

# Learning While You Teach Project Report



Society for the Advancement of Education



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By

Society for the Advancement of Education (SAHE) & Institute of Development & Economic Alternatives (IDEAS)





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## The ‘Learning while you teach’ team

**Editorial & Writing:** Amal Aslam, Farooq Naseer, Javaeria Qureshi and Faisal Bari

**Research support:** Abdullah Ali Khan, Umer Naeem, Shahroz Panjwani, Mohammad Malick and Zohra Sohail

**Communications & field support:** Zeeshan Asghar, Yaseen Inayat and Masood Sadiq

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# Abbreviations

ANCOVA	Analysis of Covariance
CPD	Continuous Professional Development
DSD	Directorate of Staff Development
DTE	District Teacher Educator
HCF	Highest Common Factor
ICT	Information and Communication Technologies
IDEAS	Institute of Development and Economic Alternatives
LCM	Lowest Common Multiple
LWYT	Learning While You Teach
PD	Professional Development
PEC	Punjab Examination Commission
RCT	Randomized Controlled Trial
SAHE	Society for the Advancement of Education
SNG	Sub National Governance Programme



An abstract graphic design featuring a complex, overlapping pattern of blue and light blue geometric shapes, primarily squares and rectangles, arranged in a grid-like fashion that appears to recede into the distance, creating a sense of depth and perspective. The pattern is set against a white background.

# 1 Introduction

# Introduction

Teacher Professional Development (PD) activity is a regular feature of education systems around the world. Criticism is often leveled that teacher PD is a waste of valuable resources with little to show in terms of improved teacher knowledge and student learning outcomes. Teacher PD persists, however, because teachers are considered to be the single most crucial determinant of student learning and it remains one of the *more* feasible policy options for raising the quality of teaching and, therefore, of student learning outcomes. Teacher PD is essential in developing country contexts like Pakistan where the quality of teaching needs to be raised urgently and where improvements in pre-service teacher education programs and teacher recruitment policies and processes (that would allow for the recruitment of better teachers to begin with) have not kept pace. Moreover, there is still a significant proportion of teachers in Pakistan, especially teaching in the early grades, with little formal education. Concerns about knowledge deficits are graver for these older teachers who possess F.Sc/F.A. or other obsolete teaching certificate qualifications and will not retire from service for another 15–20 years at least. Examination and test results from Punjab Examination Commission (PEC) as well as from other sources like Annual Status of Education Report show: a) substantial gaps between the knowledge and understanding of students in a particular grade and what is expected of them given the learning objectives for that grade and b) systematic errors in student understanding allowing speculation that teachers find certain concepts harder to grasp.

The Directorate of Staff Development (DSD) in Punjab is responsible for training teachers both at the start of their careers (through the provision of induction training) as well as during their service tenures i.e. while they teach. The DSD conducts the latter through its cascaded Continuous

Professional Development (CPD) model that caters to the in-service training of its 350,000 primary school teachers in the public sector. Currently, the CPD model is based largely on a) getting teachers together at the district level, every quarter, for 1–2 days of training and b) getting teacher mentors known as District Teacher Educators (DTEs) to visit schools twice a month to monitor teachers and provide support to them<sup>1</sup>. Despite the CPD program, there are significant concerns about the lack of conceptual understanding of teachers and their knowledge of the subjects that they teach (i.e. content knowledge). The DSD acknowledges the conceptual and content knowledge deficiencies in a significant percentage of its teachers in Punjab.

There are some weaknesses in the design of the CPD program itself that hamper improvement of teacher knowledge and skills. The current setup of the CPD model does not allow a) sustained and intensive teacher PD at a high frequency, and b) standardization of quality as the current model depends on individual DTE knowledge and/or motivation. The challenge to ensure frequent teacher PD that is of good quality and standardized, across all 36 districts of the province, while taking into account the specific needs of teachers teaching different subjects and across all grades is considerable.

We proposed and piloted a PD model that utilizes technology to address these shortcomings. Research into impact of ICT-assisted teacher PD from other countries has shown mixed results so far (detailed in Section 2). However, there is a dearth of *rigorous* studies that look at the effects on teachers and the effectiveness of ICT tools in design and delivery of teacher training and support. ICT interventions could provide effective, affordable and scalable models for designing teacher training and PD programs.

<sup>1</sup> One of the DTE's school visits is an 'assessment' visit where the DTE administers a test to students to check learning levels. The second of the school visits is known as the 'mentoring' visit during which the DTE observes the teacher delivering a lesson and mentors the teacher. Our program made use of the latter visits.

The purpose of our program was to build upon and improve the DSD's existing CPD framework by piloting a technology-enabled process for delivering in-service teacher training that would ensure access to high-quality standardized, but context relevant, videos on mathematics loaded on tablets for teachers to watch. Our program sought to improve the content knowledge of teachers specifically and videos focused on addressing content knowledge deficits of teachers.

High quality learning material in audio and video formats is now widely available on the internet and is also being produced in-house in some cases in Pakistan. The material has to be made and/or adapted to suit particular curricula and then be delivered to teachers. Delivery to teachers can be done relatively cheaply, compared to physically relocating teachers for training which is difficult during the school year, through technological devices such as tablets, computers or even smart phones. Using tablets would, therefore, enable access to high quality digital education content to train teachers within schools, without requiring that they be physically present at some other training venue—this is also more convenient for female teachers who are less mobile due to prevalent socio-economic norms especially in rural areas of the country. Building upon the existing CPD model and making use of the processes, systems and personnel already in place was deliberate on our part and a key strength of our program as it had important implications for our program's sustainability and scale up.

We evaluated the impact of our PD program using a Randomized Controlled Trial (RCT) design wherein we randomly assigned 317 DTEs (and the 1740 teachers associated with them) from three districts of Punjab—Bahawalnagar, Hafizabad and Sahiwal<sup>2</sup>—into treatment and control groups<sup>3</sup> so that we could isolate the effect of the videos on teacher and student learning. 34% of teachers in our sample had only completed their intermediate or matriculation with younger teachers being more educated. 92% of DTEs in our sample had a Bachelor's degree or above. 56.2% of our teacher sample was female while 94.7% of DTEs were

male. Roughly the same percentage of teachers and DTEs (approximately half) had more than 15 years of teaching experience.

There were 158 DTEs and 837 teachers in the treatment group. Treatment DTEs, post training, were given tablets with videos on grade-4 mathematics topics to share with grade-4 mathematics teachers in their schools on their monthly mentoring visits during our four-month rollout from September–December 2015. There were, therefore, a total of four two-hour trainings delivered to teachers in our program. Teachers were exposed to the training content for a total of 8 – 10 hours in our program. Control DTEs continued to visit, monitor and mentor their teachers as previously.

Our program included baseline and endline surveys and tests for teachers as well as a test for students at the endline only. In the full treatment sample, we found a small, positive effect of the program on teacher content knowledge that was not statistically significant. Importantly, however, our study found positive impacts on content knowledge of teachers who had lower baseline scores and of teachers with less formal education within the treatment group. This group scored 2.7 percentage points higher on average on the endline math test as compared to teachers with similar qualifications in the control group. This evidence of significant effect on the knowledge of teachers who had the largest deficiencies at the start suggests that our program played an important remedial role. We also found that the impact on teacher test scores did not differ by the gender of DTEs or teachers<sup>4</sup>. In addition, the results did not show heterogeneity based on teacher or DTE experience or on personality characteristics of teachers such as openness and self-efficacy. Moreover, results did not differ for teachers who were tech-savvy (i.e. had either used or owned smart devices or computers before) and for teachers who were not. This is crucial considering technology was such an integral feature of our training model and that training videos could only be watched by accessing them through the software application on the tablets provided. The fact that our program

<sup>2</sup> These districts were selected as a result of two considerations a) they were on the list of six districts we could potentially choose from that had been provided to us by SNG and b) they were approved by DSD as fewer pilots and other projects were taking place here and so CPD personnel were not as burdened.

<sup>3</sup> Randomization was at the DTE level and not the school level. Baseline data on DTE, school, teacher and student characteristics, showed us that our random assignment was effective: there were no differences in the control and treatment group means.

<sup>4</sup> More than 50% of treatment teachers were female while 90% of treatment DTEs were male.

was equally effective for different sub-groups of beneficiaries is promising for future replication and scale up.

Punjab has been moving in the direction of introducing more technology, mainly in the form of hardware, in schools. Computer laboratories have been set up in most high schools and even some middle schools. Students are being given laptops. DTEs have been given tablets and there are even plans to eventually introduce tablets for teachers as well as students. Even in our sample, more than 20% of teachers already had smartphones of their own. Most teachers in our sample (62%) did not require any assistance in the use of tablets and were quite comfortable with the technology being used. Given this, it makes sense for the DSD to experiment with changes to the CPD model that utilize the potential for using ICT-assisted learning

for teachers.

The remedial effect on content knowledge of teachers despite low exposure to the training materials combined with the fact that impact did not vary based on teacher and DTE characteristics is encouraging. We believe the results would be even starker if tablets and videos were provided to teachers directly (we were unable to do this in our program due to cost issues) as it would increase time access for teachers, allowing them more exposure to internalize lessons and have more time for discussions. In the next iteration of our program, we also propose the provision of videos focused on building pedagogical skills (and not just content knowledge as was done in our intervention) to ensure that better content knowledge translates into better teaching practices and student learning.

An abstract background pattern consisting of various shades of blue (light, medium, and dark) and white. The pattern is composed of overlapping, semi-transparent rectangular and square shapes, some of which are slightly rotated, creating a complex, layered effect. The pattern is denser in the corners and fades towards the center.

# 2

## Literature Review

# Literature Review

In this section, we provide a broad overview of existing literature on the importance of teacher PD and its impact on teacher and student knowledge and skills particularly in the context of mathematics PD programs. We look at how technology is increasingly being utilized to improve the efficiency and effectiveness of teacher PD programs and chances of impact. We conclude with an elaboration of some of the most important features of effective teacher PD programs as identified in the literature in addition to a discussion of whether we were able to incorporate these features in our own program design.

## Professional Development of teachers: The rationale

PD programs for in-service teachers are a key feature of education systems around the globe even in contexts where good teacher recruitment policies and practices exist. A review by Darling-Hammond et al. (2010) concluded that high performing education systems made extensive PD mandatory for teachers. The support for teacher PD comes from the potential it has to improve student performance by equipping teachers with better knowledge, skills and teaching strategies. The promise that PD holds is that of ‘turning bad teachers into adequate teachers and good teachers into outstanding ones’ (Loveless, 2014). ‘Teachers are considered to have the largest single system-level impact on student achievement’ (Meissel et al., 2016) and, as a result, considerable resources are dedicated to teacher PD. According to Invargson et al. (2005) as investment in teacher PD is rising so is policy makers’ demand for research that identifies ‘features of effective professional learning’ to guide the design of PD programs and of evidence that shows actual impact on teaching quality and student learning (p.1).

There are a number of research studies that have measured impact of mathematics PD programs on

teacher knowledge and practice as well as student learning. With regards to the former, there is mixed evidence that PD programs result in improved teacher knowledge and practice. For instance, Ingvarson et al. (2005) found that PD programs have a positive impact on teacher knowledge and practice<sup>5</sup>; Bell et al. (2010) found that a specific PD program—*Developing Mathematical Ideas*—significantly increased teachers’ mathematical knowledge for teaching. On the other hand, Garet et al. (2011) found that teacher PD had no significant impact on the knowledge of 7<sup>th</sup> grade math teachers on rational number topics. This study looked at the impact of a two-year PD program on grade-7 mathematics teachers’ knowledge of rational number topics including fractions, decimals, ratios and proportions. Treatment teachers received 100 hours of PD over 1 year, during which they attended summer institutes and seminars and also received in-school coaching. The study found no impact in teacher and student knowledge on tests designed (focused on rational numbers). One limiting factor was identified as being teacher turnover which prevented teachers from receiving the ‘full dose’ of PD. Even where improvements in teacher knowledge and practice do take place, these often do not translate into better student scores. As Yoon et al. (2007) write: ‘showing that professional development translates into gains in student achievement poses tremendous challenges despite an intuitive and logical connection’ (p.3).

Much of the literature with regards to the latter, therefore, i.e. the impact of teacher PD on student learning in mathematics shows no impact on student scores (Harris & Sass, 2007; Garet et al., 2011). Jacob & Lefgren (2004) too found no impact on student learning. However, this may have been because low income schools (i.e. already poorly performing schools) in Chicago were the focus of this study and also because the PD program was less structured and less aligned with the

<sup>5</sup> A limitation of this study, however, was that it was based on data self reported by teachers.

curriculum. There are some exceptions, however, where student performance in mathematics has improved significantly as in the case of Angrist & Lavy (2001); Sample et al. (2012) and Perry & Lewis (2011). Sample et al. (2012) found that students of middle and upper elementary school teachers who enrolled in the two full math courses offered by university lecturers over the summer (that lasted two to three weeks) and attended four workshops on lesson planning, showed significant improvement in math scores compared with teachers who did not. Perry and Lewis (2011) found that students showed a significant increase in knowledge of fractions in grades 2, 3 and 5 where teachers formed study groups that met twice or thrice a month over five months.

There is, therefore, mixed evidence of impact of PD on teacher and student learning. However, there is also a dearth of credible and rigorous research on the topic. For instance, of the 643 research studies on the effectiveness of mathematics PD programs from grades 1 – 12 in the United States, only five were considered quantitatively rigorous i.e. employed proper research designs to quantify the effectiveness of PD programs (Gersten et al., 2014)<sup>6</sup>. Similarly, Yoon et al. (2007) found that only nine of the 1300 studies on impact of teacher PD were rigorous. It is imperative, therefore, to redress this gap in the literature and to have a research design that actually allows for the evaluation of the impact of PD programs. Our study is an attempt to do this.

While the evidence and the credibility of the evidence varies, the spending on PD programs for teachers by policy makers and international development organizations continues regardless. Therefore, it must be that PD is considered a feasible policy option when it comes to raising student learning compared to alternatives such as reducing class size (Angrist & Lavy, 2001) that require hiring additional teaching resources and permanently higher spending commitments. The question has not, therefore, been whether to conduct PD programs for teachers but how to improve PD programs to increase their chances of success and impact on teacher and student learning. One solution has been to devote more resources to the testing of use of technology and ICT in teacher PD. Development of technology-enabled PD programs for teachers is at a very nascent stage; however, it presents promising alternatives to target and improve teacher effectiveness. Considering

the rapid pace of technological developments, technology-enabled PD of teachers is only set to become more relevant (Borko et al., 2009).

