Professional development:
In putting teacher training as a 'cost of using ICT' Moses correctly describes most interventions operating under the dominant paradigm, where providing ICT is a primary goal, and a secondary (sometimes absent) goal is to train teachers to use it.

Retrofitting:
A computer suite is typically dominated by the computer equipment, and it's associated wiring, benches, power supplies, cooling, window bars (and roof cages) and alarms. Moses makes no estimate of the cost of retrofitting, as there are too many variables to allow any general figure to be put forward.

I am not going to consider professional development or retrofitting in the TCO analysis here for three reasons.

Firstly, they are difficult to quantify, as the costs depend entirely upon the model of training being considered, or the extent and nature of room modification required, all of which can be highly variable.

Secondly, training is required whatever form the ICT takes, so it makes no difference to a comparative analysis of different forms of ICT, as long as the same training is applied in either case.

Thirdly, whilst the dominant paradigm *does* position training as a costly ancillary to the provision of equipment, I later argue that this is putting the cart before the horse; the equipment should be an ancillary cost in the development of teachers, schools and communities - directed by real human needs: for information and communication; for learning and literacy; for opportunity and agency.

Time period:
I have assumed a three year time period, as this seems a reasonable absolute minimum working life for any new equipment, although 'refurbished' equipment may or may not last this long.

Counting the cost of thinking as usual

Item	Description	Cost
Initial Purchase Cost (I.P.C.)	20 free computers (IPC equivalent to $20,000)	$0
Maintenance (15% I.P.C. per annum)	3 years x (15% of $20,000)	$9,000
Supplies (9% I.P.C. per annum)	3 years x (9% x $20,000)	$5,400
Electricity ($0.1 per KWh x 1600 hours, per annum)	3 years x ((20 machines @ 0.4Kw) x $0.1 x 1,600 hours)	$3,840
Total Cost of Ownership		$18,240

Thus, applying Moses' model to a typical suite of 'free' computers suggests that a school serving poor rural communities would need to find in excess of $6,000 every year, just to maintain and run the equipment. The reality is very few such schools are able to do this, because they simply do not have this sort of spare financial capacity.

> "Donated and refurbished equipment can carry significant costs" (InfoDev 2005)

Looking down the 'cost type' column, it is easy to hypothesise at least three possibly ways in which this mismatch between the TCO models predicted expenditure requirement and school budgets could be resolved:

1. Maintenance is neglected.
2. Supplies run out.
3. Machines are not used.

These are not 'esoteric hypotheses', they are daily realities for many schools. Yet the real cost of 'thinking as usual' goes far beyond the problems of financing the ongoing costs of 'free' computers (new or old). To see the real cost, the focus must move from 'ICT' to 'learning'.

In a recent joint evaluation exercise (publication forthcoming), researchers from the Open University and the Nelson Mandela Foundations' Unit for Rural Schooling worked with 45 teachers from primary and secondary schools that had, through donor programmes, received new computer suites and intensive basic ICT skills training:

- with the exception of the teaching of computer literacy, no curriculum use of ICT was reported
- there was no indication that teachers would move to independently develop curriculum and pedagogic uses of ICT without further support
- teachers expressed frustration at not being able to use ICT in their curriculum teaching.

Such findings are echoed by others who have tried to evaluate the outcomes of interventions that were 'thinking as usual':

> "The work done in the schools in his study suggests that, overall, ICT provision has not had a major impact on teaching and learning... it seems likely that the findings do... represent what is happening in other schools across the country.... computers were not regarded by most teachers as... [an] important resource for their work... too few computers...[for teachers] to have adequate access... made worse by the poor state of repair of much of the technology. This was particularly problematic when computers were networked and unable to work alone..." Cohen 2003, p200-201

Where educational ICT innovations exist in developing contexts, they are largely based on the dominant paradigm, orientated to the resource rich, office-based practices of developed economies, focusing decontextualised IT skills training in refurbished tele-centres and computer labs. Research shows that such approaches can be culturally irrelevant in rural communities (Heeks, 2005), physically unviable in remote rural settings lacking basic infrastructures (Leach et al 2006 ibid) and generally unconnected to poverty reduction strategies (OECD, 2005). They can lead to what Unwin (2005) has described as the 'computer tragedy': 'piles of hardware accumulating in dusty corners, and 'computers hidden under plastic covers that have rarely if ever been used'.

