1. Introduction

Emphasis on Universal Primary Education

The second Millennium Development Goal (MDG) adopted by the Millennium Summit of the United Nations in the year 2000 aimed at achieving universal primary education by 2015. Governments across the world have since intensified their efforts to get more children to school. As a result of these efforts global primary school net enrolment ratio is estimated to have reached 93% in 2015 with highest absolute increase over last 15 years reported from sub-Saharan Africa and South and West Asia (UNESCO, 2015). In India, enrolment rate among 6 to 14 year-olds has been over 96% for the past five years (ASER, 2017).

Quality of Education

However, teaching quality and school infrastructure have not kept pace with this increase. School education systems in many developing countries remain fraught with multiple inadequacies like non-availability physical infrastructure, lack of adequately trained teachers, and rampant teacher absenteeism. Chaudhury, Hammer, Kremer, Muralidharan, and Rogers (2006) report up to 25% absenteeism among teachers in government-run schools in India and further point out that, only 45% of teachers assigned to schools were teaching at any given point. These inadequacies in the education system are reflected in the below par reading and arithmetic skills of children in primary schools as reported by recent surveys in many developing countries. UNESCO (2015) reports several such studies from Africa and Latin America with a low quality of education in schools. In India, 25% of children enrolled in grade 8 could not read at grade 2 level, and 55% could not do simple tasks of division (ASER, 2017). In a developing country, the socio-economically disadvantaged sections of the society depend heavily on government

services for education and health and hence have to bear the brunt of these inadequacies.

Technology Use as a Solution

Over the last decade or so there is a growing expectation that Information and Communication Technology (ICT) can be used in a big way to solve development problems, primary among them being literacy and poor quality of education. The UNSECO envisages ICT to be one of the key components in its strategy to achieve the Sustainable Development Goal of Education (World Education Forum, UNESCO, 2015). UNESCO believes that ". . . ICT can contribute to achieving universal education worldwide." (UNESCO, 2016). The World Bank too recognises the need for use of ICT in achieving education goals. "Vast majority of active World Bank education projects contain an ICT component. Support for ICT in education includes assistance for equipment and facilities; teacher training and support; capacity building; educational content; distance learning; digital literacy; policy development; monitoring and evaluation; and media outreach." (World Bank, 2016) The Systems Approach for Better Education Results (SABER) initiative of the World Bank envisages use of ICT in evaluation and monitoring of education systems in order to improve quality of education. With clear direction and initiative coming from multilateral agencies such as World Bank and UNESCO, there is a significant increase in emphasis in various developing countries including India to adopt ICT in education delivery and monitoring. In India, the Tenth Plan (2002-2007) allocated Rs. 800 crores towards use of ICT in education. The Eleventh Plan (2007-2012) increased this amount to Rs. 5000 crores. The Twelfth Plan (2012-2017) integrates the scheme under the broad umbrella of Rashtriya Madhyamik Shiksha Abhiyan (RMSA) to facilitate better utilisation of resources with a total allocation of Rs. 27,400 crores.

Apart from this, large private sector players in development and distribution of online education content such as Coursera and EdX have announced plans to enter the school education segment with Massive Online Open Courses (MOOC) offerings. This is in addition to a plethora of content being developed and distributed by the government which is tailor-made for specific curriculum. This would require massive investment of resources. Industry estimates of global e-learning market size in 2011 was USD 35.6 billion and is estimated to reach USD 51.5 billion

by 2016. A major part of this growth is expected from Asia and Eastern Europe which are expected to grow at a CAGR of more than 15%. School education (K-12) segment is expected to contribute to about 50% of this growth (Docebo, 2014).

ICT Use in School Education in India

In the context of a large and developing country like India, there are several problems in promoting use of ICT in schools. Some of these include geographical remoteness and absence of last mile connectivity, lack of adequate infrastructure, lack of trained manpower at village levels, technophobia, and lack of initiative and innovation on part of school managements and teachers. This is especially so in case of government schools which increasingly serve the economically and socially disadvantaged sections of the society. In Academic Year (AY) 2014-15 a mere 26.42% of schools had a computer (U-DISE, 2016). In AY 2015-16 this number increased to 27.31% (U-DISE, 2016) - an indicator of the pace at which the program for introducing computers in schools is progressing in the country. Even where physical infrastructure and connectivity is provided by the government, it is a huge challenge to retrain teachers in adoption of new pedagogical techniques to suit technology-aided teaching. India has 8.5 million teachers. Karnataka alone has more than 400,000 teachers (U-DISE, 2016). The average in-service training given to teachers in Karnataka in AY 2013-14 was 2.16 days - an indicator of the capacity of providing in-service training in the State (U-DISE, 2016).