## Using technology in Professional Development

Technology is increasingly being used to address a number of education challenges including poor quality teacher training and inadequate teacher PD programs. The proliferation of internet resources and hand-held devices in the 1990s and 2000s has facilitated online distance learning with college degrees and professional development being acquired remotely, especially in developed countries (Spector & De la Tega, 2001 as cited in Carrier et al., 2012). While developing countries have lagged behind in making use of technology in similar ways, development partners, donors and ministries of education are now advocating for and promoting programs in these regions that involve technology (Carrier et al., 2012). Poor teacher quality is a critical challenge in developing countries and one of the main reasons for low learning levels across students. Many teachers who are already in service lack the requisite knowledge to teach students the subjects that they have been hired to teach. It is felt that teacher knowledge can be improved using technology as access to ICT can facilitate access to ‘high-quality, subject-focused’ learning resources in teacher PD programs (Vrasidas & Glass, 2005 and Leach, 2007 as cited in Mtebe et al., 2016). One of the most significant changes in the use of technology in teacher education across the globe has been the move away from merely training teachers to be computer literate to training teachers to use computers/computer technology (hardware and software) as instructional tools i.e. to access high quality digital educational content for teaching and learning subjects such as mathematics, science, social studies and languages.

In our program, we sought to improve in-service teacher training by providing access to technology as well as access to carefully selected and curated learning materials that teachers could effectively use to improve their knowledge of mathematics at the primary level. An extensive review of literature of technology in education, in particular technology and teacher training, shaped our program design. A key learning from this review was that buying up the hardware first and thinking about the digital education content to upload on it later was an

<sup>6</sup> The authors made use of the What Works Clearinghouse evidence standards to gauge which studies met requirements of rigor.

oft-repeated mistake in programs aiming to use technology in education (Trucano, 2010). Borko et al. (2009) similarly note that 'education can ill afford glitzy technology for the sake of glitz' (p.5). According to Trucano (2015) it is important to think of the hardware as the table setting or container and the actual learning materials as the main course or content.

We ensured, therefore, that sourcing high-quality learning materials for teachers forms the main focus of our program rather than the hardware and software that would enable their use. Another key learning was that while technology programs are becoming more pervasive, not all have been successful in achieving their objectives. Broadly speaking, this has been because technology programs around the world 'too often focus on providing hardware and software and pay insufficient attention to the human and social systems that must also change for technology to make a difference' (Warschauer, 2002). Meaningful access to ICT 'encompasses far more than merely providing computers and internet connections. Rather, access to ICT is embedded in a complex array of factors encompassing physical, digital, human, and social resources and relationships. Content and language, literacy and education, and community and institutional structures must all be taken into account if meaningful access to new technologies is to be provided' (ibid). Borko et al. (2009) also recognize that technologies represent a 'wicked problem... that includes a large number of complex variables, all of which are dynamic, contextually bound and interdependent' (p.3). Moreover, technologies are not neutral as is often thought; each has its own advantages and disadvantages, some of which are intrinsic to the technologies and others that are shaped/imposed by the contexts in which they are being used (ibid, p.4). To ensure access to technology in our program we would have to keep in mind the 'status quo mix of resources and relationships' (Warschauer, 2002) that we were adding to. We decided that the technology would have to be embedded in the existing CPD model being operated by the government and be integrated with the existing job descriptions of the teacher mentors or DTEs and teachers within it (this is outlined in greater detail in Section 3).

Potential for use of technology in developing contexts/resource poor environments is huge where site-based teacher PD is desperately needed and face to face interaction with experienced

and qualified mentors is not always an option. Technology-enabled PD remains promising as ongoing developments in ICT and options for the encoding of relevant knowledge in ICT friendly formats will enable better and more effective programs to be formulated. In the meanwhile it is important to continue to test out different technologies and learning materials for teacher PD. It is advised to implement technology-enabled PD programs slowly and to go to scale after multiple iterations i.e. to have a pilot and several mid-level phases (Gaible & Burns, 2005, p.35) to arrive at the best design and to examine which technologies and digital learning resources work better and why. According to Borko et al. (2009) the rapid pace at which technology develops also presents a challenge as it means that teachers and educators need to keep up to speed with evolving hardware and software. In order to stay competitive, technology partners often distribute new technologies before adequately testing them. This means that errors, bugs and incompatibility with devices pose significant challenges. In initial phases of rolling out technology-enabled PD programs for teachers it is also desirable to 'have decentralized solutions that involve NGOs or private sector providers' and to build partnerships spanning across the government, universities, telecommunications and software companies (Gaible & Burns, 2005, p.29).

## Features of effective Professional Development programs

In order to design our technology-enabled teacher PD program we consulted the rich qualitative literature on teacher training that highlights factors that make for effective PD programs for teachers. In particular, the following recommendations are made that we have tried to account for in our program and that are discussed in detail below:

- a. Teacher PD programs should include a practicum component often involving video-recording of lectures as well as video-viewing;
- b. Teacher PD programs should be aligned with the relevant curriculum and curricular goals;
- c. Teacher PD programs should preferably be *site-based*; and
- d. Teacher PD programs should be of sufficient duration and time span

Videos and technologies that support video viewing, in particular, are strongly advocated and considered key to strengthening PD programs for teachers (Krammer et al., 2006; Borko et al., 2008; Koellner et al., 2011; Gaible & Burns, 2005; Darling-Hammond, 2010). Krammer et al. (2006) found that teachers watching videos of themselves teaching and then discussing them in small groups was an effective approach. Borko et al. (2008) also found that video use was the most effective element of the PD program studied. Using videos for teacher PD has a number of benefits:

1. Videos provide teachers with powerful visual learning resources (Gaible & Burns, 2005)
2. Teachers can ‘control the rate of presentation (freeze-frame, play, rewind, etc.), enabling viewing to be interspersed with discussion or specific sequences to be repeated’ (Gaible & Burns, 2005, p.56). Videos can be used over and over again and, depending on the hardware supplied, from any place, at any time (Carrier et al., 2012). Studies note the importance of providing teachers with some level of control over the pacing and order in which they receive instructional content in the PD programs and videos offer this flexibility.
3. The cost of videos has decreased substantially while their versatility has increased making them suitable for use in low-infrastructure/poorly resourced contexts (Gaible & Burns, 2005).
4. Digital videos can be compressed and transmitted easily over the internet (Gaible & Burns, 2005).

There are many programs that have made use of technology and videos in in-service teacher training programs. In Malawi, for instance, videos were found to be the most popular feature of instruction in a pilot that made use of media players for teacher PD (Carrier et al., 2012); UNICEF launched a program in Nepal in 2014 which included using technology to provide teachers with access to PD resources including videos and a digital library (Center for Education Innovations n.d); Namibia’s Basic Education Support 2 program used videos to help teachers improve instruction—it tasked circuit inspectors with videotaping teachers’ classrooms to enable observation, assessment, and sharing of case studies (Gaible & Burns, 2005); videos and multimedia content were used for PD of secondary

school in-service math and science teachers in Tanzania (Mtebe et al., 2016)—teachers were provided with DVDs and were also able to access videos and learning materials online through a Learning Management Software specifically designed for the program. Our program, therefore, reflects continuity with this body of work.

It becomes evident that the videos used in most of these programs comprise of videos of participating teachers themselves (Borko et al., 2008) or of other teachers teaching in an actual classroom (Bell et al., 2010; Krammer et al., 2006). Teachers who are asked to try new instructional techniques benefit when they see other teachers using those same techniques. The risk in experimenting—the risk of the unknown—is reduced. They also benefit from opportunities to reflect on their own practices—to identify practices they too can model or identify shortcomings and how the teacher shown in the video can improve his/her lesson. On the whole, it is common, therefore for the focus of these videos and programs to be the improvement of pedagogical knowledge and teaching practice of teachers. While we used videos in our program, a key difference was that we focused instead on videos that improved the content knowledge and conceptual understanding of teachers which is considered a critical deficit among primary school teachers in Pakistan. The videos did not, therefore, showcase teaching practice in actual classrooms and instead comprised of a master teacher using animations to explain different topics from the mathematics curriculum. It built on an earlier study by SAHE (2013) in which teachers and students in grade-5 in selected classrooms in Pakistan were shown instructional videos on geometry using portable and regular multimedia projectors.

Although the videos used in our program contained elements of pedagogy that teachers could discern and try to emulate in their own lectures, pedagogical training was not the explicit focus of our video content. In a similar vein, Trucano (2014) notes that governments in developing countries are increasingly looking to videos such as the Khan Academy ones to improve the content knowledge of teachers, i.e. content that teachers should already know but do not. Mtebe et al. (2016) also targeted improving subject knowledge of math and science teachers at the secondary level in Tanzania through the use of technology and multimedia content.

While the education literature advocates for the

implementation of PD programs that address both pedagogical knowledge and content knowledge in the right 'mix' (Kennedy, 1999; Bell et al., 2010; Desimone, 2009; Baumert & Kunter, 2013; Harris & Sass, 2007), for this program, we felt that the greatest value addition lay in focusing primarily on content knowledge deficit among teachers given that the rest of provincial training structure is already heavily skewed towards pedagogy. In addition, as we will show in Section 5, content knowledge deficits among school teachers remain a key challenge in Punjab just like other developing country education systems. Furthermore, possessing content knowledge is the first step and a necessary precondition to being able to teach a topic well since possessing adequate content knowledge feeds into pedagogical knowledge and teaching practice. In future work, we intend to also produce and integrate pedagogy-focused videos in the overall intervention design.

Where videos are used, it is important that teacher viewing is not passive; this can be prevented by engaging teachers through prompts, questions and other exercises (Avalos, 2011). Moreover, in order for videos to be effective tools of teacher PD, ordering and sequencing of videos for teachers; providing contextual information about the videos to teachers and giving clear instructions for the 'productive' watching of videos (including clear tasks and guiding questions) that a real-time facilitator would have provided are important (Bates et al., 2016). These were incorporated in our program and are discussed in Section 3.

Of course, the ultimate goal of most teacher PD programs is to improve student learning outcomes. Even when high-quality videos are made available, they may have no impact on student learning unless teachers are motivated to use them and unless monitoring mechanisms are in place to ensure that videos are being used to teach and improve learning (Bates et al., 2016; Gaible & Burns, 2005; Mtebe et al., 2016). 'Institutionalized incentives from school administration or government authorities that make it mandatory for teachers to use digital resources to change their practices are missing and public policies can be developed in this area' (Trucano, 2014). Identifying high quality digital educational content is just one piece of the puzzle, creating conditions for effective use as it requires a number of other steps (ibid).

A second critical feature of successful PD programs is the alignment of the program with the curriculum (Angrist & Lavy, 2001; Jacob & Lefgren, 2004; Yoon

et al., 2007). This also speaks to the literature on technology use in the classroom where programs that were poorly aligned with the curriculum, or executed without sufficient attention to complementary inputs required, had no impact on student learning (Banerjee et al., 2007; Linden, 2008; and Roschelle et al., 2010). Gaible & Burns (2005) note that videos are most effective where they are locally produced i.e. are aligned with the local curriculum, developed in the local language and depict environments and materials that target teachers are familiar with. We ensured that the videos made available through the technology adopted in our program were pertinent to the Pakistani curriculum, contained a different style of teaching that focused on producing real understanding from a child's perspective and were available in the local language.

A third critical feature of effective PD programs is that they are offered close to home or are 'school-based' and job-embedded (Avalos, 2011; Meissel et al., 2016). According to Gaible & Burns (2005), PD programs for teachers vary considerably in format and structure across different countries but tend to include one or more of the following features:

- a) Standardized PD: This is PD that is centralized and delivered using a cascade model
- b) Site-based PD: This is PD that takes place at the local level or within schools
- c) Self-directed PD: This is PD that is initiated and managed by the teacher himself or herself

Site-based PD is considered to be one of the most critical types of PD especially where teachers require a significant increase or improvement in content knowledge and teaching practice. This is because 'it addresses locally based needs and reflects local conditions... and allows for more flexible, sustained and intensive PD' (Gaible & Burns, 2005, p.21). 'Job-embedded' PD is considered more effective than 'one-shot' workshops that typically constitute standardized PD (Darling-Hammond et al., 2010; Yoon et al., 2007). Site-based PD is already a feature of the DSD's CPD model in Punjab where standardized PD takes place every quarter but is ostensibly supported by site-based PD taking place within the school on a monthly basis (discussed in Section 1). We ensured that our program capitalized on these site-based PD visits and so we delivered our training to teachers every month

*within* schools. Gaible & Burns (2005) also note that videos are ideal for use in site-based PD or as a follow-up to standardized PD especially in contexts where face to face interaction with experts is limited or quality of teacher educators varies or is below standard, as is the case in Pakistan. Borko et al. (2009) make a similar observation that ‘these technologies enable PD providers to... offer just-in-time work embedded support and accommodate individual teachers’ busy schedules’ (p.6).

In order to boost the impact of PD, it is critical that PD programs be of sufficient duration. According to Yoon et al. (2007), teachers who received 49 hours of PD on average in the nine studies they reviewed<sup>7</sup> were able to boost student achievement by 21 percentile points. Five of the nine studies reviewed focused on math and provided 30 – 83 hours of

PD over a period of 4 months – 1 year. Of the nine studies, students showed improvement in the ones in which teachers received more than 15 hours of PD. Students showed no improvement in those studies in which teachers only got 5 to 15 hours of PD. Darling-Hammond et al. (2010) also note that that high performing education systems such as those in Sweden, Singapore and the Netherlands provide intensive PD and make a 100 hours of PD a year mandatory for in-service teachers. While we wanted to increase training hours in our program, we were constrained by budgetary limitations as well as the flexibility available amidst ongoing training initiatives and the institutional structure of the DSD’s CPD framework. These limiting factors combined to allow for only 8–10 hours of teacher PD across 4 months in our program.

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<sup>7</sup> Only 9 out of 1300 studies met the What Works Clearinghouse standards of rigor.



An abstract graphic design featuring a complex pattern of overlapping, semi-transparent blue squares and rectangles. The pattern is arranged in a way that creates a sense of depth and movement, with some elements appearing to recede into the background while others come forward. The colors range from light, airy blues to deep, rich navy blues. The overall effect is modern and digital, typical of contemporary corporate or educational branding.

# 3

## The 'Learning While You Teach' Program

# The 'Learning While You Teach' Program

In this section, we describe the 'Learning while you teach' program in greater detail, starting with an explanation of the existing government-supported CPD model within which our program was embedded. Following this, we describe how we selected the content and the technology for use by teachers and teacher mentors or DTEs in our program. We conclude the section with a description of how we monitored and supported target beneficiaries during field implementation or rollout from September – December 2015.