Such work points to the need for rigorous but innovative investigations of new paradigms of educational technology for development that are specifically orientated to the settings, needs and experiences of rural personnel and the communities they serve

Towards a new paradigm

Research suggests that ICT can be used far more effectively for teaching and learning, in a range of curriculum areas, when a smaller number of computers are integrated into the 'normal' classroom environment. For example:

> There is recognition among teachers that a more flexible approach is required… Changes in lesson style to allow a less formal classroom atmosphere, greater pupil autonomy, differing modes of teacher/pupil interaction, and flexible study space are all recognised as key success factors for effective use of ICT. (Harrison, Comber et al. 2003)

and

> "Placing computers in classrooms enables much greater use of ICTs for 'higher order skills' than placing computers in separate computer laboratories (indeed, fewer computers in classrooms may enable even more use than greater numbers located in separate computer labs)... increasing attention given to laptops by both teachers and students...'computers on wheels'...as well as... the use of personal digital assistants and other devices... models for successfully integrating ICT use in school and after school hours are still emerging." InfoDEV 2005

Harrison (ibid.) also found that pupils (and teachers) are quick to acquire ICT skills when they are able to explore the available ICT tools in the process of meeting their own learning needs. In other words, it is better to use ICT for some purposeful endeavour (learning about literacy, numeracy, science or other subjects, pursuing your own interests, researching and communicating things that matter to you) and pick up the ICT skills on the way, rather than 'learn about computers' for their own sake.

In such a context:

the ICT becomes literally one-of-many pedagogic means;
teachers and learners are more likely to see the subject as centre stage;
teachers and learners are more likely to use computers to support collaborative work, as well as individual computer use;
the choice of when, how and when not to use ICT driven by pedagogic understanding and intention.

But are such scenarios relevant to the development of rural education in schools serving poor and disadvantaged communities that cannot afford even 'free' computers?

The Digital Education Enhancement Project (DEEP)

DEEP, a research project exploring the potential of ICT for teacher professional development in the global south, is described fully elsewhere (Leach et al 2006; www.open.ac.uk/deep) but some key points are highlighted below:

- The main agenda, and the prime reason for the use of ICT, is the professional development of teachers
- The training is tightly focused on subject and pedagogic development (rather than ICT skills) – all activities have a classroom practice component.
- Local culture and context are recognized, valued, and integrated within the learning activities
- A range of technologies and media allow flexible and creative uses of the technology
- There is a strong emphasis on collaborative work and peer teaching
- Some equipment is personal (the hand held computer) whilst most is shared, between partner-teachers within school, and between groups of schools.
- Whole community involvement and out of school use are actively encouraged

This model has resulted in effective approaches to teaching and learning enhanced by ICT, as well as quality learner outcomes.

Whilst DEEP did not set out to research issues of cost, we have found that cost is usually the first question raised by those who are used to thinking as usual about ICT. It is assumed that even small numbers of laptops and handheld computers must be inappropriate technology for poor rural schools, on the basis of costs alone.

The first response needs to be not about the nature of the equipment or it's cost, but about the learning and development that is occurring: we would argue that much of the dynamic and purposeful learning that we have reported would not have been possible without the creative multi-media technologies that were placed in the hands of the teachers and their pupils. How each of the technologies has supported the development of teaching and learning is detailed in 'table 2: Uses of the ICT professional toolkit' within Leach et al (2006).

But that said, it is still necessary to address the issue of costs head on. Are suites of refurbished computers the only viable form of ICT for schools in developing nations, or can the use of state of the art mobile multi-media technologies be an affordable alternative?

To test this, I have applied the same TCO framework to the computer equipment used in DEEP, as was earlier applied to a donated suite of refurbished computers.

Assumptions in applying the TCO model to DEEP

Equipment:
I have modelled the shared laptop computer and and two handhelds, being the 'computer' equivalent within DEEP. As before, I have not included the costs of a printer.

Ongoing costs:
For maintenance, the costs of the DEEP equipment are over-represented here, as for the first year these should be zero, due to warranty cover. However, I have applied the same maintenance weighting to both cases for consistency.

For electricity, I have kept Moses' assumptions of a full days use, throughout the school year, but this time, there is only one laptop; the two handheld computers use negligible electricity (similar to a mobile phone) and charge from the laptop - 40w is an aggregate power rating to cover all devices.

Professional development:
Training costs are not included, as before.

Retrofitting:
There are no retrofitting costs for the DEEP equipment - they are brought into play in the classroom as required, and do not warrant any refitting of the building. Again, this ought to show some adjustment of cost in favour of the DEEP model, but I have left out retrofitting in both cases for the sake of consistency and simplicity.

