ICT implementation in school education in India - a report by Tata Trusts and IT for Change

IT for Change, Bengaluru

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1 Summary

It is widely accepted that digital technologies (popularly known as Information and Communication Technologies or ICT) have the potential to strengthen and reform school education. However, in the absence of clear framework for program design, the impact on learning processes and outcomes from numerous attempts by different governments and other actors has not lived up to this potential.

This note provides a holistic framework for such a design, covering infrastructure, teacher education, curriculum and content and education administration, aiming to support the *creation of an ecosystem of ICT integration*. The note assumes certain principles- firstly ICT program should aim to support the achievement of educational aims. A deep understanding of aims, philosophies, contexts, needs and priorities of education in India, is indispensable for meaningful and effective program design.

Secondly, ICT implementation must support the achievement of education policy. The thrust of these policies has been to support constructivist classroom pedagogies, make learning connected to local contexts and responsive to learner needs, make the school culture democratic and participatory, support decentralized school system administration by strengthening school autonomy, teacher agency and connecting the school to the local community, going beyond a narrow focus on learning outcomes.

The ‘public’ nature of education aligns strongly with free and open ICT architectures. It is recommended by the National ICT policy that the ICT implementation in school education use free and open technologies, including FOSS (Free and Open Source Software) and OER (Open Educational Resources).

The design of ICT programs must consciously aim for sustainability, where the schools and other institutions can continue the integration of ICT beyond the initial investment period. Developing in-house capacities of teachers and teacher educators to appropriate free and open ICTs for their work, can sustain the use of ICT, freed from vendor lock-ins. Using ICT to build peer networks of teachers can support continuing professional development and sustain ICT implementation in the school.

The note discusses ICT integration across five components - ICT infrastructure, school level implementation, teacher professional development (TPD), curricular resource development and Educational administration.

1.1 ICT infrastructure

An ICT Lab needs to be seen as a part of the basic infrastructure of the school, to provide opportunities for teachers and students to integrate ICT for their learning. The configuration of the devices in the lab should be based on factors including school readiness for ICT integration, remoteness of school, rural/urban contexts, basic infrastructure availability etc. The number of devices in the lab should be based on the strength of the largest section (rather than of just the school), but since this will vary across years, an approximation of the same (in multiples of 5 systems) will be required to create tiers / slabs. Few scenarios based on these considerations is in Annexure B. The lab must have a ‘school software and content server’ which provides services to other (connected) devices including file storage and access, internet connectivity etc. and serves both ‘management information system’ and ‘people information system’, latter connecting the school with its local community.

In line with National Policy on ICT in school education, FOSS platforms and applications will be deployed, on pedagogic, economic and technological grounds. Since the government school system is huge, this choice would help build an ecosystem for free and open technologies. Likewise, only open educational resources should be accessed and created by teachers and schools, for a resource rich learning environment.

1.2 School level implementation

The ICT lab requires a teacher or lab attendant for taking care of its maintenance and development. To support peer / team learning a 2:1 pupil-device ratio is considered. In the case of higher primary and high schools, it is envisaged that students would be using the lab, along with the teachers. In case of lower primary schools, the lab should be made available for teachers. The number of devices required has been taken as an average of 3, 10 and 20 desktops per lower primary, upper primary and high school respectively.

In addition, one laptop and one projector will enable teachers to demonstrate lessons in the classroom where electricity supply is available. Teachers should be encouraged (through interest free loans) to purchase their own laptops / devices, which they could use for their own professional development as well as in classroom teaching. Governments are investing in free laptops for students, ensuring teacher access and use of computers needs to be seen as a much higher priority. An annual grant is needed towards asset replacement and maintenance, electricity and connectivity.

In all cases, the school should be given an important role in the deployment design, rather than top-down procurement and supply, which invariably leads to failure due to poor local ownership. Given resource constraints, schools could be invited to apply for the lab and a token contribution from the school too could be required, to enhance local ownership. However, this has iniquitous implications and schools which cater to marginalized groups and are less resourced should be given priority, with much higher resource support.

1.3 TPD and curricular resources

Every teacher education institution should have an ICT lab which will be used in the TPD programs. ICT training should not be seen as a stand-alone program, rather using digital methods should form a part of every teacher development program, where teachers can access resources relevant to the theme of the training program, collaboratively develop OER and form communities of learning. TPD should include digital literacy, this includes developing a critical perspective on ICT, being able to judge its harmful effects and dangers. It should focus on building skills to use digital tools to teach and to make resources, not be dependent on proprietary content or software. Building skills of the large army of teachers in government schools can help in the development of contextual resources in local languages, a critical need in school education.

As the processes of building individual and institutional capacities to use ICT mature, these institutions would be able to offer blended learning programs, combining regular and predictable face to face meetings with structured virtual interactions and learning.

1.4 Education Administration

In the area of education administration, ICT can provide support for data management and decision support. In line with the policy aim of decentralization, the program should support the development of 'federated information structures and processes' than the typical centralized data management which reinforces and deepens hierarchies and pushes upward accountability instead of local accountability of the school to its community. All the suggestions in this note have been made on the basis of programmatic and research experiences in Indian school education.

1.5 Summary of investments required

A summary of the investments for country wide implementation is provided below:

Summary across components

On an average, 20 devices for high school and 10 devices for higher primary schools and 3 devices for lower primary schools

Particulars	Initial Investment (Rs in crores)	Recurring (Rs in crores)
A. ICT Infrastructure	63,762	18,976
B. Teacher Professional Development	3,099	1,550
Total	**66,861**	**20,526**

The details of the two components are provided below:

1. ICT infrastructure

On an average, 20 devices for high school and 10 devices for higher primary schools and 3 devices for lower primary schools			
ICT Infrastructure – India			
Institution	**Number**	**Initial Investment**	**Recurring**
Schools – 'Only LPS' (Government and aided)	677,648	186,353,250,930	54,211,854,816
Schools – Only HPS and Only HPS + LPS (Government and aided)	346,363	161,058,733,992	48,490,801,632
Schools – HS (Government and aided) – all other than above two	198,907	198,907,276,400	59,672,182,920
Cluster Resource Centres (CRC)	76,333	76,333,000,000	22,899,900,000
Block Resource Centres + BEO	13,500	13,500,000,000	4,050,000,000
No. of DIETs/DRCs + DEO	1,280	1,280,000,000	384,000,000
IASEs, CTEs (excludes private teacher education institutions)	135	135,000,000	40,500,000
SCERTs and state level institutions	40	40,000,000	12,000,000
National level institutions	10	10,000,000	3,000,000
Source - (MHRD annual report 2015-16, 12 Plan TE guidelines for number of institutions)			
Private (unaided) schools have been excluded from the school count in the table. Only government institutions have been considered in the count of teacher support institutions.			
Grand Total	0	637,617,261,322	189,764,239,368
Total in crores towards ICT infrastructure		63,762	18,976

2. TPD

INDIA - Teacher Professional Development			
Institution	**Number**	**Initial year**	**Subsequent years**
Teachers – Only LPS (Government and aided)	1,804,738	9,023,690,500	4,511,845,250
Teachers - HPS, HS (Government and aided – non Only LPS)	4,214,418	21,072,089,425	10,536,044,713
Cluster Resource Centres (CRC)	76,333	381,665,000	190,832,500
Block Resource Centres + BEO	13,500	303,750,000	151,875,000
No. of DIETs/DRCs + DEO	1,280	160,000,000	80,000,000
IASEs, CTEs (excludes private teacher education institutions)	135	27,000,000	13,500,000
SCERTs and state level institutions	40	20,000,000	10,000,000
National level institutions	10	5,000,000	2,500,000
Grand Total		**30,993,194,925**	**15,496,597,463**
in crores		**3,099**	**1,550**

Note – the investment amounts for '**C. State investments - Technology integration units'** are relatively insignificant and lesser than the rounding off figures in the ICT infrastructure table. Hence, these have not been shown in the summary.

Since the initial amount for establishing the ICT infrastructure is quite enormous, this will be difficult to do in one year. The investment needs to be phased across several years/ budgets. Parameters such as school type (High/higher primary/lower primary school), school size, location, existing infrastructure, explicit interest should inform the phasing.

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2 Abbreviations and acronyms

An expansion / explanation of abbreviations and acronyms used in this document.

Term	Explanation
BOOT	Build-Own-Operate-Transfer
Block / Taluka	The unit of education administration, below the district
BEO	Block Education Office
BRC	Block Resource Centre
CIET	Central Institute of Education Technology
CRC	Cluster Resource Centre
CTE	College of Teacher Education
DIET	District Institute of Education and Training, the apex academic institution at district level for syllabus, curriculum and teacher education.
District	Administration unit for education system, below the level of the state (provincial) administration
DSERT (SCERT)	Directorate of School Educational, Research and Training (http://dsert.kar.nic.in) the apex academic institution of Karnataka for syllabus and curriculum development, as well as teacher training.
FOSS	Free and Open Source Software, also known as 'open source' software or 'free software'
ICT	Information and Communication Technologies (more specifically digital technologies)
ICT@Schools	Programme of state governments in India, to introduce ICT in high schools
HS	High School
IASE	Institute of Advanced Studies in Education
ITfC	IT for Change
KOER	Karnataka Open Educational Resources - refers to the programme of the Karnataka education department in which OER was collaboratively created by a group of mathematics, science and social science teachers. It also refers to the websites in English and in Kannada containing the OER created by these teachers.
L(U)PS	Lower (Upper) Primary School
MHRD	Ministry of Human Resource Development
MOOC	Massive On-line Open Course
NCERT	National Council for Education Research and Training
NCTE	National Council for Teacher Education
NIEPA	National Institute of Educational Planning and Administration
OER	Open Educational Resources
PLC	Professional Learning Communities
RMSA	Rashtriya Madhyamika Shiksha Abhiyaan, the programme of the Ministry of Human Resource Development, Government of India, for secondary education.
STF	Subject Teacher Forum programme
TE	Teacher Education
TPD	Teacher Professional Development
UDISE	Unified District Information System for Education

3 Background

In the last two decades, the world has moved from being an 'industrial society' to an 'information society', thanks to the digital revolution. Digital technologies, popularly known as Information and Communication Technologies (ICT) are having a profound impact on our lives[1]. In the area of school education, many elite

1 This is not to say that all the changes have had a positive impact on people's lives. ICT are powerful technologies,

private schools are experimenting with ways to integrate ICT into their education processes; from providing a laptop / tablet to every student, to smart classrooms and integrated on-line school systems. Central and state governments have attempted to implement ICT education in schools through different programs. The potential for ICT to improve the quality of school education is generally accepted.