The existing CPD model in Punjab is a cascaded model for in-service teacher training that was established by the DSD, the apex institution for teacher PD in Punjab, in 2006 with support from the World Bank as part of the Punjab Education Sector Reform Program. Using the CPD framework, the DSD is responsible for the in-service training of approximately 350,000 primary school teachers in public schools across the province through its workforce of 4000 DTEs. As mentioned in Section 1, in-service training in the CPD model comprises of quarterly PD workshops for teachers as well as monthly school-based visits to teachers by the DTEs. The DSD's model, therefore, is a mix of both 'standardized PD' and 'site-based PD' as described in Section 2. The DSD recognizes that critical content knowledge deficits continue to persist across teachers in Punjab despite its PD efforts.

We designed a technology-enabled in-service training program for grade-4 teachers<sup>8</sup> that was aligned with and embedded within the existing CPD model to improve their content knowledge of mathematics. In particular, our program made

use of the DTEs and their site-based monthly visits to teachers within schools, as defined by the DSD, in the existing CPD model to improve teacher training. Using tablets would enable access to standardized, high quality instructional videos on mathematics to train teachers within schools, without requiring that they be physically present at some other training venue—this is also more convenient for female teachers who are less mobile due to prevalent socio-economic norms especially in rural areas of the country. Building upon the existing CPD model and making use of the processes, systems and personnel already in place was one of the key strengths of our program that has important implications for its sustainability and how realistic any future plans for scale up will be.

Since providing tablets to all teachers would have been too costly, we instead provided these tablets to the DTEs to deliver to teachers along with the uploaded instructional videos during their school visits. Prior to our 4-month rollout, a five-day training workshop was held in July–August 2015 in which DTEs were given a thorough orientation on our program design and objectives. They were trained by the math expert whose videos were used in our program on the content of these videos and how to use them to train teachers. They were also given a shorter training on how to operate the technology—tablets, software application and videos—for use in our program.

During rollout, the DTEs handed the tablets over to teachers on their school visits<sup>9</sup>. The teachers would watch the videos during that visit with each

<sup>8</sup> We focused on grade-4 teachers as our target beneficiaries. This was because other interventions were being piloted in Punjab at the grade-3 level (e.g. the Literacy and Numeracy Drive). Grade-5 was not selected as both students and teachers are busy preparing for the Punjab Examination Commission's high-stakes assessment.

<sup>9</sup> The DTE visits the school once a month to mentor teachers. This is known as the 'mentoring visit'—in total, the DTE's school visit lasts approximately 4.5 hours.

video lecture (comprising of a string of video clips) lasting about 60 – 90 minutes. After watching the videos, the DTEs had a discussion with the teachers on videos viewed. While the teachers had to return the tablets to the DTEs, the teachers were able to keep the handouts we developed to accompany each video lecture beyond the DTEs' visits as recall aids<sup>10</sup>. In case the teachers had any questions regarding the hardware, software or videos that the DTEs could not answer, the DTEs would relay these to the project team by calling into a call center that we set up for the duration of our rollout, the numbers for which had been provided to them. We trained the call center attendants<sup>11</sup> to answer queries regarding basic functioning and operation of the tablets, application and the videos. For queries that the attendants were unable to address, these were forwarded to us and we responded accordingly.

## Content & videos

The instructional videos used in our program covered topics that are difficult for teachers and students to teach and learn. We used the item-level analysis reports of assessment agencies in Punjab (such as Punjab Education Assessment System and PEC) and interviewed DTEs and primary school teachers in Lahore to identify what are considered difficult topics. Based on our findings, we decided to focus on the topics of division, factors, multiples and fractions in our program, with special emphasis on fractions, which is unanimously considered to be the most difficult topic.

We considered both the option of producing videos in-house and the option of using videos available in online repositories on the above topics. We opted to use existing video resources. Specifically, we chose to use *Karismath* videos in our program as they were already aligned with the Pakistani curriculum and were available in the local language (Urdu). They did not, therefore, need to be translated or adapted. In addition, the quality of the *Karismath* videos surpassed that of most available courseware and addressed content knowledge deficits amongst math teachers. The animation in the *Karismath* videos was simple and relied on the interaction of objects easily available and replicable in a classroom setting, either on the blackboard or through the use of resources like pieces of chart paper that teachers could prepare prior to class. The focus of the animation was to allow the viewer to engage with mathematical concepts through simple but accurate visual representations, with audio narration playing a vital role in supplementing this understanding.

Table 1 on the next page shows the topics, number of videos and the duration of videos teachers were trained on during rollout. Videos were embedded in the application and ordered in the sequence of Student Learning Outcomes in the National Curriculum. As a result, each video that introduced teachers to topics drew upon the foundational knowledge established in preceding videos. If a video was viewed out of order, it would not appear under the list (visible to both the teacher and the DTE) of 'completed clips' in the application, encouraging teachers to follow the recommended sequence.

<sup>10</sup> We developed these handouts with the help of two primary school teachers from Lahore. These teachers were shown the *Karismath* clips and asked to identify which screenshots they felt were most appropriate to include in the handout for recall purposes as well as that clearly summarized the content. They were also asked to identify activities that teachers could do with students using learning materials available in the classroom to illustrate the topics. The teachers were also asked to develop some assessment questions that would be included in the handout for practice by the treatment teachers. The teachers were also asked to provide references to relevant exercises in textbooks in use that teachers being trained can refer to for greater practice.

<sup>11</sup> Call center attendants were hired for the duration of the rollout—they were trained on project objectives as well as provided with protocols on how to respond to queries submitted; a list of anticipated FAQs had been generated for this purpose.

Table 1. Summary of training content delivered in LWYT

Month	Math topics & subtopics selected to train teachers on	No. of videos	Total duration of videos
September	Division; Factors & HCF; Multiples & LCM ; Introductory concepts in fractions	9	81 minutes
October	Fractions as halves, wholes & quarters; Comparing like and unlike fractions	9	73 minutes
November	Adding & subtracting fractions; Improper to mixed fractions; Mixed to improper fractions; Making equivalent fractions; Multiplying fractions with whole numbers	8	73 minutes
December	Simplifying fractions; Adding sets of unlike fractions; Multiplying fractions by fractions; Dividing fractions by whole numbers and fractions	7	61 minutes

## Technology

As mentioned earlier, tablets were selected for use in our program because of their portability/transportability and compatibility with site-based PD. We also chose to use tablets in our program instead of other technological devices because the bigger screen size afforded by the tablets would be conducive to easy viewing of videos by teachers in schools. Prior to rollout, the technology to be used was pre-tested on a smaller sample of DTEs and teachers. While a Huawei tablet was used in the pre-testing, for the final intervention design, the Samsung Galaxy Tab 4 was selected. This was because we learnt that noise level in the school setting is quite high and the latter had relatively better sound quality. Because we were using videos as the primary means to improve teacher knowledge, it was imperative that the tablet model selected have good sound quality. Earphones were also provided for use by teachers.

## Monitoring & support

As discussed in Section 2, the mere availability of technology and even high quality digital educational content is not sufficient to ensure that it is used effectively by teachers to improve their knowledge, practice and student learning. Teachers need to be motivated and monitored to use the technology and more importantly, the educational content. Monitoring and support took place through the software application developed for use on the tablets, the call center set up and physical visits for interactions with teachers and teacher educators.

With regards to the application, every DTE was provided with a log-in and password that s/he

would enter to access the application. Once the application opened, the DTE was required to select the name of the school and the name of the teacher being visited on that particular day from a dropdown menu. Data services and plans were also purchased for the digital tablets. This allowed for data to be continuously and automatically sent from the application to a server that had been developed by our technology partners. We used that data to monitor if the DTE visited the school, if the teacher viewed some or all of the videos, if the teacher paused during the videos and for how long, if the teacher skipped parts or all of the videos and so on. The application also included a DTE feedback form that the DTE filled at the end of every school visit. The responses here would indicate any issues being faced by the DTE or teacher.

We also utilized the call center to contact the DTEs and teachers directly to gather individual feedback and to monitor the intervention. The DSD gave permission to contact teachers after school hours. We called a subset of the teachers, therefore, to enquire whether the DTE had visited the school with the tablet and videos and had a discussion with the teacher about the training materials.

Face to face interaction with the DTEs took place at the end of every month during rollout when DTEs had congregated at their cluster center to receive their PD as part of the existing CPD model. Here, we would have a structured discussion and gather feedback from them on our program in a group setting. We also hired a survey firm to conduct two monitoring visits to each of our treatment schools during rollout. The purpose of these spot-checks was to check that the DTE had delivered the tablets and the videos to the teacher.



# 4

## Methodology

# Methodology

In this section we outline the methodology and research design that we used to evaluate the impact of our program. As mentioned in Section 1, we conducted an experiment in which we randomly assigned DTEs from Bahawalnagar, Hafizabad and Sahiwal districts to treatment and control groups. A total of 158 DTEs were assigned to the treatment group where we introduced our PD model described in section 3 and 159 DTEs were assigned to the control group where the DTEs continued the existing in-service training program as usual. Table 2 provides information on the number of DTEs, schools and teachers in the treatment and control groups across the

the DTEs, schools and teachers in the treatment and control groups. The most important of these characteristics were measured by the baseline survey conducted prior to rollout (discussed in detail below). The similarity of schools in the treatment and control groups at the baseline was important for our evaluation as it ensures that the only difference between the treatment and control groups was our technology-enabled training program provided in the treatment group only. This allows us to compare the outcomes in the two groups in the endline survey, conducted after rollout and to attribute any difference in these outcomes to the intervention that we implemented. This

**Table 2. Treatment and control groups in LWYT**

District	No. of treatment DTEs	No. of treatment teachers	No. of control DTEs	No. of control teachers
Bahawalnagar	85	463	86	460
Hafizabad	32	126	31	129
Sahiwal	41	248	42	250
Total	158	837	159	839

three districts. The use of random assignment of the program should ensure that the treatment and control groups were identical ex-ante. In this case, a comparison of outcomes in the treatment and control groups after the introduction of the program would allow us to determine the impact of our program relative to the existing in-service training program. As mentioned in Section 1, we conducted baseline and endline surveys and tests of teachers. We also tested students at the endline only. Furthermore, as part of the school survey administered to teachers at the baseline, we also collected information on students using a child roster.

Given that we randomly assigned DTEs (and their associated teachers and schools) to the treatment and control groups via lottery, there should be no systematic differences in the characteristics of

comparison of outcomes measured at the endline between the treatment and control group is called the post estimator. It provides a credible estimate of the impact of the program and the randomized experiment setting itself is often considered the ‘gold-standard’ of evaluation methodologies.

The most straightforward evaluation of our intervention would have been to use the post estimator which utilizes the endline data only to calculate the difference in mean outcome, say teacher test scores, for the treatment and control groups to tell us the impact of our intervention on teacher knowledge levels. However, when using the post estimator, baseline data is not used at all in calculating the impact of the intervention. As a result, very few experimental evaluations rely on just the post estimator (and endline data) to assess the impact of the intervention since

using the baseline data can significantly improve the precision of results obtained. The Analysis of Covariance (ANCOVA) estimator, for instance, calculates the program impact as a difference in the average outcome of the treatment and control group but after conditioning on the baseline measure of the outcome variable. Controlling for the pre-intervention value of the outcome variable in the ANCOVA estimator can help with the efficiency of the impact estimates identified and the ANCOVA estimator is more precise the stronger the correlation between baseline and endline values of the outcome being evaluated. Since the outcome measures we test in our evaluation are correlated between the baseline and endline rounds, we find that there are considerable gains in precision (smaller standard errors) when we use the ANCOVA estimator rather than the simple post estimator. For this reason, our preferred estimation strategy was to use the ANCOVA estimator for evaluating program impact.

The baseline data can be used to check that the randomized assignment of treatment DTEs was conducted correctly and, therefore, that the impact estimates from the experiment are credible. Table 3 shows the summary statistics regarding selected DTE, school, teacher and student characteristics at the baseline. Panel A shows the mean values of these characteristics for the full sample of schools surveyed at the baseline separately for the treatment and control groups while panel B shows the means for those schools that were surveyed at both the baseline and the endline. While we had surveyed a total of 1740 treatment and control group math teachers (who taught grade-4 students) at the baseline, we have data in *both* the baseline and endline surveys for 1462 teachers due to attrition<sup>12</sup>. Our estimates using ANCOVA use the sample of teachers in Panel B.

The means of the baseline characteristics for each sample are shown separately for the treatment and control groups so that one can assess whether the random assignment did indeed create comparable groups at the baseline. An examination of the table shows that the DTE, school, teacher and student characteristics have very similar means across the treatment and control groups in both panels. We also conducted a formal test to see if the differences in the means of these characteristics are statistically significant and find that the overwhelming majority of these characteristics are not significantly different. P-values are reported in the third column of each panel. In panel A, we see that the difference in means for only two out of the 16 characteristics—whether the school is co-educational and whether the teacher has a professional education degree—have p-values of less than 0.10 indicating that only on these two attributes the difference between treatment and control groups is statistically significant at the 10% significance level.

Since we are testing the difference in means for 16 characteristics, we expect that ten percent of these variables i.e. 1.6 (roughly 2) would be significantly different at the 10% significance level just by random chance. This indicates that the imbalance on the two characteristics found is consistent with that occurring due to random chance and that the randomization was indeed successful in creating treatment and control groups that have similar characteristics. In panel B, we see that when we limit the sample to only those teachers who were observed at both the baseline and the endline, there is no significant difference across any of the 16 characteristics between the treatment and control groups, again indicating that the two groups are comparable and the estimated impacts from this experiment should be credible.<sup>13</sup>

<sup>12</sup> Attrition occurs primarily because teachers are transferred across grades or schools and are therefore no longer teaching grade-4 which is where we intervened.

<sup>13</sup> We also tested for difference in other characteristics between the treatment and control groups but do not show those results here due to space limitations. Tables 1-4 in the appendix include similar tables testing 58 different characteristics. Since only about 14% of the tested characteristics are significantly different between treatment and control at the 10% significance levels, again, these differences are consistent with normal sampling variation indicating that the treatment and control groups are mostly balanced at the baseline.