Item	Description	Cost
Initial Purchase Cost (I.P.C.)	2 handhelds 1 laptop Total:	$1,000 $1,500 $2,500
Maintenance (15% I.P.C. per annum)	3 years x (15% of $2,500)	$1,125
Supplies (9% I.P.C. per annum)	3 years x (9% x $2,500)	$675
Electricity ($0.1 per KWh x 1600 hours, per annum)	3 years x (0.04KW x $0.1 x 1,600 hours)	$19.20
Total Cost of Ownership		$4,319.20

We can see that over three years, it is $14,000 cheaper for a school to buy and run a state of the art multimedia laptop and two handheld computers, than to use a suite of traditional desktop computers freely given by a donor.

DEEP teachers and learners also made use of a number of multimedia devices – a high-resolution camera, and a digital video camera, shared between 12 schools. Over the course of the project, there have been negligible ongoing costs associated with these devices – the IPC would be $1200 for both items together; spread over the 12 schools, this would add an additional $100 per school to the TCO for DEEP.

Both the computer suite and DEEP would would also require a printer; old and donated printers are not likely to function well, due to mechanical nature of the devices, and the high volume of use they usually experience in a corporate environment. Unlike computers, where printers are replaced from an office, it is usually because they have reached the end of their useful life. The all-in-one printer/copier/scanner used by DEEP schools would add $140 to TCO. For computer suites, a network printer might be more appropriate. These are usually significantly more expensive to purchase and power, although 'ink' is cheaper. Because of these variables, I have not included the purchase or electricity costs of printers, but the cost of paper and ink is already included under *supplies*.

Discussion

It is interesting to note that, using the model of TCO provided by Moses, and accepting those assumptions, the TCO over a 3 year period for a donated suite of desktop computers may be in excess of four times more costly to a school than purchasing brand new 'state-of-the art' mobile technologies.

Indeed, the situation is likely to be starker than the unmodified assumptions would suggest because I have not made any adjustments to take account of: higher maintenance costs and shorter usable lives for refurbished computers; lower maintenance costs for new equipment during the warranty period; the costs of retrofitting a room for a computer suite - all of these things would increase the cost differential between the computer suite and the deep equipment. A five-plus fold TCO difference in favour of the DEEP equipment seems a more realistic assessment.

Is this a result of a flaw in the TCO model? Although simple, Moses' model seems consistent with the range of TCO approaches reviewed by Scrimshaw (2003). SchoolNet Africa cite one 'thinking as usual' TCO model using suites of thin client computers, with a TCO per school of $21,000 over 5 years (SchoolNet 2004), which is in broadly similar territory, though without access to the TCO model they refer to, it is hard to draw meaningful comparisons (but for the curious, the DEEP TCO here would come in at $8,032 over 5 years). It seems that there is nothing fundamentally amiss with the model, and that, provided the same model is used each time, it forms a valid basis for comparing the relative TCOs of different ICT equipment configurations within a school.

It may be argued that more pupils have 'access' using a computer suite, than the smaller number of machines available in DEEP, to there are three quick responses:

- because mobile devices are always available in the classroom and beyond, levels of usage are very high; teachers and pupils may well have more opportunity for sustained access with a small number of mobile devices than with occasional 'ICT lessons' in a dedicated suite.
- there is evidence that a small number of mobile devices can be used effectively in primary and junior secondary schools to enable effective learning for large numbers of pupils (Leach et al 2006), within the context of a curriculum based professional development programme
- there is evidence that 'thinking as usual' has almost no discernable positive impact on teaching or learning (e.g. Cohen 2003), therefore under such circumstances it makes little difference how many pupils have 'access' to a computer, if nothing is achieved through that access.

Another concern has been around survivorship of 'fragile' mobile equipment – but of the 149 digital devices (18 laptops; 52 handhelds; 24 all in one printer/ scanners; 52 add-on cameras; 3 digital cameras) 143 remained in working order three years later at project close.

Conclusions

There is a prevailing orthodoxy around acceptable forms of ICT for poor communities, the assumptions of which are rarely challenged.

Cost is a major factor in re-enforcing this orthodoxy, although the evidence suggests that the orthodox approach may often be much more costly and much less effective than expected.

A new paradigm is required in which learning, and the contexts and purposes of the learners, are the determining factor in identifying appropriate technologies. New formulations of apt technologies may be much less costly than orthodox approaches; they may also be much more effective in bringing about successful learning outcomes.

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He is co-director of the Digital Education Enhancement Project (DEEP) www.open.ac.uk/deep , which has been researching the potential of ICT for teacher professional development and teacher practice in developing nations since 2001.

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