Over the years of ICT implementation, there has been a gradual shift from using media tools for educational and information purposes and promoting computer literacy to a more comprehensive approach towards integrating ICT into the school education system. The use of ICT in education could have two broad aims; improving quality of education by enhancing the teaching-learning process, and for the enhancement of the education processes for better administration and management. However, the measures adopted to achieve these objectives have been inconsistent and inadequate.

There are also gaps between policy and program design and between program design and program implementation. Though the ICT@School program of the central government has invested in providing ICT Labs to high schools across the country, and on paper, most schools have been provided, a smaller number of schools have functioning ICT Labs, as per the various evaluation reports on the program. A key cause for this is the low ownership of the school and teachers over the lab and its activities. The design of the program needs to be thought afresh, if further investments have to be effective.

To deliver on the potential for ICT in achieving educational outcomes, substantial investment are needed to be made across the spectrum of education, covering infrastructure, teacher education, curriculum and content and education administration. This requires understanding the requirements of individual institutions as well as the *creation of a ecosystem of ICT integration*, including teacher education, community and education administration institutions system, so that participants are able to use ICT meaningfully in performing their roles.

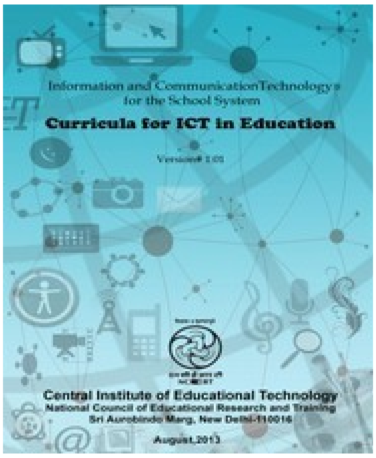

Illustration 1: NCERT ICT Curriculum (Image source - NCERT)

The most recent developments in the context of ICT in school education have been the revision of the centrally sponsored ICT@Schools Scheme in 2010, the formulation of a National Policy on ICT in School Education (hereinafter referred to as the ICT policy) in 2012 and the formulation of the "*National ICT Curriculum*" by NCERT in 2013, for both students and teachers in schools.

The ICT policy also envisions the setting up of a National Repository of Open Educational Resources (NROER), to publish and share open educational resources (OER). These documents support the imagination of ICT in empowering and enabling ways, promoting inclusive educational environments and processes and serve as a basis for planning ICT integration in Indian education.

4 Objectives

This document aims to provide a picture of what is required for integrating ICT in Indian education, towards achievement of educational aims. The document identifies the scope of such requirement and translates the same into required budgetary allocations. *While the actual financial amounts could vary based on the choices*

therefore they have the potential to do significant good or significant harm, depending on the underlying principles of the design and implementation of ICT. It is important to explore the use of ICT with a critical perspective and not assume ICT to be a silver bullet. Hence, one section of this report discusses in some detail, the principles proposed for the design of ICT integration in school education.

made, the detailing of this picture would be useful in itself, to provide inputs for deliberation by policy-makers and other actors in program design, and consequently program investments.

Hence, the report has included the following:

1. Articulation of guiding principles for ICT integration, and hence its scope
2. Components of ICT integration
   a) Planning the ICT infrastructure
   b) Bringing it together - school level implementation
   c) Teacher Professional Development (TPD)
   d) Curricular resource development – Open Educational Resources (OER)
   e) Educational administration

5 Investment summary for a country wide program

The investment for an effective program for ICT integration in school education can be broken into three components – establishing and maintaining the ICT infrastructure in schools and in educational institutions, teacher education to prepare them for this integration and thirdly establishing 'Technology integration units' in relevant educational institutions at national and state levels which would coordinate the processes of ICT integration in education.

A summary of the investments required on these three components is provided in the tables below

<u>Summary across components</u>

<u>20 devices for high school and 10 devices for higher primary schools and 3 devices for lower primary schools</u>

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<u>1. ICT infrastructure</u>

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IASEs, CTEs (excludes private teacher education institutions)	135	135,000,000	40,500,000

SCERTs and state level institutions	40	40,000,000	12,000,000
National level institutions	10	10,000,000	3,000,000
Source - (MHRD annual report 2015-16, 12 Plan TE guidelines for number of institutions)			
Private (unaided) schools have been excluded from the school count in the table. Only government institutions have been considered in the count of teacher support institutions.			
Grand Total	0	**637,617,261,322**	**189,764,239,368**
Total in crores towards ICT infrastructure		**63,762**	**18,976**

Note – UDISE provides the number of schools by management (government, aided, unaided etc) and by category (only lower primary, lower primary and higher primary etc). But these are 2 different reports. There is no report which provides number of schools by management and by category. Hence, the number of schools which are not aided for different categories has been derived through pro-rata computation.

2. TPD

INDIA - Teacher Professional Development			
Institution	**Number**	**Initial year**	**Subsequent years**
Teachers – Only LPS (Government and aided)	1,804,738	9,023,690,500	4,511,845,250
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National level institutions	10	5,000,000	2,500,000
Grand Total		30,993,194,925	15,496,597,463
in crores		**3,099**	**1,550**

3. State level investments.

C. State investments - Technology integration units			
Particulars	**Number**	**Approximate set-up costs**	**Annual recurring costs**
State OER portal	40	80,000,000	80,000,000
State Technology team	40	0	96,000,000
Software purchases (outright)		20,000,000	20,000,000
Research and Development		**0**	**0**
Total		**100,000,000**	**196,000,000**
Rupees in crores		**10**	**20**

Note – the investment amounts for '**C. State investments - Technology integration units**' are relatively insignificant and lesser than the rounding off figures in the ICT infrastructure table. Hence, these have not been taken into the summary. (Refer the '1.Summary Sheet' in the workbook which has the computations)

The cost summary makes a few assumptions, which are discussed in the relevant sections of the report. If these assumptions are modified / varied then the investment amounts would vary as well. The figures mentioned in the tables above should therefore be read as indicative of what would need to be spent. Equally, importantly, the report discusses the program design principles for these components and discussion on the costs would necessarily involve discussions on these principles. Debating these design principles and accepting or modifying or rejecting them in favour of alternatives would help in building our understanding for designing and implementing effective ICT integration in school education in India.

5.1 Investment for a state

The figures provided in the tables in the previous section are for the country as a whole. To give an idea of the investment requirements for a state, the case of Karnataka is considered here. Karnataka is considered an 'average' state in India, not too small or large. Karnataka has implemented similar ICT programs in school education like most states have, and the figures for Karnataka can give an idea of a 'typical state outlay'

Summary across components

Particulars	Initial Investment	Recurring
A. ICT Infrastructure	3,323	993
B. Teacher Professional Development	141	71
Total	**3,464**	**1,064**

The break-up for these three components is provided in the following tables

1. Karnataka - ICT Infrastructure

Institution	Number	Initial costs – ICT Infrastructure	Annual costs - ICT Infrastructure
Schools – 'Only LPS' (Government and aided)	20,516	5,641,840,050	1,641,262,560
Schools – Only HPS and Only HPS + LPS (Government and aided)	23,405	10,883,392,611	3,276,720,356
Schools – HS (Government and aided) – all other than above two	13,536	13,535,515,000	4,060,654,500
Cluster Resource Centres (CRC)	2,684	2,684,000,000	805,200,000
Block Resource Centres + BEO	408	408,000,000	122,400,000
No. of DIETs/DRCs + DEO	68	68,000,000	20,400,000
IASEs, CTEs (excludes private teacher education institutions)	12	12,000,000	3,600,000
SCERTs and state level institutions	1	1,000,000	300,000
Grand Total		**33,233,747,661**	**9,930,537,416**
in crores		**3,323**	**993**

2. Karnataka - Teacher Professional Development

Institution	Number	First Year costs	Subsequent year costs
Teachers – Only LPS (Government and aided)	41,056	205,279,987	102,639,994
Teachers - HPS, HS (Government and aided – excluding 'Only LPS')	232,688	1,163,437,701	581,718,851
Cluster Resource Centres (CRC)	2,684	13,420,000	6,710,000
Block Resource Centres + BEO	2,448	18,360,000	9,180,000
No. of DIETs/DRCs + DEO	850	8,500,000	4,250,000
IASEs, CTEs (excludes private teacher education institutions)	240	2,400,000	1,200,000

SCERTs and state level institutions	50	500,000	250,000
National level institutions	0	0	0
Grand Total		**1,411,897,688**	**705,948,844**
in crores	10,000,000	**141**	**71**

For details refer to the sheet ‘**1. Summary - Karnataka**’ in the workbook

C. Karnataka State investments - Technology integration units			
State OER portal	1	1,000,000	1,000,000
State Technology team	1	None	2,400,000
Research and Development		part of existing budgets	part of existing Research budgets
Grand Total		1000000	3400000

Note - the investment amounts for ‘**C. State investments - Technology integration units’** are relatively insignificant and lesser than the rounding off figures in the ICT infrastructure table. Hence, these have not been taken into the summary.

