Contextualized-OLPC Education Project in Rural India: Measuring Learning Impact and Mediation of Computer Self-Efficacy

Conflict of Interest: The authors declare that they have no conflict of interest.

Introduction

With mounting evidence of the potential benefits of rapidly diffusing information and communication technologies (ICTs) in learning (Elwood & MacLean, 2009; Richardson, 2011; Thang & Wong, 2010), there is a growing interest in the conditions under which educational transformations occur (Georgsen & Zander, 2013). Technology, when entering the institutional settings of an educational domain, triggers changes in teaching and learning practices (Gill, 2009). ICTs are, in turn, reciprocally evolving as a result of this interaction (Karami, Karami, & Attaran, 2013).

Recognizing the potential of ICTs in an educational reform agenda, the One Laptop per Child (OLPC) initiative has been at the forefront of introducing low-cost computers as a learning tool to marginalized populations in developing countries (Quadir & Negroponte, 2009; Warschauer & Ames, 2010). With hundreds of thousands of OLPC laptops deployed in classrooms, further investments are being planned via large-scale governmental initiatives (Bhatnagar, 2012; OLPC, 2014). Scientific evidence of learning impact is however trending well behind the media publicity surrounding the introduction of innovative technological devices (Andrews, 2013; Richtel, 2012; Yola, 2014), with Echeverría and colleagues arguing that the “mere deployment of this technology has no added educational value in itself” (2011, p. 1127).

Pressed to demonstrate educational impact, current research trends problematize the adoption of a techno-deterministic approach. We share the criticisms leveled at certain optimistic conclusions that regardtechnology introduction as a solution for educational problems faced in developing countries, without the accompanying empirical evidence (Li, 2014; Toyama, 2015; Traxler, 2010). Some studies have attempted to investigate transformations in education using technology introduction alone (Ferro et al., 2011; Schulte, 2015). Prior research established that institutional environments play an influential role in technology adoption and impact on learning outcomes However, we argue that the failure to identify and investigate factors within complex institutional environments is a research gap. The educational technology deployment models in developing countries need to consider structural issues, such as the lack of adequate human resources (teachers, teacher training, etc.) and infrastructure (schools, libraries, textbooks, electricity, etc.) (infoDev, 2010; UNESCO, 2012).

Indeed, scholars have suggested access to technology hardware itself has limited effects on learning; “what really matters is the institutional environment that makes learning possible” (Mejia, 2014, p. 1). Thus, a one-size-fits-all approach that prioritizes technology ignores consideration for end-user needs and relevance to local context (Carrasco & Torrecilla, 2012). We need to be careful that the argument here is not problematized merely as a critical approach to prevalent techno-determinist paradigms. As Castells and Himanen (2014) argued, beyond the production of advanced technologies, the pressing issue deals with building required capacity amongst users to acquire and efficiently use emerging technologies.

We argue that impactful and sustainable transformations in education are not only contingent on the provision of affordable technologies, but require paying adequate attention to contextualizing implementations (Glewwe, 2013) for specific users. Traditionally, greater attention has been given to macro-level analysis of technology impact (United Nations, 2011), with limited investigations of user psychology (Saariluoma & Oulasvirta, 2010).

The problem then is not so much the focus on technology, but the lack of consideration of the environmental context (capacity for teaching) as well as the lack of understanding of user psychology (capacity for learning), both of which influence educational outcomes. Consequently, giving primacy to mere deployment of ICTs has limited relevance to users, both in terms of use and outcome. Thus, this research examines the impact of technology introduction via the development of two key arguments. First, we argue that technology introduction requires that contextually germane factors in implementation, particularly teaching and the learning environment, are taken into consideration. Secondly, we examine impact on learning outcomes, focusing on understanding the psychological mechanisms of the learning process.