Table 3. Summary statistics of DTE, school, teacher and student characteristics at baseline

Source: Baseline survey of teachers (LWYT)

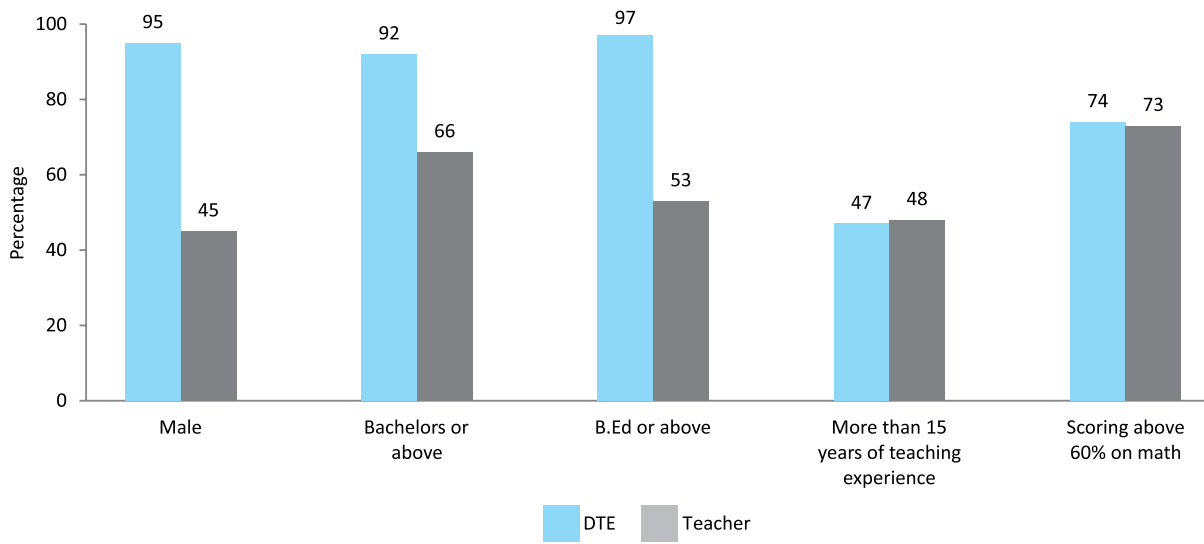
	Panel A - Baseline sample			Panel B - Analysis sample		
	Treatment	Control	P-value	Treatment	Control	P-value
DTE has at least bachelor's degree	0.975	0.981	0.697	0.974	0.981	0.678
DTE experience	3.21	3.104	0.533	3.193	3.104	0.605
Number of schools assigned to DTE	13.28	13.37	0.513	13.27	13.37	0.481
DTE math test score	0.661	0.674	0.292	0.661	0.674	0.288
School in rural area	0.892	0.888	0.666	0.895	0.893	0.737
Primary level school	0.628	0.592	0.15	0.632	0.59	0.143
Boys only school	0.354	0.329	0.228	0.348	0.333	0.432
Co-ed school	0.429	0.474	0.067	0.434	0.473	0.111
Grade 4 class size	19.196	19.031	0.842	19.136	18.978	0.742
Teacher has a bachelor's degree	0.612	0.568	0.101	0.61	0.581	0.309
Teacher primary experience	15.241	14.301	0.13	15.196	14.232	0.16
Teacher has a professional education degree	0.516	0.561	0.068	0.518	0.56	0.133
Teacher math test score	0.734	0.733	0.868	0.736	0.733	0.655
Teacher personality score	0.758	0.757	0.834	0.759	0.757	0.624
Teacher self-efficacy score	0.863	0.867	0.29	0.862	0.866	0.323
Teacher reported students' math proficiency	0.91	0.912	0.73	0.914	0.912	0.917
Number of teachers		1740			1462	

Figure 1 also presents important information about the context in which we implemented our program. The majority of DTEs have a Bachelor's degree and three years' experience working as a DTE. The average DTE scored 66.5% on the math test we administered which is similar to the performance of teachers on the same baseline test. As far as mathematical competence is concerned, therefore, the DTEs are at par with the teachers they are supposed to mentor and do not possess additional knowledge despite having had, on average, more formal education and greater teaching experience.

Importantly, both DTEs' and teachers' math test scores are similar across treatment and control groups in both panels indicating that DTE and teacher quality was balanced before the intervention. In terms of DTE workload, each DTE

is responsible for 13 schools on average and this is similar across treatment and control groups. Around 90% of our schools are in rural areas and more than half offer primary level instruction only. The average class size in grade-4 is 19 students. Teachers have lower education qualifications than the DTEs with 60% having a bachelor's degree and about half of them having a professional education degree. On average, teachers have 15 years of primary school teaching experience. To gauge student math proficiency at the baseline, we asked teachers to report whether the students in their class could solve a basic math question. These teacher reports indicate that 90% of students are proficient according to this simple measure, and more importantly, this does not differ across treatment and control groups.

**Figure 1. Comparison of DTE and teacher characteristics**  
Source: DTE interviews, baseline survey & math test for teachers (LWYT)







# 5

## Findings & Discussion

## Findings & Discussion

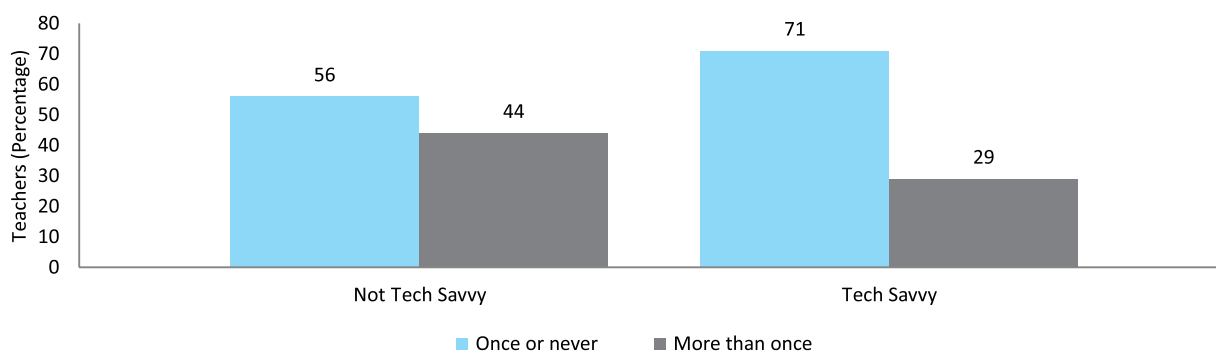
In this section we present our results relating to a) the viability of the technology (tablets, software and videos) being tested as a mode of training delivery to teachers and b) the impact of the training content itself (i.e. the videos). The former refers to whether the technology was used and operated efficiently by teachers who lack familiarity with it; whether the technology was used by teachers as directed i.e. for the purpose of watching videos; and whether teachers were satisfied using the technology and preferred it to the DSD's existing approach to teacher training. The latter refers to the impact of the learning materials i.e. videos on teacher and student knowledge of grade-4 mathematics. The section concludes with a closer examination of teacher and student performance on tests in our program and highlights some of the main challenges faced.

### Viability of technology as a means of training delivery

We assessed the viability of the technology used as a means for training delivery using the data and feedback gathered from the software application, the call center, interviews/discussions with DTEs during rollout as well as information gathered from our monitoring visits to schools and surveys of teachers at the baseline and endline.

We found that the technology we tested was viable as a mechanism for the delivery of training to teachers as indicated by its high uptake and compliance with project protocols. We found that most teachers were comfortable using and operating the technology and required little to no assistance from the DTE in using the tablet and the software application to access and watch the videos. This was despite the fact that we did not train teachers directly on the use of technology—this was mediated through the DTEs who had been given a single 3-hour long training on the use of technology prior to rollout. We distributed teachers into two groups; those who are 'tech-savvy' i.e. have previously used or owned smart phones, tablets or computers and teachers who are 'not tech-savvy'. Figure 2 shows that overall, almost 62% of teachers were able to use the technology provided during the intervention with little or no guidance from the DTE despite the fact that only 41% of teachers had used a smart device or computer before. Roughly half (56%) of the teachers who were not tech-savvy were able to use the technology with little or no assistance from the DTE. Furthermore, in the feedback collected from teachers in the endline survey regarding how the technology-enabled PD model could be improved, none of the responses indicated any apprehensions regarding the use of technology.

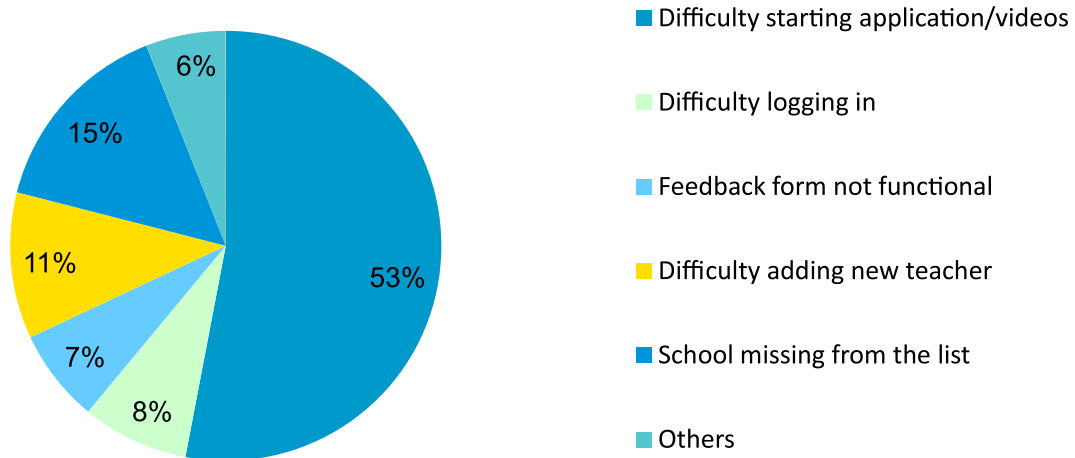
**Figure 2. Percentage of teachers who needed help viewing the videos on tablets**  
Source: Baseline survey of teachers & school monitoring visits (LWYT)



In addition, the call center received only 250 complaints—an average of two complaints a day—during rollout. Most of these complaints were related to the software application that contained the PD videos. As seen in Figure 3 below, 53% of the call center complaints pertained to the software application not starting; 8% to difficulty logging in to the application and 7% to the feedback form not functioning. While the complaints

We found overwhelming evidence that teachers were using the technology for the purpose outlined i.e. to actually watch the videos on grade-4 mathematics. We found that 84% of teachers watched at least two-thirds of the training videos and that 99% of teachers watched some of the training videos during rollout (as shown in Figure 4). This indicated that a) DTEs took interest and ownership in playing their part which was crucial

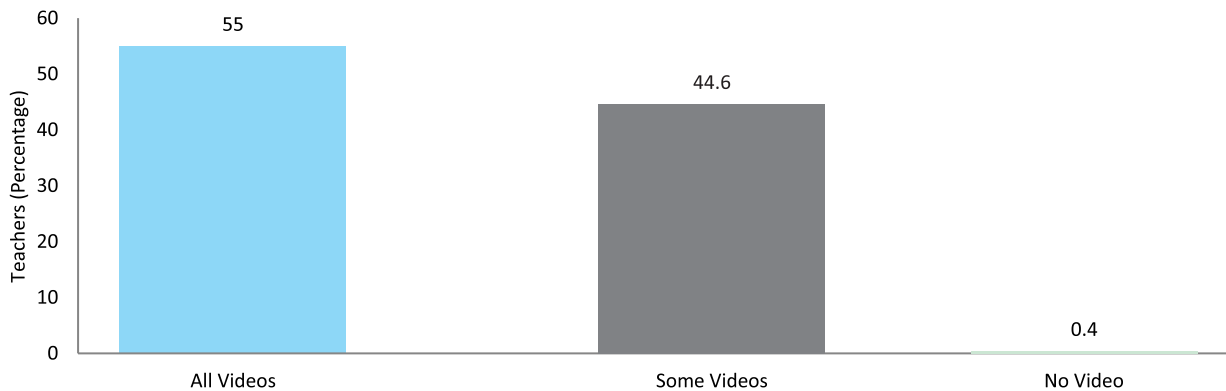
**Figure 3. Nature of complaints received by call center during rollout**  
Source: Call center data (LWYT)



were resolved quickly and did not hamper the provision of teacher PD, we learnt that the teachers’ experience could have been improved significantly by refining the software application. This reaffirmed recommendations in the literature of the importance of building sufficient lead time in technology-driven teacher PD projects for developing, testing and resolving any bugs in the software.

to the success of our technology-enabled teacher PD model as the DTE had to hand over the device for use by teachers every month and urge teachers to watch the videos and b) teachers were also self-motivated and interested in the new PD model considering that, in most cases, DTEs were not physically sitting with and monitoring teachers while they watched the videos<sup>14</sup>.

**Figure 4. Videos watched by teachers during rollout**  
Source: Monitoring data (LWYT)



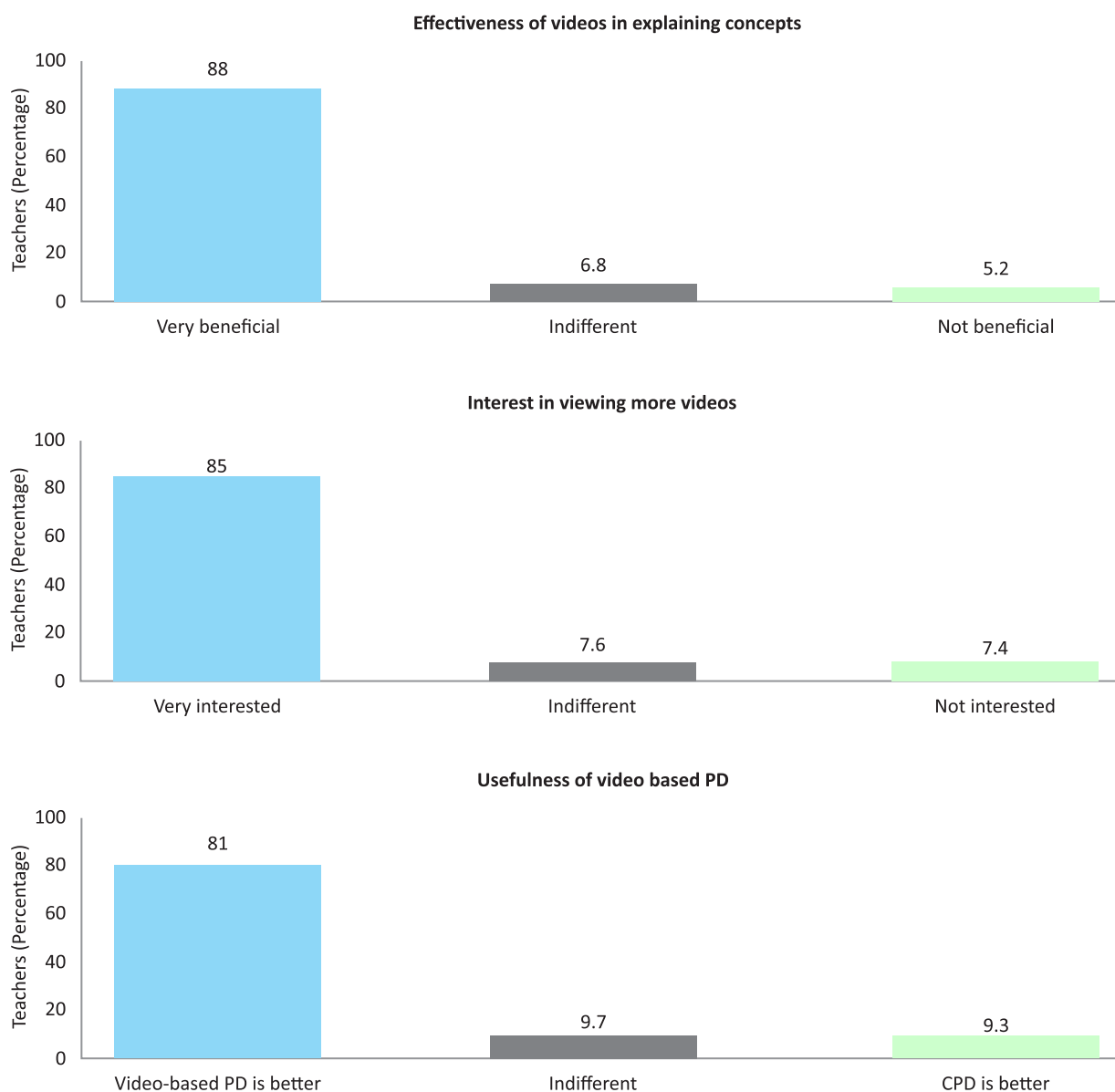
<sup>14</sup> DTEs are not just responsible for mentoring teachers but are also required to complete a number of other tasks and reporting requirements as outlined by the DSD on these monthly visits to schools. While the total visit lasts 4 hours, how much of that time is physically spent with a single teacher varies considerably.