5.2 Phasing of investment

Since the initial amount for establishing the ICT infrastructure is quite enormous, this will be difficult to do in one year. The investment needs to be phased across several years/ budgets, the following parameters can inform the phasing:

1. The high schools need to be enabled first, followed by higher primary schools and then by lower primary schools. In high schools and higher primary schools, both teachers and students would use the infrastructure, while in lower primary schools, the infrastructure is for the teachers mainly. Secondly, basic infrastructure needs to be strengthened much more in HPS and LPS (in that order) before they can assimilate the ICT infrastructure.

2. Schools which are larger (student strength) need to be provided first and then smaller schools. This will enable greater access with the same investment

3. Schools with existing electrical power supply can be covered first. Schools which need electrification can be included later. In this regard, solar power supply will also need to be considered.

4. An important factor for the phasing can be the interest of the school / teachers in establishing the lab. Traditionally, the labs have been set-up usually in a pure ‘supply’ mode, where the wishes of the teachers are not ascertained before providing the lab. *Where teachers are not keen on the ICT lab (due to lack of awareness or any other reasons), it could be futile to expect them to use the lab*.

Hence, initially, the state could invite applications from schools, desirous of having ICT labs. The application could provide background data of the school, explain its eagerness to have the ICT lab and share work done earlier, and discuss its support needs to use the lab. The application can also seek a commitment from the school about making use of the lab. Though this ‘demand-based’ approach will make the logistical aspects (delivery of items etc.) more complex, it can have an important salutary effect on the use of the lab.

In the interest of equity, a certain percent of the labs could be reserved for schools that are located in / serving marginalized communities. Resource support for such schools should be at a higher level.

5. Schools that have assured supply of electrical power can be prioritised. As per UDISE, 40% of schools in

India, do not have electrical power connection. Provisioning electrical power should be a higher priority, post which ICT labs provisioning can be done.

Phasing is also useful, so that the provisioning of ICT infrastructure is simultaneously complemented with the other critical investments that are required to make the infrastructure investment effective. Hence, each year, the program should invest on ICT infrastructure and also on the other components so that the infrastructure is used for the purposes intended, in a sustainable manner.

6 Principles underlying ICT integration in school education

It is important to discuss the principles underlying this exercise, since these would influence the direction and the priorities for the investments in ICT integration. These principles are the basis on which assumptions for program design have been made.

6.1 Situating ICT firmly within education

The aim of ICT implementation should be to support the achievement of educational aims, nothing more and nothing less. While this may seem obvious, the history of ICT implementation has often seen a disproportionate focus on technological aspects, which have compromised educational possibilities.

Education is complex and multi-disciplinary and a deep understanding of the aims, philosophies, contexts, needs and priorities of education is necessary for a meaningful and effective design of ICT programs in education. ***Hence, it is critical that ICT policy/ program design be shaped by educationists, and not by technology companies / or the IT business sector.***

While companies can be expected to supply goods and services, as they do in many areas (such as the production and supply of school furniture), their role should be restricted to the supply of goods and services and not extend to the core areas of curriculum, pedagogy and assessment. This role clarity has often been absent in past implementation of national ICT programs, which has been one of the causes for their failure (see box below). ***This caution is important since, there are numerous technology vendors including large transnational corporations, who seek to sell their (often proprietary) goods and services, these may not be adequately grounded in educational principles and concerns***. Often, ICT programs announced by governments in 'collaboration' with technology vendors, are thinly veiled offerings of the products of the company for the teacher/student population and this should be avoided.

The aims and principles of education and experiences of educators must drive policy, program design and implementation.

<u>Experiences in not situating ICT design within education – evidence from past programs</u>[2]

1. Curriculum - What was 'taught' was either 'Office applications' (unconnected to school subjects), or simple audio-visualization of existing print-based content. These do not usually tap into the possibilities of ICT to enrich educational content.
2. Resources - The main digital resources used were proprietary; popular proprietary operating system, proprietary office suite and copyright content. This was a constraint to the teachers and students imagining a sharing and learning environment which would permit wider dispersion and active collaboration.
3. Transaction - ICT were introduced usually through poorly paid 'computer' faculty with no background in education, bypassing the regular teachers. This usually meant that the program remained stand-alone. Possibilities of enriching existing pedagogical approaches of the regular teachers were largely not

2 Kasinathan, G. (2009). Computer learning programmes in schools Moving from BOOT models to an integrated approach

attempted.

4. Not holistic - ICT were introduced as an intervention aimed directly and exclusively at the student, and not comprehensively built into the school's educational processes.

6.2 Support for implementing education policy

ICT implementation must support the achievement of education policy, which in the Indian context, includes documents such as National Policy of Education, 1968 and 1986, National Curricular Frameworks (including 2000, 2005), National Curricular Framework for Teacher Education 2010, National Policy on ICT in School Education, 2012 and the National ICT Curriculum, 2013.

The letter and the spirit of these policies has been, to support constructivist classroom pedagogies, make learning connected to local contexts and responsive to learner needs, make the school culture democratic and participatory, support decentralized school system administration by strengthening school autonomy, teacher agency and connecting the school to the local community. ICT program design and implementation should be aligned to these aims. This principle also means that the ICT program has to be systemic and holistic.

6.3 Foregrounding educational processes

Eisner, an eminent educationist suggested that the heart of the educational processes is content and pedagogy (the 'what' and 'how' of teaching), calling them the 'systole and diastole' of teaching. The TPCK (Technological-Pedagogical-Content Knowledge) framework for teacher education[3] suggests that teacher knowledge consists of three kinds of knowledge – technological knowledge, pedagogical knowledge and content knowledge, and that ICT (technological knowledge) can potentially alter both the pedagogy and content (pedagogical knowledge and content knowledge) of teachers. Some ways by which this can be designed include:

Illustration 2: TPCK Framework. (Image source - IT for Change)

1. Access to digital repositories can support *self-learning* by teachers and by students.
2. ICT has the potential to support curricular resource *creation*, an important academic process. ICT can support '*constructionism*' through the processes of 'creating to learn' and 'learning to create'.
3. ICT can support sharing, peer learning and *collaboration*, and can support the development of 'communities of practice' which are seen as powerful methods of CPD (continuing professional development).

Thus self-learning, peer-learning, collaborative learning must be the processes that the ICT program must support.

Often in the past, the program has focused only or primarily on providing ICT infrastructure to schools. However, preparing the teachers to understand the role ICT can play in supporting their work and professional development is perhaps more important than providing the infrastructure. Developing a deep understanding of teachers and teacher educators about the role ICT can/should play and should not play is very important and

3 Mishra, P. & Koehler, M.J. (2006). Technological Pedagogical Content Knowledge: A framework for teacher knowledge

neglect of this has been the most important reason for failure of ICT programs, which manifest through symptoms such as non-use of the infrastructure, neglect of maintenance, lab activities being stand-alone and not linked to schools mainstream processes. It is easier to provide computers than to prepare teachers and officials to understand how best they can adopt ICT for meaningfully achieving their goals, but this will lead to program failure.

6.4 Strengthening autonomy and subsidiarity

The National Policy on Education, 1986 gave a clarion call for decentralization of the education structures and processes. In the large and federal structure of Indian education, ICT can and should be used to support decentralization of education administration. ***ICT has the potential to further centralise control; for people at the centre, the 'benefits' of centralisation tend to be obvious***. However, use of ICT to strengthen centralisation can adversely affect people at the peripheries and the grass roots[4].

ICT design and implementation which supports the greater participation of teachers, teacher educators, parents and students should therefore be an important principle of ICT design. ICT implementation should strengthen the capacities and agency of teachers and participation of parents / communities in schools and strengthen school autonomy. If learning is to be contextual, resources must be contextual as well. For teachers to go beyond a standard curriculum, they must be creators, and their creation is more likely to meet local needs.

ICT implementation should build the capacities of the education administration to support the school academically and administratively, rather than only monitor and supervise for accountability extraction. By improving transparency of decision-making and supporting local / community participation, ICT can support the decentralization of the education system.

This principle also implies that the guidelines for the program (for Central government support) should be flexible and allow different states to use the financial support in different ways, based on their local contexts and needs. The 'common' rules should be kept to a minimum.

The principle of autonomy can inform the 'selection' of schools. Instead of deciding centrally which schools should 'receive' the ICT Labs, schools should have a say in the matter. Schools that are keen to have ICT labs should get the support. Schools that are not interested should not be forced to implement the program (these schools need to be engaged with and persuaded over time about the benefits of ICT, and the lab should be provided after they change their views. Forcing them to accept or even change their views will adversely affect the chances of the success of the program).

6.5 Free and open technology architecture

It is generally accepted that education is a public good and has a critical role in the evolution of society. It is the tool with which society attempts to reshape itself and hence the aims of schooling (and the processes of education) need to emphasise this 'larger' role of education, beyond empowering individuals. ICT implementation should support this larger aim of education in society, for which ICT infrastructure and resources should be publicly owned to enable universal access and equitable participation.