To differentiate this study from prior OLPC studies, we label it as the Contextualized-OLPC (C-OLPC) education project. We theoretically situate the study design on the Technology Community Management model (Author, 2008, 2009) and build upon an earlier field study (hereafter called the 2011 study) that identified key contextual factors. Based on the model, the formative research identified three community-based factors of teacher training, unbiased gender access and local language use. In this study we measure the impact of contextualized design on actual users by implementing these three factors. To do so, we first investigate whether the C-OLPC implementation design led to significant increases in learning outcomes; operationalized as functional and technological literacies. Second, we investigate the psychological mechanism of impact at the user level, conceptually situating the quasi-experiment in the social cognitive theory of learning (Bandura, 1997) to test the mediating effect of computer self-efficacy (Compeau & Higgins, 1995) on learning outcomes from the C-OLPC implementation.

Literature Review

The acquisition of 21^{st} century literacy, encompassing both technological and functional knowledge and skills (Jones-Kavalier & Flannigan, 2006), is often acknowledged as a fundamental tool for development (Paran & Williams, 2007), and economic growth (Sundaram & Vanneman, 2008). However, the developing world has historically encountered low overall literacy rates. While the number of illiterate persons has fallen over the past decade, the 775 million adults who still lack basic reading and writing skills are concentrated in the regions of

South and West Asia, home to 52% of the global illiterate population (UNESCO Institute for Statistics, 2012). Harnessed into educational institutions, technology has been touted as a savior. Certainly, computer usage is associated with 21st century literacy (Cartelli, 2013), and consequently with academic performance and learning outcomes (Kennedy et al., 2008; Streatfield & Markless, 2008).

The association between technology and learning became a clarion call for developers of supposedly revolutionary hardware and software, such as the Intel Classmate PC, India's Simputer, Computador Popular from Brazil, and Jhai PC in Laos (infoDev, 2010). Within this spectrum, the OLPC initiative was uppermost in capturing the imagination at the 2005 World Summit on the Information Society (Savage, 2012). Based on the idea of a US$100 computing device, millions of dollars have been invested in these laptops (Nugroho, & Lonsdale, 2009). With ongoing deployments in the thousands in Brazil, Peru and Uruguay, planned distribution to millions of users in Asia (Leaning, 2010) would be a marketing coup. However, ambition of such diversity in reach and scope draws attention to our argument that technology implementations require understanding the complex socio-cultural systems in various developing country contexts. Likewise, Toyama (2015, p. 24) asserts that "technology and people interact in complex ways."

While initial reception to the OLPC in developing regions were positive, a number of limitations have been observed largely due to the lack of contextualized implementations (Cristia et al., 2012; Flores & Hourcade, 2009). Kleine, Hollow, and Poveda, (2014) summarized emerging criticisms of de-contextualized OLPC projects, highlighting that institutional leaders had become consumed with the acquisition of hardware in schools, with limited consideration given to their integration with pre-existing curriculum, insufficient technical and maintenance support in the form of institutional resources, and a lack of understanding of the needs of teachers and students within the local community. Instead, such initiatives have viewed "technology as an end in and of itself" (Kleine et al., 2014, p. 36). Heeding criticisms of techno-deterministic perspectives, we next present an integrative model that marries user perspectives with technological inputs.

Technology-Community-Management Model

The Technology–Community–Management (TCM) model (refer to Figure 1; Author, 2008, 2009) argues for an integration of community perspectives with technology influences in order to achieve impact in a sustainable manner. The model proposes that the intersection of software and hardware dimensions of technology interventions with project management dimensions of stakeholder characteristics, the regulatory environment and financial requirements, requires the participation and involvement of the community for successful projects. Most relevant to this study, the TCM model's community dimensions of (1) ownership (that is, promoting ownership by making access available), (2) needs (that is, making ICTs relevant to user needs), and (3) training (that is, building capacity through technology training) (Author, 2011a) echo Tessmer and Richey (1997, p. 88), that "context is a medley of factors that inhibit or facilitate to varying degrees."

The TCM model echoes prior literature (Cristia et al., 2012; Garba, Byabazaire, & Busthami, 2015; Richardson, Nash, & Flora, 2014), emphasizing that specific community aspects need to be addressed to introduce contextually relevant technology interventions in education. First, the 'ownership' factor captures the ability to have physical access to technology, in terms of the amount of time, the frequency, the extent of engagement, as well as the extent of barriers when one uses technology (Byker, 2014; Hohlfeld, Ritzhaupt, Barron, & Kemker, 2008).