Teacher satisfaction with the videos was very high as seen in Figure 5 below<sup>15</sup>. Almost 90% of the teachers believed that the videos were “very beneficial” in explaining concepts and 81% of teachers believed that training through videos was better compared to training methods used in the DSD’s existing CPD framework. 78% percent of the DTEs also perceived the training videos to be very useful for teacher PD (not shown). Treatment teachers were 5.1% more likely to consider a DTE visit very helpful for increasing conceptual knowledge of mathematics where videos were used compared to

control group teachers. Even though the difference was small, the impact was statistically significant at 5% (Appendix Table 11). We found that less educated teachers in the treatment group (those with educational qualifications below a Bachelor’s degree) felt more positively about the videos used in our program compared with more educated teachers in the same cohort. The former reported a 12.4 percentage point greater likelihood, also statistically significant, of incorporating DTEs’ suggestions in their teaching practices (Appendix Table 12).

**Figure 5. Teacher feedback on the usefulness of video-based PD**

Source: Endline survey of teachers (LWYT)



<sup>15</sup> This particular feedback was collected during our school monitoring visits during rollout and during the endline survey of treatment teachers.

As per feedback collected, however, 54% of the DTEs and 46% of the teachers felt that the program could be improved by giving the devices and training content to teachers directly while 17% of DTEs suggested scaling up the program as it is. Providing the devices to teachers directly would increase their exposure to the training content and provide them greater control over the video viewing process i.e. greater freedom to watch, rewind and re-watch videos as and when they please.

### Impact of training videos

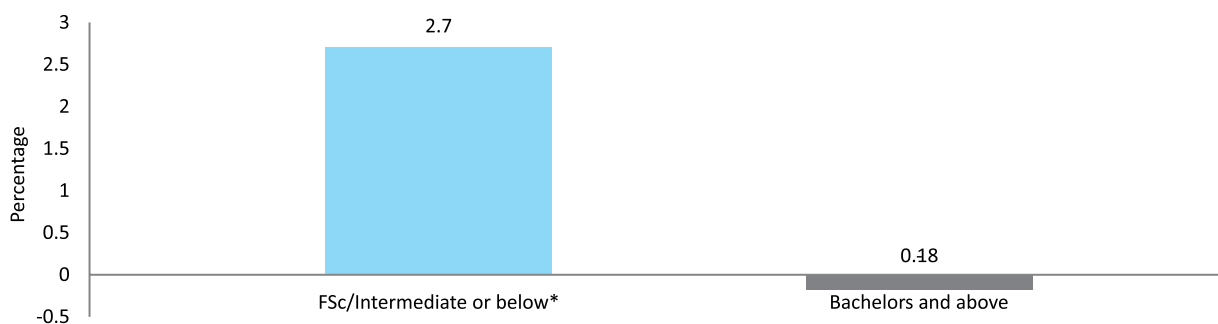
We measured the impact of our program on teacher knowledge—specifically content knowledge—and student learning. We measured the former using teacher scores on math tests taken at the baseline and the endline. We measured the latter by comparing the test scores of students on math tests in the treatment and control group schools at the endline only.

Starting with the impact on overall teacher knowledge, the difference between treatment and control group teachers was positive but not statistically significant (Appendix: Table 5). Treatment group teachers scored 0.695 of a percentage point higher than control group teachers. There were reasons why the impact though positive, was small; chief among these being the very brief exposure of teachers to training videos. Teachers were only exposed to training videos during four DTE visits in the rollout period. On average, therefore, teachers were exposed to the videos for only 8–10 hours in our program—approximately two hours each month. The teacher viewed videos at a stretch during these two hours which would have made it difficult to absorb and

internalize the material. Moreover, teachers were not able to revisit the videos once the DTE left the school with the tablet. As discussed in Section 2, while consensus is far from unanimous, researchers generally find that programs with teacher PD of 5 to 15 hours have no impact. As discussed in Section 1, however, this was unavoidable due to the resource constraint as a result of which tablets could not be provided to teachers directly in our program.

We did, however, observe a positive and statistically significant impact on the knowledge of teachers who possessed lower educational qualifications such as those who had only completed their matriculation or intermediate (FSc) education (see Figure 6). This group scored 2.7 percentage points higher on average on the endline math test as compared to teachers with similar qualifications in the control group (Appendix: Table 6). Since the RCT methodology used controlled for any other factors that may have affected our outcome, we could safely attribute this improvement in test scores to the training delivered as part of our program. We saw no impact (slightly negative but statistically insignificant) on the test scores of teachers who had Bachelor’s degrees or greater formal education. The asymmetric results by teacher education are consistent with less educated teachers having weaker knowledge of mathematical concepts compared with more educated teachers as a result of which they benefited more from exposure to the videos. That less educated teachers had weaker content knowledge was apparent from the baseline as well—the average baseline test score among teachers with educational qualifications lower than a Bachelor’s degree was 66.4 percentage points (13.6 sd) while it was 71.8 percentage points (13.6 sd) for teachers with a Bachelor’s degree or higher.

**Figure 6. Treatment effect by teacher qualifications**  
**Source: Baseline and endline surveys & tests (LWYT)**  
 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 (After adding controls)



To further investigate this remedial effect i.e. the effect on the subject knowledge of the weakest teachers, we grouped teachers by their performance on the baseline test and analyzed the effect of our program on each group separately. Figure 7 shows that teachers in the first and second quartile of the baseline test scores benefited most from our program, showing a gain in test scores of 2.2 percentage points and 1.7 percentage points respectively compared with their counterparts in

effective for different sub-groups of beneficiaries is promising for future replication and scale up.

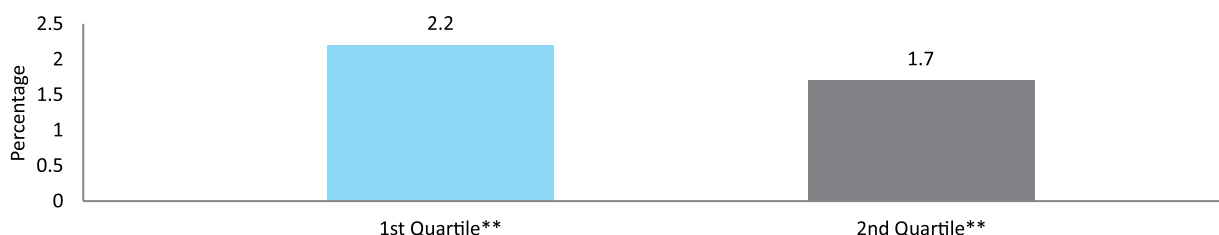
Finally, our program had no impact on student knowledge (Appendix Table 14). We anticipated that improved content knowledge of teachers would translate to better teaching and student learning in the classroom. However, we found that even in the case of teachers whose knowledge had improved, their self-reported teaching

**Figure 7. Treatment effect by baseline test score quartiles**

Source: Baseline and endline tests for teachers (LWYT)

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$  (Before adding controls)

Teachers with low score on the baseline test gained more from the treatment, but not robust to adding controls



the control group. Controlling for the unbalanced characteristics of teachers (explained in Section 4), the result of the quartile analysis would be insignificant but in an expected positive direction (Appendix Table 7). The videos were, therefore, useful for boosting the performance of low-performing teachers on the math test. This also confirms that the videos were of high quality and easy to understand.

We found that the impact on teacher test scores did not differ by DTEs' and teachers' gender. Whether they were of the same gender or not made no difference<sup>16</sup>. In addition, the results did not show heterogeneity based on teacher and DTE experience or on personality characteristics of teachers such as openness and self-efficacy (Appendix Tables 8, 9 and 10). Moreover, results did not differ for teachers who were tech-savvy and for teachers who were not. This is crucial considering technology was such an integral feature of our training model and that training videos could only be watched by accessing them through the software application on the tablets provided. The fact that our program was equally

effectiveness and practices (measured by the use of new examples and methods) did not change significantly<sup>17</sup>. It is possible that the improvement in teacher knowledge was not substantial enough to impact teaching practice and student learning. This could be attributed to the limited exposure of teachers to the training content (discussed above) as well as the limited focus of the videos on pedagogy and teaching strategies<sup>18</sup>. For the future, therefore, apart from addressing content knowledge deficits amongst teachers, the program should also account for a more explicit focus on pedagogy and motivating teachers to alter their teaching practices and lecture content on the basis of the videos they have watched and learned from.

### A closer look at teacher & student performance on endline tests

While our program had limited impact on teacher knowledge and no impact on student knowledge, performance on tests administered during our program give us greater insight about existing levels of mathematical knowledge among both

<sup>16</sup> More than 50% of treatment teachers were female while 90% of treatment DTEs were male.

<sup>17</sup> We had no way of directly measuring whether teaching practices or lecture content improved as a result of improved teacher knowledge. It is possible that teaching practices did change but this change was not captured adequately by questions included in the survey instrument for teachers.

<sup>18</sup> As discussed in Section 2, videos selected for use in our program focused on affording conceptual clarity on selected topics (content knowledge) as opposed to how teachers could teach those concepts better (pedagogical knowledge), even though modeling of teaching methods was implicit in the videos to some extent.

groups and what is needed in the next iteration of this model.

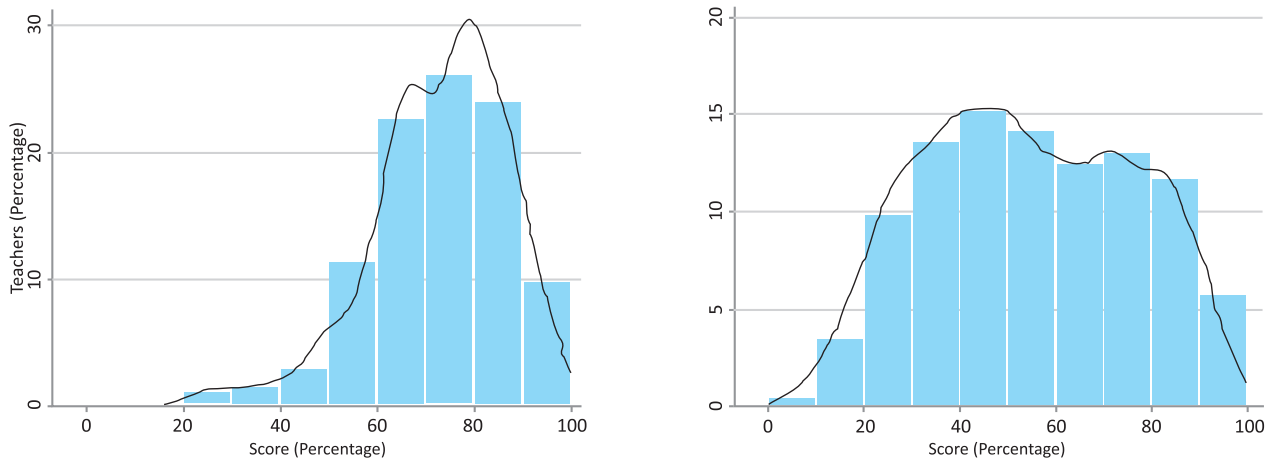
The endline test taken by teachers covered subject knowledge of mathematics from the syllabi of grades 3, 4 and 5. It had 32 questions in order of increasing difficulty (easier questions corresponded to the grade-3 curriculum and difficult questions to the grade-5 curriculum). On average, teachers scored 70% on the endline test. The endline test given to students comprised of 30 questions from the syllabi of grades 2, 3 and 4. On average, students scored 54% on the endline test.

content knowledge deficits exist across teachers; b) teachers have inadequate pedagogical skills; and c) teachers are not fully aware of their students' competencies and actual abilities. Each of these is discussed below.