The 'public' nature of education aligns strongly with free and open ICT architectures. It is recommended by the National ICT policy that the ICT implementation in school education use free and open technologies, including FOSS (Free and Open Source Software) and OER (Open Educational Resources). Unlike their proprietary equivalents, both FOSS and OER permit free use, re-use, revision and re-distribution, creating a sharing environment. Promoting FOSS and OER can help create a rich digital learning environment. It also reduces or

4 Kasinathan, Gurumurthy. 2015. Domination and emancipation, a framework for assessing ICT and Education programs

avoids software piracy, which is an unethical and illegal, but not uncommon practice.

Since the government school system is huge, its choice of free and open technologies could support the building of the ecosystem for free and open technologies as well. This is seen in the case of the IT@Schools program of Kerala.

In the area of ICT, the 'private' often becomes 'proprietary' by which the owner of the ICT becomes the sole arbiter for its design and use, limiting the role of teachers, learners and the education system through legal and technological constraints. Use of software that cannot be shared freely, constrains its distribution and use, limiting the digital environment. Use of copyright content, constrains its free sharing and modification / enrichment. This can become inimical to the larger role of education.

The National Policy of ICT in School Education, 2012 has recommended the adoption of free and open source software. ICT resources that are free and open, can be freely accessed, shared, modified and re-distributed. The use of FOSS software applications is essential to support universal access to software. In addition, since FOSS allow modification by all, this allows possibilities for interactions between teacher communities and free software communities and helps teachers and learners move from being 'users / consumers' of ICT to participants in its creation, enrichment and sharing.

The environment of FOSS can support teachers and students to visualise development of simple apps/ applications that can meet their local needs. Information analyses solutions using databases or spreadsheets can help teachers explore research or assessment data locally and identify issues and solutions. Such apps or solutions could be shared with other schools across the learning community networks. Such an environment will go a long way in building the 'Make in India' or the 'Tinkering' spirit.

6.6 Sustainability

ICT programs in schools often have not sustained beyond an initial period where the infrastructure has been provided / developed. The causes for this have been discussed in section 'situating ICT firmly within education'. The design of ICT programs must consciously aim for sustainability, where the schools and other institutions can continue the integration of ICT beyond the initial investment period.

Education systems should avoid the temptation to embrace the latest technologies before they mature. Schools are conservative institutions and the pace of change has to be slow enough for it to be understood well and meaningfully internalized. Technologies that are unproven (and have not been around for a few years and used widely) should not be opted for. Sophisticated (and expensive) devices should not be preferred over simpler, widely used, robust and inexpensive devices, the former is much more prone to failure. The obsession with 'digital smart board' is a case in point. These are expensive, prone to failure since local support for addressing major and minor problems is non-existent. KISS (Keep it Simple and Straightforward) should be an important principle for maintainability and hence sustainability. Secondly, harmful effects of a new technology may manifest later[5] and education as a process involves young learners, who need to be protected from such harmful impacts. For instance 'gaming' has been a buzz word for supposedly supporting learning, buts its harmful effects (such as addiction) are beginning to be evidenced by research.

Developing in-house capacities of teachers and teacher educators to appropriate ICTs for their work can support the sustainable use of ICT, freed from vendor lock-ins. Using ICT to build peer networks of teachers can support continued learning and professional development and serve as a sustainable method of TPD as well as sustain the ICT implementation in the school.

The use of free and open technologies also avoids vendor lock-ins, these lock-ins can affect continuity of the

5 'Five Things We Need to Know About Technological Change' by Neil Postman must be read by all technology-fixated teachers and administrators.

program, if the vendor stops their support. FOSS applications can be periodically upgraded without licensing constraints, which would enable the use of more relevant applications or versions. For the same purpose, governments must activity promote and use open standards in ICT artefacts. Closed, proprietary standards are vulnerable to failure when the provider is no longer existing or willing to support and also promote rent extraction, which is against public interest. (India is one of the few countries in the world to have a policy on open standards in governance, this needs to be fully implemented).

The document proposes an architecture of ICT implementation in line with these principles.

7 Scope and methodology

This document provides an approach to ICT implementation for the school education system in India, covering government, aided and unaided schools from grade 1 through grade 10 along with public academic, administrative and programmatic institutions supporting school education.

The data was collected through secondary research / desk research and the following sources were accessed:

1. UDISE 2015-16 statistics from NIEPA (for data relating to the number of schools, number of students and teachers).
2. Evaluation and impact report of ICT programs from CIET, NCERT
3. Curricula and policy documents of MHRD, Government of India
4. Papers, research articles relating to ICT programs in India

Based on the data collected on these institutions, cost benchmarks for different components for a national program of ICT integration in school education has been developed.

While the actual financial amounts could vary based on the choices made, the detailing of this picture would be useful in itself, to provide inputs for deliberation by policy-makers and other actors in program design, and consequently investments.

8 Components

Each of the components of the ICT program, listed earlier are discussed in this section. The attempt has been to design each component for comprehensive impact. Focusing on some components and ignoring others has been a mistake in the past. In many programs, the focus was largely on infrastructure provisioning with much lesser emphasis on teacher preparation or community participation or meaningful ICT integration into the mainstream educational processes at the school level.

8.1 Basic infrastructure

An ICT Lab needs to be seen as a part of the basic infrastructure of the school, to provide opportunities for teachers and students to integrate ICT for their learning.

The setting up of an ICT Lab in the school requires initial investment for creating the lab covering civil, electrical works and furniture. It is suggested to keep wiring to the minimum to reduce maintenance costs. Wireless Local Area Networks (LAN) should be set-up to avoid traditional LAN with wiring. Wiring will be required for providing electricity to each lab. Dependable power supply is an important criterion for success of the program. Solar power costs are rapidly reducing and this should become a model to consider seriously and invest in. The scale of electrifying schools will allow further reduction of solar energy costs due to economies of scale.

The lab requires furniture to allow for the learners to use the devices comfortably and to allow the devices to connect to power and internet sources. Securing and storing the devices safely and providing 'charging' access for devices with batteries is another requirement.

Civil costs are not considered in this estimate. In a decentralized program, the school and its local community could be asked to provide this component, this is the practice in the Kerala ICT@Schools program.

Cost estimate for this component
The civil expenses of the room for the ICT lab and electrical wiring is not part of this estimation.
Furniture is taken at Rs 2,000 for one workstation. For a 20 computer lab, assuming a 2:1 student-computer ratio, the furniture costs for the lab would be Rs 40,000 per lab, and Rs 10,000 for a 5 computer lab.

8.2 ICT Infrastructure

Hardware

In the past, the desktop computer has been the mainstay device for the lab. However, given that there are diverse parameters in the choice of devices such as cost, affordances for participation / creation processes, power consumption and dimensions / weight, it may be preferable to consider a hybrid set of devices for the lab, this includes desktop computers, laptops, tablets, smart phones. The value proposition of each of devices[6] across these parameters is provided in Annexure B

Desktop computers, laptops, tablets and mobile phones are in a spectrum of capabilities with the initial costs and recurring costs (mainly power consumption) reducing from the first to the last, and so do the processing capabilities of the devices. Hence, while desktop computers have been the mainstay of ICT infrastructure in schools, with the increasing use and popularity of the mobile phone, it may be useful to think of a hybrid set-up with desktops, laptops, tablets and mobile phones.

Intensive learner activities will need students to share computers, supporting collaborative learning; but when they are accessing information, each can have access to one access device like a tablet or a phone. However, a hybrid environment would put additional pressure on the maintenance front, since different kinds of devices would have different maintenance issues/ requirement. Hence, the extent of hybridisation can be a function of the level of sophistication of use in the school / institution. Where the sophistication is very low (first time access to ICT), providing one type of device may make the maintenance simpler / easier.

The scope for active learning should also guide the choice of devices. Devices like tablets or smart phones support 'see and consume' rather than 'doing and learning', the latter being an important emphasis of our curricular policy (such as NCF 2005). Rote memorisation based learning processes are deeply embedded in Indian education and ICT devices that support consumption of content will further these processes. On the other hand, moving to devices that support doing and learning can support moving to a constructivist learning environment, hence desktops/laptops must be the mainstay device in the lab. Even from a pragmatic perspective, the greater the role teachers and students have in using and understanding ICT, the greater the scope for ownership and success. Energy efficiency should be a parameter to consider, given the shortages of electricity in many parts of the country.

In case of traditional centralized procurements, the tender document must consciously stay out of prescribing specific brands (while no tender for cupboards will specify 'Godrej cupboards' it is common for ICT tenders to specify brands like a particular chip set or Office suite or operating system). The generic specifications for the hardware should be provided, so that the government is not promoting the products of any particular provider.

Secondly the outsourcing/tendering must not mix the technological components (hardware, connectivity) with

6 Each device is itself available in numerous models with diverse characteristics. The table goes by the general characteristics of the popular models in each of these device types.

the educational (curriculum, teacher development, student learning) components. The latter must be within the domain of the schools and school support institutions, while the former is the domain of technology vendors. Mixing the two in the BOOT model, has been an important cause of failure of past ICT programs.

Also, the school should have a role to play in deciding the kind of devices they will have in their lab. Decentralising this decision will allow for greater ownership of the infrastructure and will also allow for more effective use. The government can provide simple guidelines to support schools which want to procure the devices themselves. Schools can prepare a 'technology feasibility statement', outlining their contexts, needs and priorities with respect to the lab. Schools can chose to also take the help of the state/district institutions for procurement. One extension of this would be to provide the funds to the school and ask the school to choose its infrastructure design, providing guidelines and advice as required. A school could even choose to purchase radio receivers or Television set(s) if they feel it is required.