Second, the 'needs' factor captures the provision of locally relevant content, particularly with local language (Martins, Steil, & Todesco, 2004). Finally, the 'training' factor captures the formal acquisition of technological and pedagogical skills that facilitate productive ICT use by teachers and students (Angeli & Valanides, 2009; Vanderlinde, Aesaert, & van Braak, 2014). In essence, the three factors suggest that training needs to be considered alongside acknowledging different needs of users, while providing undivided access to educational technologies (Author, 2011a), along with addressing issues related to extant socio-cultural, psychological and informational barriers in the community (United Nations Development Programme, 2009; Zhao, 2008).

The model has been applied in the developing nation context in the domains of disaster management (Author, 2009) and healthcare projects in China (Author, 2009), Indonesia (Author, 2010) and Thailand (Author, 2012), but more relevant to this study, in an ICTE project in India (Author, 2011a). This last (Author, 2011a) study formed the basis of our research trajectory on contextualized ICT implementations. The study identified three factors based on the community dimensions of ownership, training, and needs that inform the strategic implementation of contextually germane educational technology projects, namely unbiased gender access, teacher training, and local language use.

Ownership: Unbiased gender access. In the rural Indian context, a historical bias in favor of male children sparks issues of a gender divide in homes and in schools (USAID, 2008). Further, entrenched gender disparities result in almost 20% lower functional literacy rates, or the basic acquisition and use of reading and writing skills needed in everyday life and for work (Coombe, 1992), among females than their male counterparts in Uttarakhand (School Education Government of Uttarakhand, 2015). Our 2011 study found that the socio-cultural barrier of gender favoritism carried over to teachers' biased attitudes towards preferential access for computer learning among boys. Gender discrimination was even exhibited by children, when boys enforced a sense of power and control over the girls in the computer classroom, dominating laptop use and sometimes resorting to aggressive methods to gain control of the OLPC laptops.

Needs: Local language use. Presenting information in local language eases content-comprehension in educational devices, making information easy to find, understand, and navigate (Kozma & Vota, 2014). There was a need to address informational barriers of the OLPC laptop by maximizing application of local language within technology and content, especially for computer programs that used English as the primary medium. Indeed Psetizki (2009) reported that the OLPC's translations to local languages were inadequate. In the 2011 study, students' lack of basic technological literacy and language familiarity hampered their comprehension of various computer terms and symbols necessary to use the technology (Author, 2011a). Although children referred to corresponding picture icons to navigate some programs in the OLPC laptops, this often resulted in frustration and usage withdrawal.

Training: Teacher training. In this digital age, integration of technological resources is pivotal on teachers and teacher training (Almerich, Orellana, Suarez-Rodríguez, & Díaz-García, 2016; UNESCO, 2011; Voogt et al., 2013). Teachers are at the frontline of educational transformations (Angeli & Valanides, 2009) and need to acquire the necessary technological skills to implement ICTs in their teaching practices (Kabakci, Yurdakul & Coklar, 2014; Ottestad, 2010; Wastiau et al., 2013). Various efforts have attempted to address the complexities of teacher training (Aesaert & van Braak, 2015), from courses on internet and computer use, to operation of computing systems (Bingimlas, 2009) and subject-specific educational software training (Author, 2015). However, the technical focus of many teacher training efforts prioritize the acquisition of basic digital literacy skills over mastering a pedagogical use of ICTs (Afshari et al., 2009; Krumsvik, 2014).

Some scholars (Cristia et al., 2012; Melo et al., 2014) have attributed the OLPC program's ineffectiveness to a lack of viable training programs for instructors. Certainly, teachers in rural areas of developing countries face difficulties in acquiring technical skills for teaching using the OLPC laptops (Levin & Wadmany, 2008) and in accessing educational materials in local languages with locally-relevant content (Dlodlo, 2009). Consequently, teachers are overwhelmed with ICT terminologies that are difficult to comprehend (UNESCO, 2007a), additionally complaining that digital tools "didn't follow the curriculum," and they "didn't know how to incorporate digital tools for teaching" (Toyama, 2015, p. 6).