Research Gap

Despite huge investments in ICT in school education mentioned above, it is seen that research on impact of ICT on student learning outcomes shows mixed results. A review by Cuban and Kirkpatrick (1998) of research conducted in three decades before 1998 concludes that the evidence on the benefits of computers in education is inconclusive. After nearly two decades, a more recent review by Bulman and Fairlie (2016) reaches a similar conclusion. A re-reading of papers reviewed by Bulman and Fairlie (2016) points to some commonalities in projects that have shown positive and significant results. These include a low student-to-computer ratio and a substantial change in pedagogy and classroom practices, thereby requiring major retraining of teachers. These aspects make the research designs unsuitable for developing countries. In

addition to this, most research designs are implemented on a very small set of schools, typically less than 50 schools in intervention group, and implemented by a dedicated team of volunteers or research assistants. As such the generalisability of findings from these studies remains a matter of concern (Muralidharan & Niehaus, 2016).

An important aspect of research designs that use ICT for education is that the students interface directly with the computer software often leaving the teacher out of the teaching-learning transaction (Campuzano, Dynarski, Agodini, & Rall, 2009; Lai et al., 2013; Linden, 2008; Shapley, Sheehan, Maloney, & Caranikas-Walker, 2009). This largely relies on the constructivist approach to learning wherein the students are encouraged to take charge of their own learning and explore their field of interest either on their own or in groups (Hung, 2001; Schunk, 1996). The teacher plays a role of a facilitator or a "scaffolding" (Biesta, 2013). Interestingly, there is a parallel literature that looks at the attitudes of teachers towards technology adoption. This literature largely recognises the central role of teachers in the teaching-learning process with technology as merely aiding the teacher. In such a scenario the manner in which the teacher perceives technology becomes critical. So far the literature on teachers' attitudes to technology has predominantly concluded that the teachers are mostly resistant to use of technology. The literature so far has primarily looked at this as unwillingness to change, and, to use a phrase by Achinstein and Ogawa (2006), a form of "psychological deficiency". The second part of this research investigates teachers perceptions about use of technology in school education. The research asks if teachers think technology in school is capability enhancing, and what are the socio-political and institutional factors that shape their perceptions.

Research Questions

This research is divided in two parts. The first part is quantitative in nature and attempts to measure the impact of a technology based intervention in school education that takes into account the ground realities of infrastructure availability in school education in a developing country context, on student learning outcomes. The research questions for this part of the study are as follows -

1. What is the impact of a technology based intervention with low student-computer ratios

on student learning outcomes?

2. What is the impact of a technology based intervention with minimal requirements of prior retraining of teachers on student learning outcomes?

3. What is the impact of a technology based intervention on student learning outcomes when implemented at a large scale?

To answer these questions, an intervention is designed that is characterised by low student-computer ratio, and low prior retraining of teachers and implement it at a scale comparable to some of the government sponsored programs. The impact of this intervention on student learning outcomes is tested. The intervention design, however, gives us only a joint answer to all the above questions. The research design is not able answer each of the above questions individually.

In the second part of this study focuses on teachers' perception of use of technology in school education and various factors that determine this perception. The research questions for this part of the study are as follows -

1. How does use of technology in classrooms affect capabilities of teachers?

2. What are various factors that constrain or enable achievement of these capabilities?

Research Design and Methodology

The first part of the study which is quantitative in nature is designed as a randomised control trial (RCT). An intervention is designed that uses technology to deliver better quality education through lectures delivered by expert teachers using multimedia animations and transmitted using VSAT technology. This intervention is conducted as a Public-Private-Partnership between IIM-B led consortium of private sector service providers and DSERT.

This RCT is conducted on a large scale in 1823 randomly selected schools across 18 districts in the state of Karnataka, India. The design identifies 1000 schools for intervention and another set of 823 schools for comparison with randomisation done at the subdistrict level. The intervention began in November 2014 and continued in the academic year 2015-16.[1] The in-

[1]The school year in Karnataka begins in the month of June and the lectures end in the month of February.

tervention uses technology assisted teaching to replace one-third of in-school instructional time for English grammar, Math, and Science and is targeted at students from grades 5 to 10 in rural public schools. These are the subjects that students typically find difficult and do not score well in the SSLC exams. It combines computers and broadband / cellular connectivity with more conventional satellite technology to deliver classes taught by expert teachers at a central location using multimedia teaching aids. These lectures cover the standard syllabus prescribed for all schools in the state by the State Department of Education. Students from each grade get to watch two lectures each of English, Maths and Science per week. Each lecture is of 40 minutes duration and includes a 10 minute interaction session at the end of the lecture. During this session students can use the mobile telephone provided under the project to each school to call expert teachers and ask questions pertaining to the topic covered in the session. This call takes place either over broadband or cellular network as per availability in respective school.