The scale of the Indian education system can potentially allow for specialised manufacture possibilities, for instance, IIT Mumbai has developed a laptop that costs 9,999 INR.

Server

In all cases, the lab must have a 'software and content server' which provides services to all the other devices including file storage and access, internet connectivity etc. School servers are the hubs at school that will serve up content of all learners, as a repository of course work and analytical data, as a platform for the learners to learn, co-operate and store their work and create the environment for the teachers to create their own content and enable them to share/use the same and enable 'Communities of Practice'

CIET, NCERT is developing a school server using the components of a normal desktop computer CPU, which can provide the services mentioned. There are also simpler computing devices such as the Raspberry PI, which could be considered by more sophisticated environments, these can act as servers or as regular clients.

Cloud architecture is becoming popular, where the software and data are remotely hosted. Cloud architecture enables easier management and maintenance, however it has two demerits – the need for connectivity and reduction in the local location and ownership of the data and software components. Hence, local hosting of the software and data the school / institutional on server should be preferred.

School MIS (Management Information System) and PIS (People Information systems) for supporting the regular transactions of the school and providing information to parents and community members should be done through a school server, using available free software tools. Kerala has customized the free software 'Fedora' and adopted it in all government schools. The school server should also house the OER repository for providing content to support learning opportunities for teachers and students. Communicating with parents and other stakeholders using relevant software tools[7] is another school requirement.

Peripherals

Apart from the computers and hybrid devices, each lab should have at least one digital camera, a printer and a web cam if required. The peripherals would be available to all devices through the server. If the lab has desktops, then power back is essential, consisting of UPS and battery. Devices (both client access devices and the school servers) that can run for at least six to eight hours (this would be a function of the general power supply conditions) before we have to recharge them, are essential. Annexure A (spreadsheet) provides details of the physical lab set-up and rough set-up costs.

Software

7 Voice broadcast applications are available, which can enable the school teachers to reach out to parents, many of who may be text illiterate

This note assumes the use of FOSS and hence does not provide for licence fees towards proprietary software. It is possible that applications will need to be developed for many new areas. If required, these should be purchased by the government, from FOSS vendors, and licensed as FOSS, so that there are no constraints on its distribution. The government should actively encourage and support FOSS communities to develop and maintain FOSS applications.

Connectivity

It is essential to look at learning with and through ICT, not only as interacting with a device, but as learners interacting with one another and with the world wide web. Connectivity should emphasise collaborative learning processes amongst teachers and learners.

Connecting the devices to one another in the lab and to the internet is essential. The former can be by enabling Wi-Fi functionality in the school server, so that all devices can connect to the server and to one another through the server itself, avoiding the internet for this. In addition, through the server, the devices can also connect to the internet. It is recommended to connect through the server, for keeping a track of the actual use of connectivity. Also, as a practice, if the regularly used/required content is stored in the server and accessed locally, it will reduce the need for internet connectivity. For this, every state should consider the data that will be provided as a part of such school content repository.

There are different options available for connectivity, including wired broad band, wireless broadband, dongle based, mobile phone (SIM) based etc. Since the connectivity available will differ from location to location, suitable connectivity options (and perhaps more than one option) will need to be considered by the state (or district/block/cluster/school as the case may be). Local peer-to-peer, mesh networks can provide inexpensive connectivity options and must be explored.

Wi-Fi connectivity has the advantage of avoiding wires in the lab, while a wired LAN provides better bandwidth. This means desktop computers could be connected through LAN and all other devices through wireless LAN.

Providing connectivity should be seen as a public utility function, similar to providing roads or electricity. Hence, government funds (including from the Universal Service Obligation Funds) should be used to build broad band infrastructure (or alternatives, if broadband is not possible or feasible) to every panchayat, village and school in the country.

The flip side of connecting, is exposure to security risks and hazards. As connectivity becomes ubiquitous (and internet of things more common), more attention and resources will be required towards infrastructure, data and network security. This component is not costed in this note, as its dimensions are still emerging.

Cost estimate for this component
The initial establishment of the ICT labs in all schools and government support institutions is expected to be around 63,762 crores.

8.3 Bringing it together in the school

School lab

The school ICT labs are for both students and teachers. A school is the basic unit for ICT implementation. A hybrid model for hardware (computers and tablets with server) and a generic model for software (FOSS tools) can be used to meet the local and diverse requirements.

The design of the lab should also factor in multiple (and conflicting requirements) – place for students to sit in teams of 2-3 to collaboratively work on devices, space for teachers / students to demonstrate and make presentations, assessment of student work (individually or in teams) by teachers etc.

ICT program in-charge

In each institution, it is necessary to make a faculty responsible for the lab and this role should be rotated amongst faculty members, adjusting for existing work loads. A 'lab assistant' may be required to support the Lab-in-charge faculty, depending on the size of the lab. Alternately students can be roped in, over time, to provide support to the maintenance and use of the lab. The estimates do not provide for the hiring of a 'lab assistant'. In large schools, the lab assistant could support the teaching of basic ICT literacy.

ICT Lab v/s device in the classrooms

There are two ways by which teachers and students can work using ICT, in a separate ICT lab in the school, or through devices made available in the regular classrooms. Making a device available to every student in the school is considered to be not feasible on economic grounds. Having a 2:1 or 3:1 computer learner ratio is also seen as having pedagogical advantage of supporting peer learning possibilities, where 2-3 students work together.

It is assumed that every school would have one ICT lab (with required number of computers in one or more rooms) and the teacher and students would work in the lab for sessions where these devices would be used, during specific identified class periods, as per the time-table of the school. The lab would also be used by the teachers for their TPD and for preparing lessons and developing resources.

The ICT Lab will also support the science lab, mathematics lab, language lab, audio-visual lab etc. In each of these areas, digital tools/methods can support accessing/creating resources, new pedagogies and hence learning.

Student - device and school – device ratios

If the digital device is seen as a 'personal' device, then the program needs to ensure availability of one device per learner. However, as mentioned earlier, a device per learner is not considered feasible or desirable. The number of devices in the school needs to be a function of the number of students of the 'section' which has the maximum strength in the school. In this note, we assume that two students would work with one device, so the number of devices provided to the school must be half of the number of students in the largest section.

While the number of students in each school is available with the government (which collects and publishes this data through the UDISE program / portal), the number of students in each section in each school is not collected / available. It is assumed that the maximum section strength is 60 in 25% of the schools, 40 in 50% of the schools and 20 in the remaining 25% of the schools, for computing the requirements of devices in school labs. Considering a student-device ratio of 1:2, this requires a 30 device lab in 25% of the schools, 20 device lab in 50% of the schools and 10 device lab in the remaining 25% schools. ***This averages to 20 devices per school. The investment computation assumes each school ICT lab will, on an average, have 20 desktops/ laptops.*** The actual number of devices required would need to be modified based on the actual strength. Secondly, as the actual strength will change from year to year, this should be roughly calculated and provided for on the higher side.

A large number of schools are small schools with student strength lesser than 50 and with relatively poor basic infrastructure. The ICT lab may require 5 – 10 computing devices, and this should be planned within the overall basic infrastructure (rooms, electricity) provisioning. On equity grounds, small schools also need to have their ICT Labs, mobile labs will not provide the same continuity of learning. ICT devices life in a mobile lab may be lesser, so mobile labs should not be seen as a replacement for school ICT labs.

It is assumed that every section would get 3 periods[8] per week in the lab (for transactions in different subjects),

8 This is the assumption made by the NCERT National ICT Curriculum. As the integration of ICT matures, it is likely that there will be higher demand for the lab and over time, more than one lab may be required in the school, along with providing laptop and projector in few classrooms.

and the number of periods available in the week in the school would be sufficient to provide 3 periods for all sections. (For instance, if a school has classes 6 – 10 and 2 sections per class, it has a total of 10 sections, and will need 30 periods in the time table for ICT integrated learning). Assuming that an average school has 45 periods in a week (8 periods for 5 days and 5 periods on Saturdays), one lab can support a maximum of 15 sections.

While the provision is for the school, it is envisaged that the students from the higher primary and high school sections would be using the lab, along with the teachers. In case of lower primary schools, the lab is available only for the teachers. The number of devices required for lower primary schools has been taken as an average of 3 desktops per school, this is around the ratio of the number of teachers in lower primary schools, to the number of lower primary schools.

In addition, one laptop and one projector is provisioned per school, this can enable the teacher to demonstrate lessons to students in the classroom where electricity supply is available. Teachers should be encouraged (through interest free loans) to purchase their own laptops / devices, which they could use for their own professional development as well as in classroom teaching, this is in line with the universal trend of BYOD (Bring/Buy your own device). Over time, each classroom should have a provision for a laptop and projector (as is already the case in several colleges), this will allow teachers and students to use ICT in their own rooms instead of needing to move out to a lab. This will also reduce the possibility that many classes need the lab at the same time.

As discussed earlier, the 'outsourced computer faculty' has been an important reason for the failure of the BOOT model. ICT learning should not be separated completely from ICT enabled learning. In Kerala[9] ICT Lab is used by the regular subject teachers, who are responsible for both ICT learning and ICT enabled learning, the latter is often subsumed in the former. For instance, while preparing a excursion report for a science expedition, the student will also learn text (and perhaps image) editing skills. Instead of a computer faculty teaching text editing software in a de-contextualized manner, the science teacher teaching the text and image editing applications during the process of preparing the study report will make it a meaningful activity. Similarly, audio and video resources are important components of language teaching-learning and the language teacher could teach audio and video editing tools, as a part of language resources making and language teaching.