In contract, the Plan Ceibal program in Uruguay offers evidence that OLPC laptops may be a catalyst for transformations in education (Hinostroza, Jara, & Brun, 2011). Wwhen implemented with due consideration for contextual relevance along with the constraints and motivations of teachers (Villanueva & Olivera, 2014), Plan Ceibal successfully trained 18,000 teachers to improve the impact of digital technology access to over 400,000 children in primary schools (Hinostroza et al., 2011). The program's initial deployment was critiqued as being "too focused on how to use the machine itself, and not focused on how to use it in the learning process" (Derndorfer, 2010, p. 1). In response, a revamp championed the introduction of 'formadores' (teacher trainers), focusing on equipping teachers with technical skills. Another radical redesign of the teacher training program in 2010 incorporated 'maestros de apoyo Ceibal' (support teachers of Ceibal) and 'amigo Ceibal' (friend Ceibal) to train and mentor colleagues on integrating OLPC laptops in classrooms (Hinostroza et al., 2011).

The 2011 study reported psychological barriers to teachers' willingness to use technology, beyond gaining the requisite technological skills for teaching. Teachers expressed resistance due to an impression that training to use the OLPC laptops for teaching would be too complex, that instructions and expectations would be beyond their capabilities (Author, 2011a), combined with a fear of not knowing how to troubleshoot when technical problems arose.

Measuring Impact

After implementing the C-OLPC based on the TCM model, we assessed the impact of this contextualized ICTE project (Heeks & Molla, 2009), whilst acknowledging measurement difficulties (Santiago et al., 2010). ICTE project evaluations have often emphasized infrastructure assessment, in terms of hardware-indicators and pupil-computer ratio, rather than more complex learning outcomes (Hollow & Masperi, 2009; Pischetola, 2011). Concomitantly, a significant trend in ICTE studies (Mills-Tettey et al. 2009; Pal et al., 2009) indicates a common preference for the adoption of qualitative research methods. While qualitative data allow for deep understanding of human experiences supported with rich data that cover the complexities and subtleties of a topic covered, even with smaller sample sizes (Bernard, 2011; Taylor, 2005), it fail to make complex assessments of the causality of an impact.

Prior OLPC studies find mixed evidence of educational impact. A study of 319 public primary schools in rural Peru failed to find evidence of increased learning in Math or Spanish Language (Cristia et al., 2012). In contrast, a quasi-experiment of 27 participating schools of Uruguay's Plan Ceibal showed that OLPC use had a positive effect on children's achievement in mathematics performance, but had no impact on reading (Ferrando et al., 2011). An Ethiopian OLPC program found development of abstract reasoning among students (Hansen et al., 2012). A longitudinal two-year design in Uruguayan schools found no impact on math and reading of OLPC usage (Melo et al., 2014).

We argue that these assessments of the OLPC program focus on the ultimate objective of educational impact, neglecting to examine mechanisms within which learning occurs. We propose that understanding the influence of user psychology on academic outcomes can both counter criticisms of technological determinism, as well as suggest non-technological strategies for improved educational advancement. We first explicate measures to determine technological and educational impact, followed by an elaboration on the mediating effect of self-efficacy on these impact measures.

Technological literacy. We argue that ICTE projects first require users to gain technological knowledge, which then allows for learning in broader educational domains. Technological knowledge has broadened as a measure over the years. Prime's (1998) characterization narrowly focuses such knowledge to terms and signs used in computers. Pearson and Young (2002) then defined technological knowledge as the content that students were expected to learn, while distinguishing capabilities as hands-on skills development and utilization of technology in learning. More specifically, for children who have had little to no exposure to computing technologies, technological literacy was conceptualized as the critical skill-set and ability to operate the technology on their own. The enlarged dimensions of technological literacy encompass not only the ability to understand and use technological knowledge and skills in the classrooms, but in real-world situations as well (Amiel, 2006). We utilize the variable of technological literacy as a measure of technological dimensions of learning, distinct from broader concepts of learning such as functional literacy.