### Content knowledge deficits

A closer examination of teacher tests scores reveals that teachers were able to correctly answer 76.5% of the easier/medium difficulty questions which corresponded to grade-3 and 4 curricula. However, teachers were only able to correctly answer 65%

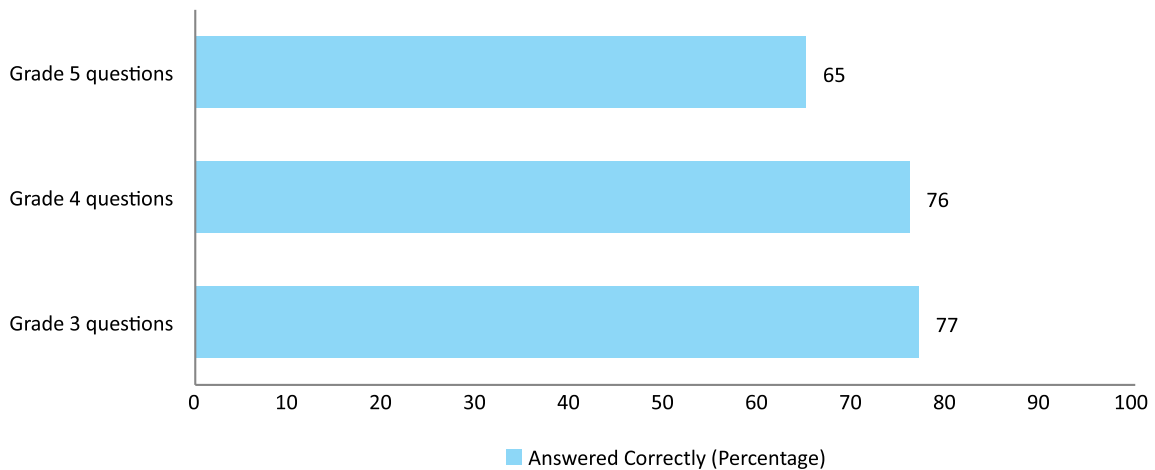
**Figure 8. Distribution of teacher & student test scores**  
Source: Endline tests for teachers and students (LWYT)



The tests for both teachers and students focused primarily on fractions, the focus of videos used in our program; however, we also included some questions pertaining to other topics to establish baseline learning levels for future research. A detailed analysis of test score data reveals that a)

of the questions pertaining to topics in the grade-5 curriculum (see Figure 9 below). This shows that teachers do not have adequate content knowledge of the subject. To be able to teach grade-4 mathematics well, teachers are required not just to master competencies of grade-4 mathematics

**Figure 9. Teacher performance on test questions relative to difficulty level**  
Source: Endline test for teachers (LWYT)



(or that of earlier grades) but also more advanced material such as that pertaining to grade-5.

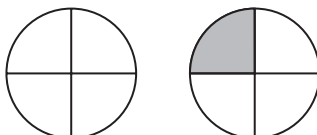
The example below (Figure 10) shows that 73% of students and 45% of teachers were unable to identify the fraction which represented the shaded region in the figure. Where teachers are struggling with topics, it is fair to assume that students will struggle too.

Even where teachers appeared to possess content knowledge and answered questions on some topics correctly, it became apparent that their conceptual understanding of the same topics was limited. Figure 11 on the next page shows that even though teachers were able to answer questions on basic operations correctly, 80% of them still lacked conceptual understanding about operations.

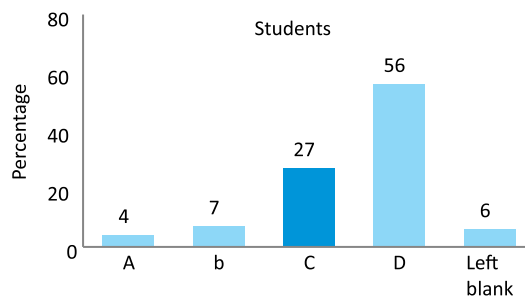
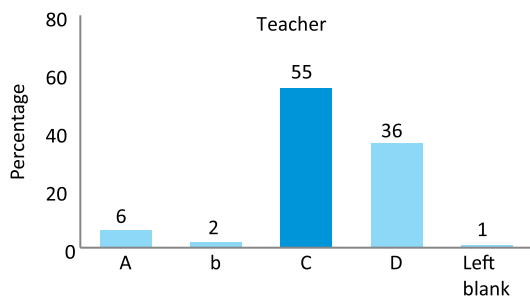
**Figure 10. Teacher & student responses on questions pertaining to fractions**

Source: Endline tests for teachers & students (LWYT)

what fraction of the two breads (Roti) is she illustrating below?

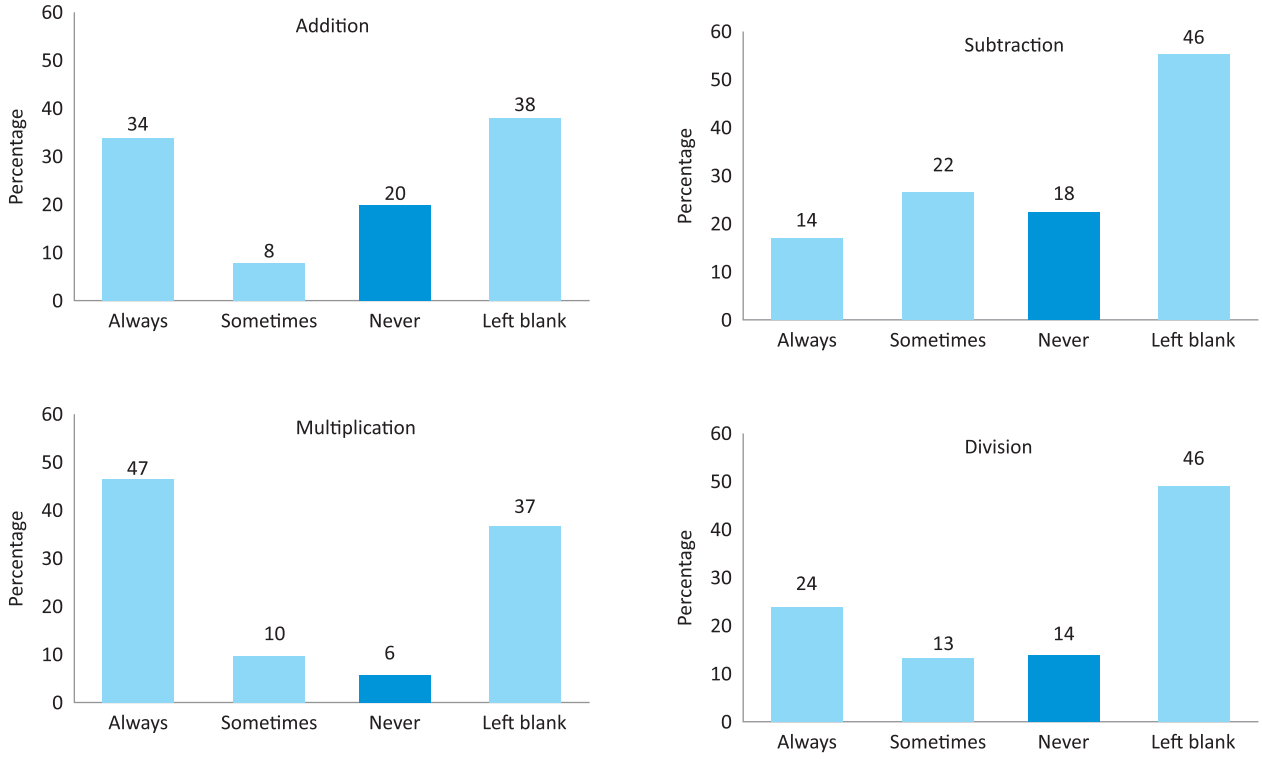


- a)  $5/4$
- b)  $5/3$
- c)  $5/8$
- d)  $1/4$



**Figure 11. Teacher performance on conceptual questions related to basic math operations**  
 Source: Endline test for teachers (LWYT)

Teachers were asked whether the statement “two negatives makes a positive” is always, sometimes or never true in the following cases (correct answer is colored in dark blue):

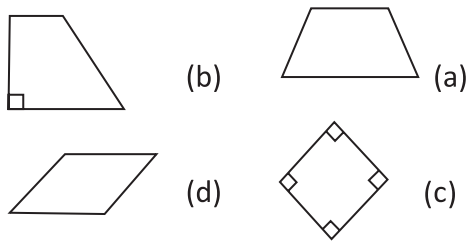


It was also apparent from teacher performance on the test that content knowledge deficits are more pervasive and restricted not just to fractions

and related concepts but to other topics as well including geometry (See Figure 12 below).

**Figure 12. Teacher performance on questions related to geometry**  
 Source: Endline test for teachers (LWYT)

Which quadrilateral has two acute angles, two obtuse angles, and two pairs of opposite parallel sides?



55% answered incorrectly

Salman draws a triangle with one 90o angle. What could be the measures of the other two angles in Salman’s triangle?

- a) 30° and 60°
- b) 90° and 90°
- c) 60° and 120°
- d) 60° and 180°

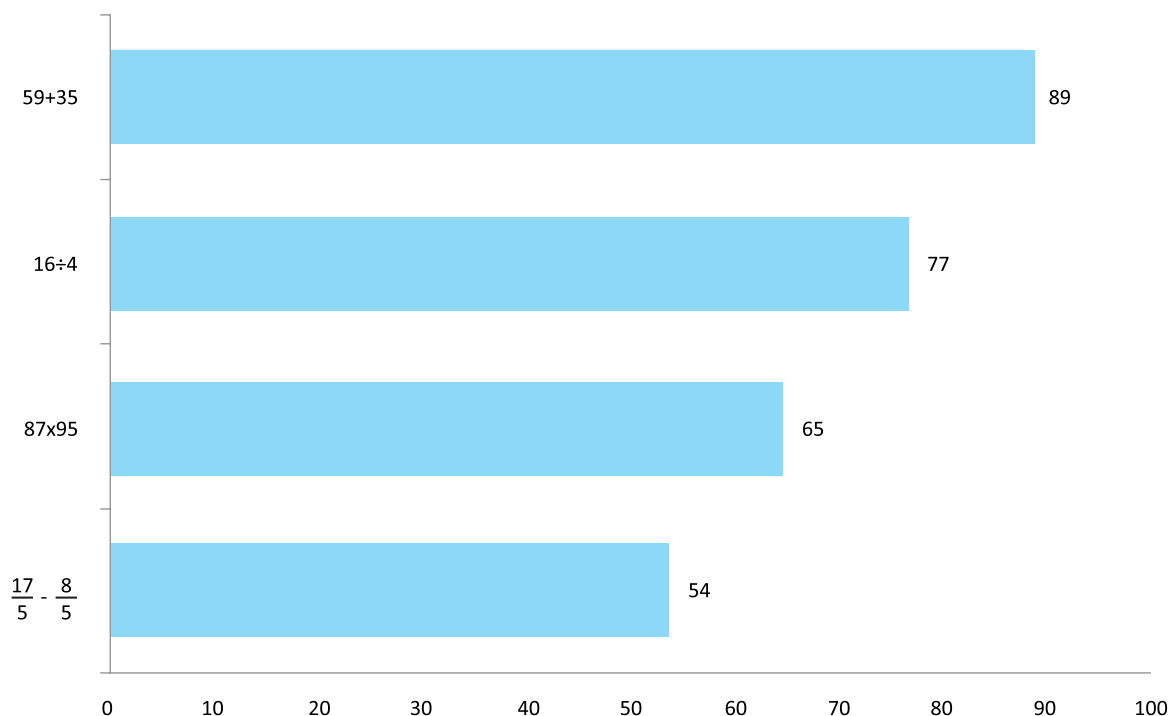
30% answered incorrectly

## Inadequate pedagogical skills & teaching practices

While students were able to answer questions on the endline test from the grades-2 and 3 syllabi correctly, more than half of them were unable to

students. Taking these 20 questions alone, we find that teachers scored 81% on average (standard deviation was 14.7) while students scored 46% on average (standard deviation was 25) on the same set of questions. Figure 14 on the next page compares teacher and student performance

Figure 13. Student ability to solve basic math operations  
Source: Endline test for students (LWYT)

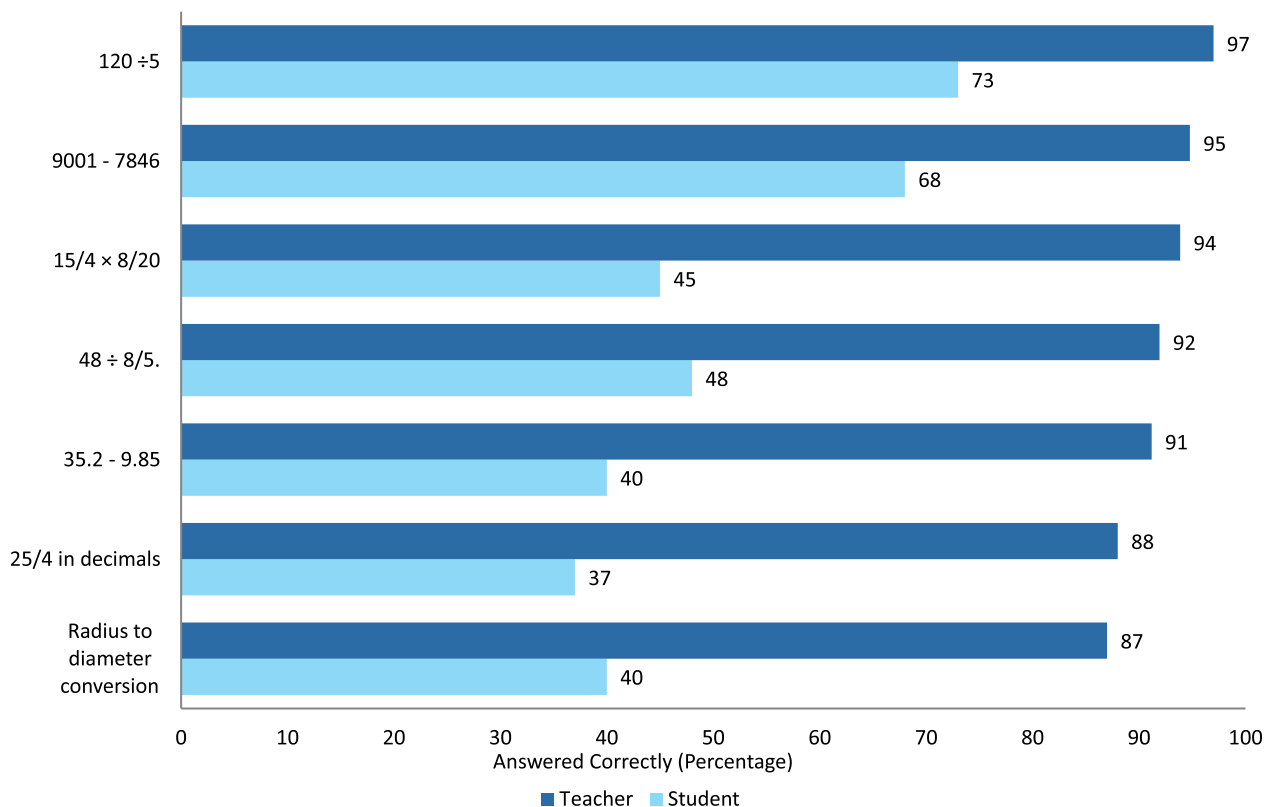


answer questions from their own grade curriculum correctly. As seen in the figure above, most students were able to perform basic two-digit addition and 65% were able to perform two-digit multiplication. However, 5 out of 10 students were unable to perform simple subtraction of fractions.

There were 20 questions that were common to endline tests administered to both teachers and

on selected questions on the tests. It shows that students were getting wrong the very same questions that the teachers were getting right. So even in instances where teachers *did* have adequate content knowledge of certain topics, they were unable to adequately translate that understanding into student achievement on the test. To a certain extent, this indicates the existence of pedagogical deficits and scope for training on pedagogy.