8.3.1 Scenarios

Based on the assumptions made, the investments required for the program have been computed. Three different scenarios have been considered (see table in the workbook), each providing for a different level of investment in the ICT infrastructure (other elements remain the same)

1. Scenario 1 – Schools with basic readiness for the program (level 1) will be provided 3, 10 and 20 devices, on an average, respectively, for each lower primary school, higher primary school and high school
2. Schools with basic readiness for the program (level 1) – with provision of 3 and 20 devices on an average, respectively, for each lower primary school and non lower primary school
3. Schools in advanced state of readiness (level 2), these would have more complex and hybrid set of devices.

The investments required for each of these three scenarios is provided in the work book.Only scenario 1 costs are taken in this report.

8.3.2 Initial and recurring costs

Apart from the initial set-up costs, the lab will need support for recurring operating costs including towards electricity, internet connectivity, hardware maintenance and consumables. This can vary widely from state to

9 Karnataka and Telangana are also adopting this approach

state and from time to time. ICT infrastructure is relatively fragile and hence replacement of hardware items needs to be also planned on an ongoing basis. This will avoid the situation, prevalent currently, where hardware is fully bulk procured at a point in time, not renewed and hence becomes fully obsolete or unworkable at the same point in time in the future, necessitating large investment at a point in time. By providing for regular replacement and renewal, this activity becomes an ongoing activity, with support from government funding or alternate public / private funding support, or through fresh purchases. *The investment computations assumes renewal costs at 20 %* [10] *of the initial investment costs.*

In the Kerala IT@Schools program, where the ICT lab was under the custody of the school (and not the vendor, which is the case with the BOOT model adopted elsewhere), the head teachers and teachers in many schools attempted to replace/renew the computers in the lab, through support/donations from the community and other available public and private funds. Ownership of the lab can be a motivator to the school, to keep the lab functional. If the ownership is outsourced to a private business entity, such motivation would not be there, and the private business would not encourage such additions since it would add to its operating costs.

Annual Maintenance Contracts (AMC) and insurance are other potential recurring costs. Again, the overall cost-benefit of outsourcing this to vendors versus absorbing the costs (given the large scale of implementation) needs to be considered, the latter may be beneficial in a centralized implementation. In a decentralized implementation, the decision should be made by the school (they should have the required data and guidelines to make an informed choice). Decentralisation can enhance the accountability of the vendor to the school, in a centralized program, the warranty/AMC remains on paper since the school is not interested in, or unable to enforce it against the vendor, whose primary accountability is to the state level authorities.

Cost estimate for this component
The annual recurring expenditure of the ICT labs in all schools and government support institutions is expected to be close to 19,000 crores

8.4 ICT infrastructure in school support institutions

Every teacher education institution requires an ICT lab to support ICT integrated teacher education. It is important to envisage the use of ICT in all teacher education programs, not only in ICT teacher training. In every teacher training program, there must be access to an ICT Lab for teachers and teacher educators to use, for activities connected to the training itself (accessing resources, interacting with one another during the program, writing and submitting assignments digitally etc.). ***The investment computation assumes each institutional ICT lab will, on an average, have 20 desktops/ laptops, similar to that of a high school.*** This is considered as the minimum required.

There is a need to also integrate ICT across teacher education system, so that educators working in teacher education institutions are able to use ICT meaningfully in pre-service and in-service teacher education. Making available a functioning ICT Lab in every teacher education institution can support the integration of ICT in both pre-service and in-service teacher education. In Karnataka and in Telangana, this has been done through the regular in-service teacher education program (RMSA) of the government.

ICT also has an huge potential in strengthening education administration, by improving efficiencies as well as transparency and participation in the management of the system at school to state levels. Hence, there is a need to provide a personal digital device to each teacher, teacher educator and education administrator. Providing a personal device is necessary to allow the person to create and store digital materials/content and use this subsequently, as a personal digital library. The provision of a personal device also allows for use whenever required. Teacher educators should be encouraged (through interest free loans) to purchase their own laptops / devices (BYOD), which they could use for their own professional development as well as in teaching and

10 Assuming a five-year life for an asset, on an average.

teacher support. **This should be seen as a higher priority than distributing laptops to students.**

Cost estimate for this component
The initial establishment of the ICT labs in all schools and government support institutions is expected to be around 9,000 crores. This is less than 10% of the total ICT infrastructure investment cost and hence should be prioritised. Education departments have prioritised school ICT infrastructure over ICT infrastructure in teacher support institutions, but this needs to be reversed.

8.5 Teacher training and capacity building

While success of ICT implementation will depend on many inter-related factors (provision of ICT infrastructure, basic infrastructure, teacher preparation and curriculum), perhaps the most important of all is teacher preparation. Without the required teacher preparation, providing infrastructure or specifying ICT integration through the syllabus would not be effective. However, the weakest component of ICT implementation in school education, has been the inadequate and sometimes irrelevant preparation of teachers to understand the use of ICT for their own professional development and for use in teaching.

One problem with past teacher training has been a predominant focus on teaching the use of few popular proprietary software applications. Instead, the program needs to focus on understanding the nature of the ICT (digital literacy[11]), use of subject teaching related software tools, accessing web resources, encouraging teachers to create digital resources using a wide variety of (free and open source) authoring tools etc.

Secondly, as world becomes more complex, teacher education needs to prepare the teacher and the learner to be capable of adapting to new environments and tackle new challenges. Being able to develop one's capabilities is much more important than content knowledge, and the focus of ICT integration for TPD should focus on capability development and not merely on sharing or supplying digital content.

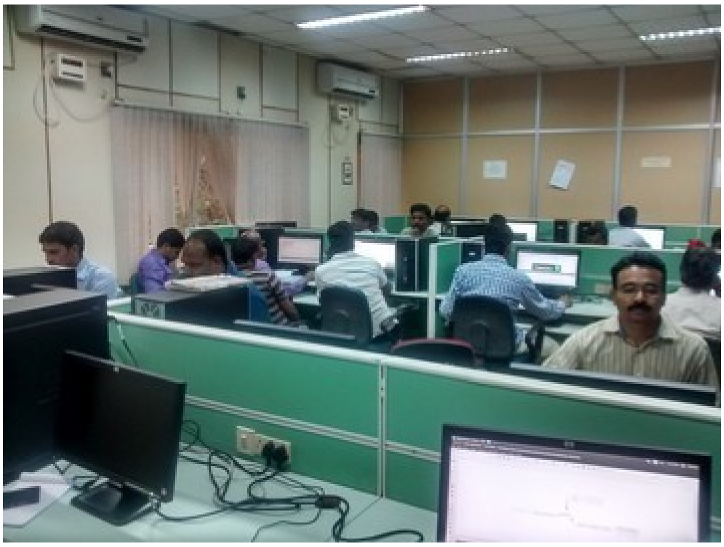

Illustration 3: Professional Learning Community building - Teachers workshop in Telangana

A universal program of teacher education on these aspects would empower teachers to become comfortable and competent in using ICT for their own development, creation of digital resources and in subject teaching. Hence, it is necessary to envisage this training as a part of the regular in-service teacher education program for all teachers, and not as a stand-alone effort.

All state governments prepare their teacher education plans for the next academic year, with budgetary support from the state government along with that of the central government through the SSA and RMSA programs. Digital literacy could be subsumed as part of the content (subject) and pedagogy related teacher education planned for the teachers.

This has been attempted by the Subject Teacher Forum program of Karnataka, where IT for Change was the resource institution, designing and implementing the teacher education program for government high school teachers along with the Karnataka RMSA and SCERT. The program requires ICT Labs availability at state,

11 Critical understanding of ICT is very important, teachers have to go beyond the hype of ICT and understand that as a powerful tool, ICT can cause great harm as well, if not used appropriately. What to do and when and how, and when to advocate against ICT, is important part of digital literacy

district, and (where necessary) at block levels for conducting the teacher education workshops. The section on 'School support institutions' discusses this requirement.

The National ICT Curriculum, prepared by NCERT provides a program for TPD, consisting of face-to-face interactions in workshops, complemented with on-line / virtual refreshers. The content of this document should inform the TPD design, though it may require to be contextualized by each state.

Apart from the hard infrastructure, structural arrangements need to be created in the teacher education institutions, from the state level SCERTs to the regional level IASEs and CTEs, district level DIETs and block level Resource Centres, to designate teams/faculty who will have the responsibility of co-ordinating these in-house ICT integration capacity building programs[12].

Since the program requires a 1:1 access by teachers to devices to be effective, the number of teachers who can participate in this program would be limited to the number of devices in the lab. This is likely to require a phasing of the teacher education program, focusing on groups of teachers in different years[13].

Such a program can create 'professional learning communities' of teachers, who can continue to be contact with their peers and their faculty for their continuing professional development. This 'connecting to learn' has been emphasized in the NCERT National ICT Curriculum as an important application of ICT in education. These communities will learn to use digital tools for networking to share and peer-learn from one another. The teachers will also learn free and open source educational applications and generic resource creation applications for use in their teaching.

8.5.1 Supporting the teacher

It is sometimes envisaged that ICT can replace the teacher in the school and address teacher shortages. However, this perspective confuses sharing information (in whatever interactive manner), with teaching. A good teacher can never be replaced by any device, since good teaching requires sensitivity to the context of each learner, her/his learning levels, needs, aspirations. As per the concept of 'social constructivism', learning is a social process, a good teacher facilitates complex interactions amongst learners in a classroom, to enable all learners to move towards the outer limits of their 'zone of proximal development[14]'.