The intervention requires one computer per school, which for the schools in the State translates to a student-to-computer ratio of 135:1, and is similar to what is observed in most developing countries. While the intervention uses multimedia tools for teaching, the pedagogical adjustments and prior training requirements for the school teachers are kept at a minimum. This, along with a high student to computer ratio makes the program unique and easy to scale-up. The project design attempts to address some of the challenges typically faced by education administration in a developing country setting such as teacher absenteeism, low availability of computers and internet connectivity in schools, and challenges associated with change in pedagogy and retraining of teachers. It also attempts to offer a viable policy alternative keeping in mind the need for scalability.

For the first part of this study, the impact of intervention is evaluated using scores of students in pre and post tests conducted respectively at the beginning and the end of academic year 2015-16. These tests were conducted in both intervention and comparison schools for grades 8 to 10 for a sub-sample of 74 intervention and 69 comparison schools. The sub-sample was selected using a randomisation process similar to that followed for selection of the larger sample of 1000 intervention and 823 comparison schools. Separate tests were conducted for English grammar,

Year-end exams are conducted in the month of March. During April and May, schools are closed for vacation.

Math and Science based on the curriculum as prescribed by the state authority for all grades. The test scores are evaluated using a difference-in-difference (DID) method with controls for district and school characteristics, and errors clustered at taluk level. Attrition between pre and post tests is modelled using Heckman selection method.[2]

Most project designs that use technology in school education emphasise the use of self-tutoring software that takes over the role of human teacher. The intervention described above on the other hand, is aimed at enhancing the capabilities of the teacher by providing a readymade teaching aid that uses multimedia content. The intervention is used as an anchor to provoke teachers to think about their perceptions about technology use. Teachers' perception is seen through the Capabilities Approach (CA) (Sen, 1987, 1992, 2001) as operationalised by the Choice Framework (Kleine, 2011) within a broad ontology of structuration theory. The question asked is whether the project has brought in functionings that are perceived as valuable and hence adopted by the teachers thereby leading to enhancement of their capabilities. The research also also outlines some factors that act as enablers / disablers in adopting these functionings. A qualitative approach was adopted for this part of the study. An interpretive field study is conducted in 4 schools that are exposed to intervention in Mysuru district. In these schools regular and tele-education classes are observed, and in-depth interviews of teachers and headmasters / headmistresses (HMs) are conducted. This qualitative data is then analysed to answer the research questions.

Summary Findings

The intervention had a statistically significant positive impact on student learning outcomes ranging from 0.1σ to 0.17σ.[3] The results were more robust for classes 8 to 10 as compared to classes 5 to 7. The results remain robust even after adjusting for attrition. The intervention has had an equal impact for all students regardless of their pre-test scores. Further, the impact was higher in Science as compared to English and Mathematics. As mentioned earlier, the intervention design gives only a combined answer to the three quantitative research questions.

[2]Attrition in this study is defined as a student who has appeared for pre-test but has not appeared for post test. This may not necessarily be a result of student dropping out of the project or the school.

[3]For the purpose of this analysis all scores are standardised around mean and standard deviation of the comparison group at the baseline. The regression coefficients, therefore, are in terms of standard deviations and have an effect size interpretation which can then directly be compared across different studies.

We achieve this increase in learning outcomes at an estimated cost of USD 11.2 per student per year per one-tenth of standard deviation, as against another recent study in India conducted by Muralidharan et al. (2016) which reports a cost of USD 50 per student per year and the estimated cost incurred by government of Karnataka of USD 109 per student per year to achieve an effect size one-tenth of a standard deviation. The intervention design therefore offers real policy alternative by using resources more judiciously.

As regards the impact on capabilities of teachers, the teachers found the use of multimedia visuals in teaching to be the most useful addition to their capabilities. In addition to this, increase in student responsiveness in regular classes was also reported. However, excessive institutional emphasis on SSLC results and the Comprehensive and Continuous Evaluation (CCE) which required teachers evaluate large number of assignments claimed major part of time and efforts of the teachers.[4] This left teachers with little time to focus on improvement in teaching and class experience of students. In presence of these constraining factors, ICT projects that are lower on the determinism continuum are more likely to be successful.

Flow of Chapters

Rest of the thesis is organised as follows - Chapter two discusses the theoretical frameworks used for the research. The chapter dwells on some of the major literature on the research questions and identifies the research gap. Chapter three outlines the methodologies used for answering the research question. Chapter 4 gives details of the intervention carried out in order to answer the research questions. The intervention constitutes the major source of empirical data used in this research. Chapter five presents key results of for the first research question - i.e. impact of use of technology on student learning outcomes and chapter six presents findings for the second research question - i.e. capability enhancement of the teachers. Chapter 7 concludes.

[4]SSLC (Secondary School Leaving Certificate) exam is conducted by Karnataka Secondary Education Examination Board for all students completing 10 years of schooling in the schools following syllabus prescribed by the state government. The exam is mandatory for students who desire to pursue further formal education.