**Figure 14. Teacher & student responses on the same questions**  
 Source: Endline tests for teachers & students (LWYT)



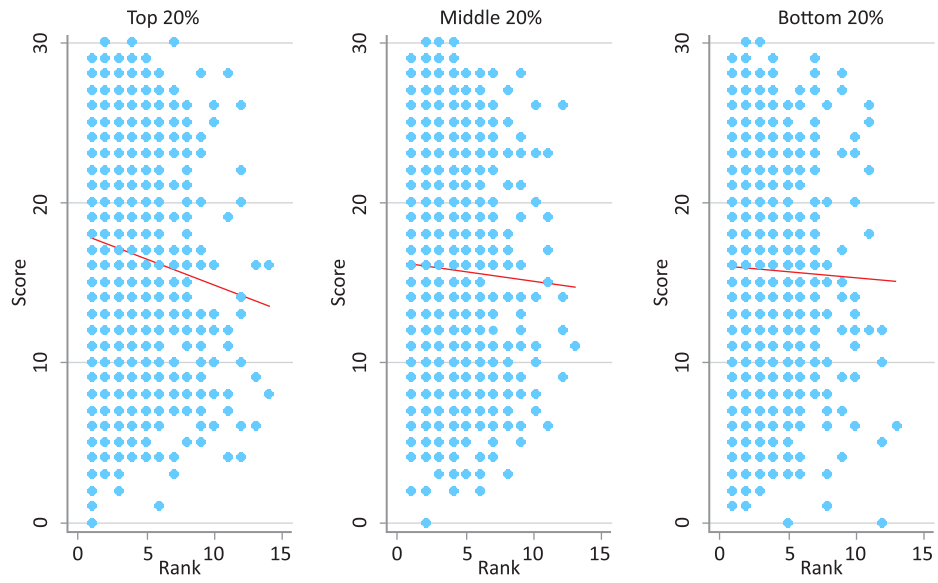
### Lack of awareness of student competencies

In order to teach effectively, teachers need to have knowledge of their students’ abilities so that they can cater to the needs of both the class at large and of individual students. This is referred to in the literature as Knowledge of Content and Students (KCS) and is considered an essential component of Mathematical Knowledge for Teaching (MKT). To get at an absolute measure of perceived student ability, we asked teachers to tell us if they thought that each of their students could solve the question  $120 \div 5$ . In addition, to obtain a relative ability measure, we also asked teachers to assign a rank to each of their students based on their ability in mathematics.

With regards to the former question, teachers reported that 90% of their students in grade-4 could solve  $120 \div 5$  whereas in actual fact, only 65% of students were able to solve the question correctly. It is possible that teachers were overstating their students’ ability in case this is construed negatively as a reflection on their performance.

With regards to the latter i.e. teachers’ assigning a unique rank to each of their students, we found that the overall correlation between teachers’ assigned ranks and students’ scores was quite low at  $-0.0539$ . Figure 15 on the next page shows the three groups of students based on teachers’ ranking: the top 20%, the middle 20% and the bottom 20% and plots the ranking assigned to these students against the marks obtained by them on the LWYT endline test. While we expected to see significant differences between the performance of students ranked the highest and students ranked the lowest we found that their performance did not in fact vary that much. While the average score of the top 20% of students (as ranked by teachers) was 16.9 out of 30, the average score of the bottom 20% (as ranked by teachers) was 15.8 out of 30. There was only a difference of 1.1 marks while the standard deviation in the test scores of all students was 6.6. The fact that the standard deviation in the scores of both cohorts of students was not different further substantiates the claim that teachers do not have sufficient knowledge of student competencies.

**Figure 15. How teachers ranked their students vs. how students actually performed**  
Source: Endline survey of teachers & endline test for students (LWYT)





# 6

## Conclusion

# Conclusion

In our program ‘Learning while you teach’ we made use of technology—tablets, software and videos—to design and pilot a teacher PD model that could improve the content knowledge of grade-4 mathematics teachers in government schools in three districts of the Punjab province within the DSD’s existing CPD structure in Punjab. Our study comprised an RCT—we randomly assigned 317 DTEs and the 1740 teachers associated with them into treatment and control groups. We studied the viability of the technology as a means of training delivery and evaluated the impact of the training content itself (i.e. videos) on teacher and student knowledge. We learned that the technology piloted was viable with evidence of a high level of compliance and satisfaction amongst teachers and found that the training content had a positive and statistically significant impact on the content knowledge of low-performing and less educated teachers in our program.

The motivation for this study came from the fact that significant learning gaps persist across students in Pakistan. A major cause of this is a lack of well qualified and well trained teachers in the country; teachers being considered the single most critical determinant of student learning. Research is needed, therefore, on how student learning can be improved and, specifically, on how teacher PD can be made more effective. We saw a role for technology in the design and delivery of a better teacher PD model. Using tablets would enable access to standardized, high quality instructional videos on mathematics to train teachers within schools, without requiring that they be physically present at some other training venue (also more convenient for less mobile female teachers in rural areas of the country). Apart from sourcing the hardware, we also sourced high-quality math videos aligned with the Pakistani curriculum and available in Urdu to train teachers. Purchasing the hardware first and thinking about the educational content to upload on it later is considered one of the worst practices of ICT use in education the

globe over and our design took this into account. As discussed in Sections 1 and 2, there is a dearth of credible and rigorous research, that employs RCT methodology specifically, on impact of teacher PD programs in developing countries and Pakistan is no exception. Our program on the use of technology to improve teacher training and our research on its impact are, therefore, pioneering in the context of Pakistan.

We found that teachers were highly receptive to a technology-enabled PD model. As mentioned in Section 5, there was high uptake of the technology with 84% of our treatment teachers in all districts watching at least two-thirds of the math videos on the tablets. Teachers were comfortable using the technology and the majority of them required no or very limited assistance to operate the application and videos which is encouraging considering that only a minority have had access to smart devices or computers before. 88% of teachers felt that the videos were “very beneficial” in explaining concepts and 81% thought the videos were superior as a training method compared to those used in the existing CPD framework.

We were able to see positive and statistically significant impact on teacher knowledge in the case of teachers who scored low on the baseline math test and in the case of teachers with less formal education (i.e. with educational qualifications lower than a Bachelor’s degree). The careful design of the evaluation ensured that the difference in performance can only be attributed to the training model and content piloted in our program and nothing else. This is extremely encouraging and indicative of the potential of the right use of technology to improve education in Pakistan. As discussed in the previous section, overall we found no impact on student knowledge as a result of our intervention.

The results of this study are extremely promising given the “light-touch” nature of the intervention. Despite teachers having been trained through

videos for a total of 8–10 hours during the 4-month rollout, evidence of remedial effects i.e. largest benefits for teachers who had low baseline knowledge and lower education suggests that technology can be used to improve teacher knowledge and skills. The lack of effects for students suggests that the design needs to be tweaked to translate the improvement in teacher content knowledge to improved teaching practices. We need to include the following features in our program design when taking this research forward:

1. Increase teacher viewing time: Teachers were exposed to training content for a very limited duration in this study. In order to increase exposure, tablets and videos need to be provided to teachers directly (instead of mediating their access through the DTE) so that they can view the training content as and when they please both at home and in school. In this study, this was not possible due to resource constraints—we only provided the tablets to the DTEs who would lend them to the teacher for the duration of their monthly school visit (i.e. a couple of hours a month). This was not sufficient. Our findings make a case for the provision of hardware and content to teachers directly. We anticipate much larger gains in teacher knowledge where training time using videos is increased.
2. Introduce additional videos that focus on pedagogy explicitly: Reducing the content knowledge deficit of teachers was the main aim of our study. However, as established in Section 5, we also need to address the pedagogical skills deficit among teachers. The videos we selected in our study while demonstrating teaching methods mostly focused on affording conceptual clarity on the selected topics. Videos that promote teacher reflection on their practices more explicitly need to be introduced as part of the training as well.
3. Monitor teachers' use of videos in classroom teaching practices: It is important that teacher use of video training and their incorporation of what they have learned from the videos in their lessons in the classroom be monitored. As already mentioned in the literature, it is not enough to have comprehensive and useful digital educational content. Teachers need to be motivated and monitored so as to incentivize them to make real changes to their teaching practices. DTEs are already engaged by DSD to

conduct classroom observations of teachers they mentor during schools visits. These can be made use of and the DTE can check to see that teachers are not just watching the videos but using techniques used in the videos to teach children better.

The implications of our study and its findings for in-service teacher training in Punjab are far reaching. First, our model fits in neatly with the existing CPD framework and integrates well with the existing role of the DTE as defined by the DSD. This is critical given that education initiatives normally bring with them new infrastructure, processes and personnel. Our model requires none of these. Building upon the existing CPD model and making use of the processes, systems and personnel already in place is critical to the sustainability of the program. Second, it addresses one of the key challenges of the current CPD model which is that teachers are not trained in a standardized way across the province. Teacher training is in large part dependent on the knowledge, skills and competencies of the DTE who is available and appointed at the local level. By identifying high quality digital education content i.e. videos in Urdu that are aligned with Pakistan's curriculum, we have provided the government with an option to use standardized high quality videos to train all their teachers sitting where they are. We also found that there was no heterogeneity of impact on the basis of DTE experience or teacher gender, demonstrating that the training was indeed standardized. Designing and producing videos as a learning resource from scratch is no easy task. Neither is translating or adapting existing resources. Both require highly specialized expertise that government institutions often do not have. *Karismath* provides an affordable and sustainable solution and has been identified by us after an exhaustive review of available resources. The Punjab Government must capitalize on this effort and consider it seriously for use by both teachers and students moving forward.



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# 7

## Appendix

# Regression Tables

Tables 1 – 4 show the 58 baseline outcomes for which balance was checked. Highlighted p-values indicate unbalanced variables.

**Table 1**

DTE Level	Variable Label	T	C	p-values
bach_degree	DTE Education - Bachelor Degree	0.785	0.774	0.777
bach_edu	DTE Professional Educ - Education Degree	0.327	0.316	0.832
dte_govt_exp	DTE Experience as teacher	14.369	14.165	0.832
dte_exp_dte	DTE experience as DTE	3.211	3.103	0.631
dte_schl_assign	Number of schools assigned	13.165	13.346	0.188
dte_tech_mentor	Number of teachers assigned	32.570	35.843	0.021
dte_touch_use	DTE usage of touch devices	12.767	13.106	0.855
dte_comp_use	DTE usage of computers	13.209	13.247	0.94
dte_resp_cpd	DTE response to CPD	4.153	4.063	0.251
dte_score_norm_m	DTE score in math test	-0.063	0.059	0.258
dte_score_norm_s	DTE score in science test	-0.014	0.028	0.628
dte_person_scor	DTE personality score	-0.001	0.008	0.894
extroversion_norm	Big5 Test - Extroversion	0.000	0.007	0.91
openness_norm	Big5 Test - Openness	0.052	-0.053	0.356
agreeableness_norm	Big5 Test - Agreeableness	0.039	-0.034	0.515
conscientiousness_norm	Big5 Test - Conscientiousness	-0.095	0.110	0.056

**Table 2**

School Level	Variable Label	T	C	p-value
Rural	School in rural area	0.892	0.888	0.666
PrimarySchool	Primary level school	0.628	0.592	0.15
MiddleSchool	Middle level school	0.231	0.255	0.331
HighSchool	High level school	0.130	0.132	0.861
HigherSecondarySchool	Higher secondary level school	0.011	0.019	0.157
MasjidMaktabSchool	Masjid maktab level school	0.000	0.002	0.155
schl_tot_enrol	Total enrolment in school	153.424	155.507	0.636
tech_tot_prim_lvl	Total teachers in primary level	4.583	4.585	0.932

Male	Gender enrolled: Male	0.354	0.329	0.228
Female	Gender enrolled: Female	0.217	0.197	0.269
Both	Gender enrolled: Both	0.429	0.474	0.067
g4_class_size	Grade 4 class size	19.196	19.031	0.842

Table 3

Student Level	Variable Label	T	C	p-value
Male	Student Gender: Male	0.550	0.541	0.602
child_abs_ten_days	Child Absenteeism	0.530	0.635	0.082
child_quest_solve	Can child solve 120/5	0.910	0.912	0.73
Lessthan15000	Child HH income: Less than 15000	0.855	0.864	0.644
Between1500045000	Child HH income: Between 15000 & 45000	0.126	0.117	0.589
Morethan45000	Child HH income: More than 45000	0.003	0.002	0.292
Idontknow	Child HH income: Teacher don't know	0.016	0.017	0.835

Table 4

Teacher Level	Variable Label	T	C	p-value
bach_and_below	Teachers education: Bachelors and below	0.612	0.568	0.101
master	Teachers education: Masters	0.368	0.406	0.146
phd	Teachers education: Phd	0.020	0.025	0.478
tech_g4_exper_prim	Teacher primary experience	15.241	14.301	0.13
tech_g4_exper_math	Teacher G4 math experience	14.230	13.258	0.104
tech_g4_exper_sci	Teacher G4 science experience	10.046	8.996	0.069
tech_prof_edu_deg	Teacher professional education - yes or no	0.516	0.561	0.068
tech_period_day	Periods per day	6.718	6.732	0.878
g4_and_3_or_more_class	Teacher teaching G4 and 3 or more classes	0.356	0.377	0.502
tech_tot_stu	Total students under this teacher	161.975	166.810	0.366
tech_hrs_week_class	Hours in a week spent on class	24.827	25.237	0.048
tech_hrs_week_lesson	Hours in a week spent on lesson plan	3.361	2.908	0.00
tech_hrs_week_admin	Hours in a week spent on admin duties	1.526	1.446	0.295
tech_hrs_week_oth	Hours in a week spent on other activities	0.160	0.154	0.933
tech_lwyt_score_m_norm	Teacher math test score	0.040	0.015	0.564
tech_lwyt_score_s_norm	Teacher science test score	-0.058	-0.055	0.988
tech_person_score	Teacher personality score	-0.019	-0.030	0.754
tech_self_eff_score	Teacher self-efficacy score	-0.003	0.036	0.27
extroversion_norm	Big5 Test - Extroversion	-0.019	-0.038	0.684
openness_norm	Big5 Test - Openness	0.002	-0.041	0.349
agreeableness_norm	Big5 Test - Agreeableness	-0.018	-0.013	0.97
conscientiousness_norm	Big5 Test - Conscientiousness	-0.042	-0.029	0.805
tech_tech_savvy	Teacher familiarity with touch and computer devices	3.302	3.329	0.946

Table 5

**Overall effect on endline math test scores**

VARIABLES	(1)	(2)
	ANCOVA - No Control	ANCOVA - With Controls
treatment	0.938 (0.732)	0.695 (0.743)
score0	0.315*** (0.0284)	0.316*** (0.0285)
Observations	1,462	1,462
R-squared	0.111	0.118

Robust standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

Strata fixed effects not shown

Table 6

**Heterogeneity in treatment effect on endline math test score by teacher education.**

VARIABLES	(1)	(2)
	ANCOVA - No Control	ANCOVA - ANCOVA Controls
treatment	0.141 (0.819)	-0.184 (0.854)
below_bach <sup>1</sup>	-3.478*** (1.015)	-3.606*** (1.015)
teach_t_below_bach	2.500* (1.404)	2.715* (1.421)
score0	0.302*** (0.0285)	0.302*** (0.0285)
Observations	1,462	1,462
R-squared	0.119	0.126

Robust standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

Strata fixed effects not shown

<sup>1</sup>Below\_bach is a dummy variable which has value 1 for teachers with F.Sc or less education qualification.