A teacher who relies on content transmission could perhaps be replaced by a computer, but quality education requires us to move from content transmission/consumption to meaning making. This is a complex process which requires good teaching. Hence the ICT program must not make a mistaken assumption that schools that lack teachers should be provided labs, teachers must come first.

8.5.2 Complementing the 'workshop' mode of TPD

Teacher professional development is a life-long journey. While workshops are a good method of building teachers capacities, these pull teachers out of their regular work in their schools. A second challenge in teacher development is the lack of continued support. It is possible to integrate ICTs for 'connecting and learning' and introducing on-line courses for TPD which complement workshop based learning. The advantages of use of ICT include:

1. Continuous learning possibilities without disruption caused by travel. The learning can be a series of physical interactions in workshops, interspersed with on-site work by teachers in their schools with readings and virtual interactions. This 'blended learning' over a longer time period can provide more meaningful

12 The 12th plan for teacher education discusses the organizational restructuring of the DIETs and other teacher education institutions, including to cater to this requirement.

13 Refer http://karnatakaeducation.org.in/KOER/en/index.php/Subject_Teacher_Forum for details about planning and implementing such a program

14 Both social constructivism and zone of proximal development concepts owe to the Education psychologist Vygotsky

learning opportunities than point in time workshops, that have limited or no planned prior and post learning activities

2. Possibilities of learning beyond geographic restrictions, allowing for large scale reach and impact
3. Courses can be structured in collaboration with pre-service teacher education institutions, thus connecting teacher and teacher educator communities and institutions
4. Teachers can opt for courses based on their need and interests

MHRD is offering courses for teachers and teacher educators through its 'swayam' MOOC portal. While initially, blended or e-learning courses would be designed and transacted from the state SCERT, over time, DIETs, CTEs and IASEs should develop capacities to offer such courses to the teachers who they serve. This would help make TPD more contextually relevant. These institutions can also use e-learning platforms for their pre-service teacher education programs as well[15].

Another important way by which ICT integration can support TPD, is to have workshops/ teacher education programs focused on the collaborative creation of OER by teachers and teacher educators (on the lines of the Karnataka Open Educational Resources program, which was part of the Subject Teacher Forum program of RMSA and DSERT Karnataka). In this program, teachers can also take up translations / re-purposing of materials in English language, to their local languages and contexts. Since this is done digitally and shared on-line, it is immediately available to a larger audience. It is also possible to refine the translations with feedback from teachers, this can be a continuous process, in contrast to the infrequent printing of text materials. In this way the training processes can help teachers not think of themselves only as 'users', but see themselves as 'co-creators'.

Webinars can mirror traditional seminars and conferences for allowing small groups of interested teachers to come together with facilitators.

These are relatively advanced methods of TPD and should be taken up after a basic immersion in digital literacy has been completed for the teacher population in a state.

Thus, ICT should not be seen as 'one item' in TPD, rather ICT should be seen as a method to reform and strengthen pre-service and in-service teacher education. Along with acquiring digital literacy, teachers should see ICT as a method to improve their content and pedagogical knowledge.

8.5.3 Pre-service teacher education

The NCERT National ICT Curriculum should be introduced in all pre-service teacher education programs. Based on this curriculum, syllabi and source books are available, these have been prepared for Karnataka Diploma in Elementary Education program, Bachelors of Education program of Bengaluru University by IT for Change. Since these are released as OER, they can be adapted for other courses, by other institutions.

8.5.4 Assumptions relating to TPD

For an extensive ICT integration in teacher education, functioning ICT Labs are essential in all teacher education institutions where teacher training is conducted. Secondly, along with the processes of TPD, curricular resources (including student text books, teacher hand books, work books etc) need to be developed to support ICT integration in TPD and in classroom teaching.

Cost estimate for this component
The investment in teacher preparation for ICT integration is expected to be less than 4,500 crores in the first year, for 10 days face to face training per teacher. Subsequent years, the face to face component can be reduced to 5, which can reduce the investment to less than 2,250 crores.

15 An example is the Bachelors of Education program of Vijaya Teachers College, Bengaluru

The supplementing of this face to face teacher preparation with virtual modes (blended learning) will not require additional funding, as this should be done through the existing teacher education institutions and faculty. The preparation of the teacher educators to take on these new roles is also part of this component

8.5.5 Phasing of TPD

The investment in TPD can also be done in a phased manner. Teachers who are from schools where the ICT lab is active / has been provided can be part of the TPD program first. Secondly, like in the case of schools, teachers can be invited to apply for participating in the TPD program. Thirdly, teachers from high schools and higher primary schools can be considered before teachers from lower primary schools, the latter provide 30% of the total teacher population.

8.6 Content and curriculum

8.6.1 Development of digital resources (Open Educational Resources)

After teacher professional development, the area in which ICT can make a significant difference is in the creation, revision and sharing of digital curricular content. The marginal costs of sharing digital content is negligible. A large number of digital tools are available to create digital resources, in text, image, animation, audio and video formats. Moving beyond the 'text book' to include additional formats of resources can create a rich learning environment, in which teachers have a wealth of materials to chose from, based on their needs and priorities. Teachers also need a common space where they can access resources for their classroom teaching, and also for TPD.

The size of the public education system in most states could help to create a sufficient volume of interaction in the professional learning communities. The networking of teachers using digital technologies can make the large size of the system as a strength, as the large number of teachers participating in the network could be a benefit in terms of the volume of resources created and shared by them. Even if only a very small percentage of teachers from the public education system participate, in absolute numbers, it is likely to be large enough to provide a base for OER creation.

It is necessary to license all these digital resources as 'open educational resources' (OER), since that would enable the resources to be freely re-used, revised and re-distributed. This also needs to be formalized through state curricular policy, by which all materials developed using public funding would be released as OER[16].

In Karnataka, teachers have collaborated to develop open educational resources for their text book topics and published these on the KOER Portal, which has over 7000 web resource pages and 5,000 files.

In a case study that he carried out on the STF-KOER program, as a part of a Wawasan Open University project, Rajaram Sharma (Vignettes of Selected Asian Experience. WOU Press. 2016. Edited by G. Dhanarajan, page 65) states: "The exposure to the free and open source software applications has introduced teachers to a variety of resource formats, enabling their movement from the common "power point presentations" to mind maps (using Freemind), interactive simulations (using Geogebra), text and presentations (using Libre Office), web links and video files (using RecordmyDesktop)."

E-content in local languages can reduce the disparity between resources in English and Indian languages and greater availability of local language and contextual content can support equitable quality of education. This

16 NCERT has provided an exemplar, releasing the digital resources created by CIET, on the NROER platform. NCERT has also invited institutions to submit content created by their members as OER on the NROER platform.

will require the establishment and maintenance of state and central OER repositories (such as NROER of NCERT, which was launched in 2013 or Deeksha of NCTE). In many states, people living in the border regions speak the main language spoken in the neighboring states. There is a potential to seek and share resources of those languages with the neighboring states, to increase the availability of e-content. Teachers can be encouraged to translate / trans-create existing OER into their languages. This process was not easily possible with the text resource environment, but the digital environment can facilitate collaborative creation, sharing and publishing. This can create a virtuous circle of e-content and cause an exponential increase in availability.

The OER should not be restricted to the area of ICT integration in education, it should cover all curriculum design and development. The processes of syllabus, text book, hand book design and development can be made more open and participatory through using ICT, by allowing for feedback from people who are not part of the core group entrusted with the activity. Thus, all text books can become 'e-books', containing image, animation, audio, video resources along with text. It will be possible to create bi-lingual and multi-lingual versions of these books digitally and make it available, to support learning in different languages.

The OER repository will need regular maintenance both from user-content and technology perspectives. The former could be catered to by virtual groups of teachers/teacher educators for each subject area. The latter will need to be developed from within the technology team in the education system.

The resource repository will only mature over time, with feedback from teachers, teacher educators and education experts to result in contextualized good quality resources. The state repositories should link up with National Repository of OER (NROER) and with one another for accessing and sharing OER. States should collaborate on multi-lingual OER creation, covering languages spoken in both states, to alleviate the requirement of curricular resources in 'minority' languages.

8.6.2 Assumptions relating to curriculum

Content created by teachers can be of varying quality, there is a need for a group of experts / mentors who can work with the teachers to improve the quality of the OER before it is published on the OER repository.

8.7 Educational administration and State platforms

ICT infrastructure is required at the education administration institutions to enable the administrative and management activities to be performed using ICT. Applications for managing school infrastructure, school support programs/schemes are already in use in many states. Currently, data is collected from the field level, digitized and processed for decision-making at central levels. ***A federated use of this data could support decision-making at all levels, and support decentralization.*** It must be noted that ICT implementation in transnational corporations, many larger than state governments (in terms of personnel, budgets etc.) have managed to use ICT to support decentralized decision-making, suitable to

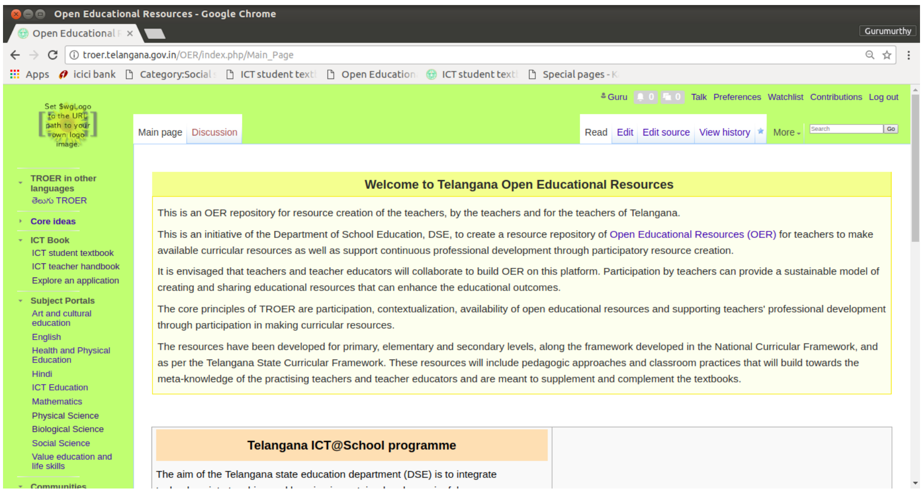

Illustration 4: TROER - Telangana Repository of OER

local and diverse contexts, within norms centrally established. Similarly, within policies laid from the centre/state levels, actual implementation could be afforded maximum leeway, within these norms, to cater to diverse needs. This can avoid the 'one-size-fits-all' program design and implementation that can characterize many government schemes.