**Table 7****Quantile effect on endline math test score**

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	ANCOVA - No Control - 0.25th Quantile	ANCOVA - No Control - 0.50th Quantile	ANCOVA - No Control - 0.75th Quantile	ANCOVA - ANCOVA Control - 0.25th Quantile	ANCOVA - ANCOVA Control - 0.50th Quantile	ANCOVA - ANCOVA Control - 0.75th Quantile
treatment	2.222** (1.130)	1.667** (0.718)	-0 (0.708)	1.043 (1.172)	0.495 (0.808)	0.373 (0.818)
score0	0.400*** (0.0356)	0.300*** (0.0269)	0.240*** (0.0307)	0.376*** (0.0407)	0.315*** (0.0299)	0.255*** (0.0344)
Observations	1,462	1,462	1,462	1,462	1,462	1,462
R-squared	0.109	0.108	0.101	0.114	0.113	0.107

Standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

Strata fixed effects not shown

**Table 8****Heterogeneity in treatment effect on endline math test score by teacher's tech savviness, teacher's professional education and if DTE Teacher were of same gender.**

	DTE Teacher Same Gender		Teacher's Tech Savvy		Teacher Professional Education	
VARIABLES	(1)	(2)	(5)	(6)	(9)	(10)
	ANCOVA - No Control	ANCOVA - ANCOVA Controls	ANCOVA - No Control	ANCOVA - ANCOVA Controls	ANCOVA - No Control	ANCOVA - ANCOVA Controls
treatment	0.427 (1.014)	0.305 (1.002)	0.731 (0.857)	0.555 (0.865)	1.643 (1.106)	1.501 (1.105)
same_gender	3.977*** (0.965)	4.074*** (0.972)				
score0	0.292*** (0.0278)	0.292*** (0.0279)	0.312*** (0.0285)	0.313*** (0.0285)	0.304*** (0.0286)	0.305*** (0.0286)
treat_same_gender	0.972 (1.444)	0.784 (1.430)				
tech_tech_savvy			0.0601	0.0657		

			(0.0715)	(0.0717)		
treat_tech_savvy			0.0654	0.0466		
			(0.0986)	(0.0972)		
tech_prof_edu_deg					2.764***	2.864***
					(0.969)	(0.967)
treat_prof_edu					-1.148	-1.336
					(1.423)	(1.461)
Observations	1,462	1,462	1,462	1,462	1,462	1,462
R-squared	0.134	0.140	0.113	0.119	0.118	0.124

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05,

\*p<0.1

Strata fixed effects not shown

**Table 9**

***Heterogeneity in treatment effect on endline math test score by teacher's gender, teacher experience and DTE experience.***

VARIABLES	Teacher's Gender		Teacher's Experience		DTE Experience	
	(5) ANCOVA - No Control	(6) ANCOVA - ANCOVA Controls	(9) ANCOVA - No Control	(10) ANCOVA - ANCOVA Controls	(13) ANCOVA - No Control	(14) ANCOVA - ANCOVA Controls
treatment	0.304 (1.044)	0.149 (1.036)	-0.0147 (1.018)	-0.350 (1.036)	0.379 (1.120)	0.198 (1.133)
score0	0.290*** (0.0279)	0.291*** (0.0280)	0.303*** (0.0286)	0.303*** (0.0286)	0.315*** (0.0283)	0.316*** (0.0285)
tech_male	4.106*** (0.944)	4.186*** (0.956)				
treat_male	1.055 (1.437)	0.936 (1.423)				
tech_exp_10			-2.908*** (0.925)	-2.958*** (0.921)		
treat_tech_exp_10			1.677 (1.416)	1.837 (1.419)		
dte_exp_dte_3					-1.295 (1.024)	-1.264 (1.026)
treat_dte_exp_3					1.063	0.965

					(1.485)	(1.509)
Observations	1,462	1,462	1,462	1,462	1,462	1,462
R-squared	0.136	0.143	0.117	0.124	0.112	0.119

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Strata fixed effects not shown

**Table 10**

**Heterogeneity by personality characteristics (self-efficacy and openness).**

VARIABLES	ANCOVA - No Control	ANCOVA - ANCOVA Control	ANCOVA - No Control	ANCOVA - No Control
treatment	0.918 (0.731)	0.677 (0.742)	0.923 (0.733)	0.682 (0.744)
t_openness_norm	0.443 (0.507)	0.439 (0.504)		
t_t_openness_norm	-0.172 (0.725)	-0.201 (0.720)		
t_tech_self_eff_score			0.101 (0.887)	0.318 (0.881)
score0	0.314*** (0.0284)	0.314*** (0.0286)	0.317*** (0.0283)	0.317*** (0.0284)
Observations	1,462	1,462	1,462	1,462
R-squared	0.112	0.118	0.111	0.118

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Strata fixed effects not shown

**Table 11**

***Outcome variable is teachers’ response when asked if “DTE training was helpful in increasing conceptual knowledge of Mathematics”<sup>1</sup>***

	(1)	(2)	(3)	(4)
VARIABLES	ANCOVA - No Control	ANCOVA - Ancova Controls	ANCOVA - No Control	ANCOVA - Ancova Controls
treatment	0.0469*	0.0508**	0.0679**	0.0733**

<sup>1</sup>Response was recorded on the Likert Scale. For this regression the dependent variable is a dummy variable with 1 if Likert score was 5 (extremely positive) and 0 otherwise.

	(0.0249)	(0.0253)	(0.0294)	(0.0300)
s05q16_d_0	0.114***	0.112***	0.108***	0.106***
	(0.0262)	(0.0262)	(0.0260)	(0.0261)
below_bach			0.100***	0.100***
			(0.0357)	(0.0359)
t_below_bach			-0.0669	-0.0705
			(0.0525)	(0.0527)
Observations	1,462	1,462	1,462	1,462
R-squared	0.090	0.094	0.095	0.099

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Strata fixed effects not shown

**Table 12**

**Outcome variable is teachers' response when asked if they "incorporated DTE suggestions into their classroom teaching?"<sup>1</sup>**

	(1)	(2)	(3)	(4)
VARIABLES	ANCOVA - No Control	ANCOVA - Ancova Controls	ANCOVA - No Control	ANCOVA - Ancova Controls
treatment	-0.0151	-0.0124	-0.0586**	-0.0572**
	(0.0222)	(0.0220)	(0.0275)	(0.0278)
s07q17_0	-0.0151	-0.0142	-0.0163	-0.0151
	(0.0256)	(0.0261)	(0.0254)	(0.0258)
below_bach			-0.0611**	-0.0631**
			(0.0284)	(0.0281)
t_below_bach			0.123***	0.124***
			(0.0452)	(0.0452)
Observations	1,399	1,399	1,399	1,399
R-squared	0.018	0.027	0.024	0.033

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Strata fixed effects not shown

<sup>1</sup>Response was recorded on the Likert Scale. For this regression the dependent variable is a dummy variable with 1 if Likert score was 5 (extremely positive) and 0 otherwise.

**Table 13**

**Outcome variable is “additional time (in minutes) spent viewing lesson plan or other resources shared by DTE” reported by the teachers.**

	(1)	(2)
VARIABLES	ANCOVA - No Control	ANCOVA - Ancova Controls
Treatment	13.56*** (1.748)	13.76*** (1.736)
s07q05_0	-0.00602 (0.0298)	-0.00821 (0.0292)
Observations	1,399	1,399
R-squared	0.077	0.084
Robust standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		
Strata fixed effects not shown		

**Table 14**

**Impact on student test scores in the endline survey**

	(1)	(4)
VARIABLES	Simple	With All Imbalance
treatment	-0.628 (1.323)	-0.476 (1.334)
Observations	12,052	12,018
R-squared	0.042	0.079
Robust standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		
Strata fixed effects not shown		

## Selected questionnaires and surveys

A small sample of the survey tools used in the study are provided below.

Sample Tool 1: Teachers Background and Household Information		
<i>To be filled by enumerator</i>		<i>Enumerator Instructions</i>
1	Are you a resident of the Mauza (village) in which this school is located?	Yes=1. No=2 --> Q4
2	If Yes, since how long have you been living in the Mauza (village) in which your school is located?	1= since birth --> Q.4 , 2=since 20 or more years, 3=since 15-20 years, 4= since 10-15 years , 5= 5-10 years , 6= less than 5 years
3	why did you shift to this Mauza (village)	1= For Employment 2= Due to Marriage 3= For Education 4= Others, Please write down the reason
4	What kind of transportation do you use to get to the School?	1=on my own motorcycle, 2=on my own car, 3=public transport, 4= on foot
5	How long does it take for you to get to the school from home?	Please note in minutes
6	What is the average monthly expense of travelling to and from the school to your home?	Write 00 if you walk to the school
7	Besides your own salary and allowances as a teacher in this school, do you have any other sources of income?	1=yes, 2=No,-> section 5 3= I can't disclose--> Q11
8	Please specify the source	1= either cultivate agricultural land or have given agricultural land on lease --> Q11 , 2= another occupation , 3= rent from land/shop/ house->Q11, 4= profit from saving certificates-> Q11 5= other source (please explain)-> Q11
9	What other occupation do you have?	1= Teaching in another school/college 2=tuition center/home tuition 3=own a shop/work in a shop 4=sewing/stitching/embroidery/ handcraft 5=newspaper/news channel/media 6=other part time jobs 7=other full time jobs (explain) 8=other (please explain)
10	How many hours a week do you spend while practicing your other occupations?	
11	What percentage of your total earning comes from your remuneration as a teacher in this school?	Write in percentage form.

**Sample Tool 2: Teacher Information – Technology**  
To be answered by the Teacher

Information Technology has revolutionized the way we access information and a lot of educational material is now available on the internet. For the first time, one can now afford to watch videos/lectures prepared by expert educators elsewhere in the world. In partnership with DSD, a new project is being launched in your district where a subset of DTEs will be selected through a random ballot to receive digital tablets containing educational videos on math and science. The DTE will show these videos to teachers like you on a school's mentoring visit and discuss/share handouts on the videos' content. We would now like to ask you some questions about your perceived value of this project as well as your experience with technology.

1	If the DTEs brought short educational videos relevant to the SLOs on the Mentoring Day, would you be interested in watching them?		1= Yes 2=No
2	Do you think that watching educational videos can improve your subject knowledge or teaching practice in MATHS?		1=Yes, Subject knowledge only 2= Yes, Teaching practice only 3= Both can be improved 4= Neither can be improved 88= if they don't teach maths
3	Do you think that watching educational videos can improve your subject knowledge or teaching practice in SCIENCE?		1=Yes, Subject knowledge only 2=Yes, Teaching practice only 3= Both can be improved 4= Neither can be improved 88= if they don't teach science
4	In your opinion, what percentage of teachers would be happy to watch and learn from these videos?		Report in percentage (0-100)
5	Do you think technology can be used to improve the quality of education in public schools?		1=Yes 2=No
6	Do you think that it will be useful if the DTEs discuss the video and its SLOs with the teachers, once the teachers finish viewing the videos?		1=Yes 2=No
7	Would it be more effective for teachers to see these videos as a group, rather than individually?		1=yes 2=No
8	Do you think that all teachers would benefit equally from the videos?		1=yes 2= No
9	If No, then which teachers would benefit more from the videos? (more than one response is allowed)		1= Teachers with a lot of experience 2= teachers with no experience 3= Teachers with high qualifications (Bachelors or above) 4= Teachers who don't have high qualifications 5= Teachers with a lot of work load 6= Teachers with less work load 7= Highly motivated teachers 8= Teachers who are not motivated 9= other (please explain)

10	Do you think a note accompanying the video (summarizing the video and containing related problems) will help improve teacher's learning from the videos?		1=yes 2=No
11	Now we will ask some questions regarding new technology and its use Do you use a mobile phone?		1=Yes 2=No
12	Do you, or someone else you know, own a touchscreen phone ("smartphone") that you can use to watch educational videos as often as required?		1=Yes 2=No
13	If yes, please provide the following details: a. Size of screen (approx)		
	b. Manufacturer		1=Samsung,2= Q-Mobile,3= Nokia, 4=Sony,5= HTC, 6=LG, 7=Huawei, 8=Other(explain)
	c. Relationship with the owner of smartphone		1= My Own 2= Other Member of my HH 3=Colleague 4= Friend 5=Other (specify: _____)
14	Do you, or someone else you know, own a computer/laptop that you can use to watch educational videos as often as required?		1=Yes 2=No -->Q16
15	If you use a computer then whose computer do you use? (more than one answer is allowed)		1= my own 2= spouses' 3=children's 4=colleagues' 5= friends' 6=siblings' 7=parents' 8=school lab/office 9= other (explain)
16	If you use a smartphone or a computer then how much time, on average, do you spend using internet on that device in a WEEK?		Please note the time in hours per week
17	How much time do you spend using these two devices in a WEEK on average?	Smart Phone	Please note the time in hours per week If the respondent doesn't use a particular device then enter -99
		Computer	

Sample Tool 3: SCHOOL INFORMATION						
Module to be Filled by Enumerator					Instructions for the Enumerator	
7	No. of Teacher Positions filled	Regular		Contract		
8	No. of Teachers who are regularly attending school	Regular		Contract		Exclude those teachers who are on long term leave/long term medical leave
9	No. of Female Teachers in the School	Regular		Contract		
10	No. of Male Teachers in the School	Regular		Contract		
11	No. of Teachers Teaching Grade 4	Regular		Contract		
12	No. of Teachers Teaching Grade 3	Regular		Contract		
13	What is the total student enrollment of the school?	Boys		Girls		
14	What is the total student enrollment in Grade 4?	Boys		Girls		
15	What is the total student enrollment in Grade 3?	Boys		Girls		





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