Each state must develop its OER portal. It must also have its e-learning course platform, from which it can offer courses for teachers and teacher educators (this could also be done in partnerships with universities). Telangana has developed its state OER portal (http://TROER.telangana.gov.in) on which it intends to make available all the curricular resources created (in digital format) by the education department and by teachers and teacher educators.

Cost estimate for this component
There is no specific cost taken for the curricular resources component, as this will be part of the regular mandate of the SCERT, DIET/CTE institutions.
The development of the state OER portals and platforms, is expected to entail an investment of Rs 10 crores. The regular maintenance of these platforms and the costs of the Technology teams/units at Central and State levels is expected to cost another Rs 20 crores every year.

8.8 Research and documentation

There is limited research in India on the role of technology in teacher education and its use in classrooms. Often technology choices are made based on inadequate understanding and this leads to sub-optimal outcomes. There is also a danger from vendor-sponsored motivated research in this area. Hence, there is a need for rigorous research and documentation, of program design, implementation processes and outcomes, to identify strengths as well as limitations, analyse programmatic outcomes, and provide a basis for refining and maturing the models.

The areas of research would include classroom integration of digital technologies, development of open educational resources, assessment of student learning, teacher academic support and school institutional development. The research would also need to explore new free and open technologies and tools and the manner in which these could be integrated for addressing new requirements and challenges in education and for achieving education system aims and priorities. This component should be a part of the regular education research budgets of different institutions.

Cost estimate for this component
There is no specific cost taken for the research component, as this will be part of the regular mandate of the SCERT, DIET/CTE institutions.

8.9 Ecosystem of ICT integration

One reason for failure of ICT integration in school education has been the piece-meal nature of such efforts. Providing ICT infrastructure to schools, partial automation of administrative processes have been given more importance. However, all four components as discussed in this note, have to fall in place for an eco-system of ICT integration to emerge and sustain.

Four important components of ICT integration in school education	
Provision of ICT Infrastructure in schools, and institutions for teacher education and education administration	Professional Development of teacher and teacher educators, and building of professional learning communities
Development of curricular resources (for students and teachers), as 'Open Educational Resources'(OER)	Building state level infrastructure to facilitate ICT integration, including OER repository, platform for blended / e-learning courses

Secondly, it is necessary for the education system to develop teams at state, district and block levels to support these four components. Some teams would need to be dedicated, such as the state technology support team, but other teams could comprise teachers who can work part-time through virtual networks, such as OER district resource groups, contributing to the state OER portal. The responsibility of coordinating these groups could be the teacher education institutions. In Kerala, even the maintenance of school hardware is supported by teachers-members of 'mobile hardware clinics'.

Research on identifying relevant ICT tools and methods for education, could be subsumed as part of the research expected to be undertaken within school education.

9 Costs

The costs for the program have been provided in the section for each component. The details of these are computed in a spreadsheet, separately provided, based on the scope and assumptions made in this document.

The first sheet provides the summary of the budgetary requirements for establishing ICT Labs in schools and other institutions in the Indian education system including at the cluster, block, district, state and national levels, recurring annual costs for maintaining and renewing the infrastructure, TPD, Research and State infrastructure. The second sheet provides similar details for Karnataka state. The third sheet provides the details of the ICT lab infrastructure, the fourth sheet discusses the investment in teacher professional development (based on the data available regarding number of teachers in schools, teacher educators in TE institutions, costs per day, number of workshop training days per year, for the initial year and subsequent years) and the fifth, the state level investments for the state portal and state technology support teams.

10 Technology platforms (illustrative)

This note refers to different ICT application areas, that will be required for the program. These are listed in the table below as an illustration. The actual choice of the tools and platforms may vary from site to site, considering local contexts, priorities and aims. However, as a principle, the preference should be for free and open source (public) software, so that it can easily be shared across locations, teachers and students, and also enable maintenance of these tools to be provided by any vendor or community, without lock-in.

Area	Tool / platform
Desktop / Laptop operating system	GNU/Linux
Tablet / Mobile phone	Android
School server	Being developed by CIET
Course platform	Moodle
Mailing lists	Mailman
OER repository (internal)	MediaWiki
OER repository (external)	Youtube (Videos), Wikimedia Commons (Images)

11 About IT for Change

IT for Change (ITfC) is an NGO located in Bangalore, India, that works for an innovative and effective use of information and communication technologies (ICT) to promote socio-economic change. ITfC works at global, national and local levels in programs relating to research, advocacy and field projects in the substantive areas of education, governance, gender, community informatics, internet governance and social policy across the technology governance and community informatics domains.

ITfC believes that a critical perspective is essential in understanding the impact of ICT on society and equity and social justice must underpin its appropriation. The research and field projects of ITfC aim to understand the dangers and challenges that ICT pose to society and deliberate on designs that can support the realisation of a just, equitable and democratic information society. In the area of education, this has meant working on ICT programs that support school autonomy, teacher agency as well as participatory and constructivist learning approaches.

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13 Annexure A – Investment computations

This is separately provided in a workbook.

14 Annexure B – ICT Lab possibilities

Device type	**Cost**	**Affordances for participation / creation**	**Form factor**	**Power consumption**	**Dimensions / weight**
Desktops	Costlier than tablets and mobile phones	Allows for learners to participate as creators, due to form factor	Largest of all devices. Easy to work with	Needs uninterrupted power supply and power backup.	Bulkiest of all devices. There are models, with small enough CPU to fit to the back of the monitor
Thin client	Cheaper than desktop and laptop, and even tablet and mobile phone	Comparatively, lesser than desktop due to lower processing power. But better than tablet or mobile phone due to form factor	Similar to desktop	Power requirement lesser than desktop.	Similar to desktop
Laptops	Similar cost to desktop	Similar to desktop, can be moved from one location to another	Similar to desktop	In-built battery makes it more robust to power outages	Lighter than desktop
Tablets	Lower than desktops and laptops	More an access device than a participation device, due to lower processing power	Screen smaller than that of desktop monitor but larger than a Mobile phone	In-built battery makes it more robust. Requires lesser electricity	Easy to move around. Smaller than desktop and laptop and larger than a mobile phone
Mobile phones	Lowest	More an access device than a participation device	Smallest of all devices	In-built battery. Least requirement for electricity	Smallest. Easiest to move around.

Desktop computers are dust prone, consume more power, have many parts – so cleaning, space requirements are more and present more failure points. Laptops have in-built web-camera, WiFi as well, but are less rugged due to miniature components.

Server (as an alternative option, which is more feature rich*)

Aspect	Features
Physical dimensions to be portable	275 mm x 175 mm x 100 mm (approx) Rugged body that handles drops, dust, and weather
Cooling arrangements	At least two fans mounted on grills on two opposite sides, to aid cross-ventilation
School ready 'boxed'	Minimum 8 hour battery life in Full Power Mode, 32 GB of on-board RAM (Upgradable to 64GB), at

hardware	least i7-8th Gen Processor or its equivalent.
Storage	At least 2 TB of internal hard disk drive and 4 TB of backup external hard drive
Network / communication capabilities	802.11 b/g/n Wireless, 10/100Mbps WAN/LAN Port. WiFi Bridge and Client modes , WPA/WPA2 PSK, WPA Enterprise, and WEP Encryption. External GSM Antenna Port . Support for 2.4GHz networks, ADSL+ Router-Modem Support for 8 Ethernet ports (switch capability),
Network & System monitoring capabilities	Ability to handle 30-40 concurrent connections, management of connections and multiple devices per account . Standard preloaded configurations Monitoring and management of - Network Settings, Power, Uptime, Bandwidth, Expansion Port Logging.
Expansion I/O	32K Flash . 20 General Purpose I/O Pins . 8 x Analog to Digital I/O 2 x 5V 500ma Power output. External USB-host port on GPIO expander. Standard Power input, standardized connector with open-hardware pinout. Realtime clock
Port requirements	RJ45 Ethernet LAN/WAN Port for backward compatibility. Easy Change SIM Card Slot. RP-SMA External Antenna Connection for 3G/4G antennas
Power requirements	Ability to handle 180V – 320 V. 4-18V power iUSB Host Port, with mobile device charging capacity. Input for the server system MicroUSB and GPIO expander power inputs. BCS 1.2 Compliant Charging input

* Note – in the budget, we have provided for a server that can cater to the schools' requirements. However, it does not capure the latest advances in hardware. For schools that are keen to adopt more sophisticated hardware, the above table can be relevant. Apart from higher costs, latest hardware may have a higher rate of failure compared to more mature hardware products.