Functional literacy. Functional literacy has been recognized as part of lifelong learning (Leino, 2014), with Ryan (1995, p. 90) claiming that “it is, in effect, a measure of one’s capacity to cope with the educational challenges of a given environment.” A functionally literate individual is defined by UNESCO (2008) as being enabled to continue to use reading, writing and calculation for his or her own and the community's development (Bhola, 1995; Rogers & Herzog, 1966). In addition to boosting the confidence to communicate, improving functional literacy enables one to solve personal and social problems (Literacy House, 1967). Prior studies have demonstrated the positive relationship between computer use and students' functional literacy (Fiorini, 2010; Torgerson & Zhu, 2003; Wood, Pillinger, & Jackson, 2010). We utilize the variable of functional literacy as a broad measure of learning outcomes. As a consequence, our research question and hypotheses are stated as:

RQ1: Does contextualized implementation of the OLPC (C-OLPC) project in rural Indian primary schools lead to positive learning outcomes?

H1: The increase in technological literacy of rural Indian children in the C-OLPC project (test group) will be significantly greater than that of the control group.

H2: The increase in functional literacy of rural Indian children in the C-OLPC project (test group) will be significantly greater than that of the control group.

Mechanisms of Impact

We critiqued prior assessments of OLPC impact for neglecting to examine the psychological mechanisms of learning from a user perspective. We suggest that understanding the mediating effect of user psychology on academic outcomes can counter criticisms of technological determinism. Social cognitive theory (SCT) of learning (Bandura, 1977) investigates psychological mechanisms that impact beliefs and behaviors of people, and has been tested often in educational environment; yet the application within the OLPC context remains a research gap.

Self-reflecting on one's confidence in being able to do a task at hand allows for a competence assessment of past experiences and current skills (Bandura, 1997). SCT proposes that self-efficacy is closely tied to an individual's performance (Saleh, 2008), hence a potent predictor of behavior (Akin & Kurbanoglu, 2011). Researchers can thus examine motivational perceptions relevant to outcomes (Bandura, 1992; Schunk & Pajares, 2004).

Self-efficacy has been found to be an important predictor of learning outcomes (Kapucu & Bahçivan, 2015; Liou & Kuo 2014) since the pioneering work of Schunk (1981) in educational settings. Early studies validated the significance of efficacy beliefs to subsequent performance on related tasks, often concerning the acquisition of knowledge (Bandura, 1982, 1986; Hackett, Betz, O'Halloran, & Romac, 1990). Echoing extant assertions to build technology-related capacity (Castells & Himanen, 2014), the theory posits that usage and resultant knowledge creation are determined by one's belief in their ability to successfully perform a given behavior (Bandura, 1986; Schunk & Pajares, 2004). Specific to the acquisition of new information and skills, Abrahamson and colleagues (2013, p. 2) found a positive relationship between an individual's self-efficacy and knowledge generation, defined as the acquisition and application of "justified belief that increases an individual's capacity for effective action.

Self-efficacy research traditionally looked at academic outcomes (Bandura, Barbaranelli, Caprara, & Pastorelli, 1996; Muris, 2002), with studies demonstrating that efficacy beliefs positively predict students' motivation and educational achievement (Bandura, 1986; Hackett & Betz, 1981; Pajares, 1992; Schunk, 1981) and in increasing learner autonomy (Tilfarlioglu & Ciftci, 2011). Of significance is the concept's predictive value in motivating the adoption of learning strategies (Mattingly & Lewandowski Jr., 2013; Uzuntiryaki & Çapa Aydın 2009).

Self-efficacy is commonly understood as domain-specific, examining the "perceived ability to successfully complete a specific task regarding a subject area" (Huang, 2012, p. 779). This is consistent with investigations attesting to the influential role of self-efficacy beliefs in fostering educational attainments (Bandura, 2006), especially given the advent of digital technologies for learning (Richardson, 2011). Computer self-efficacy (CSE), or individuals' perceptions about their abilities to perform a computing tasks successfully (Compeau & Higgins, 1995), affects a person's acceptance of new communication technologies and skills (Wartella & Jennings, 2000).

Specifically, CSE beliefs may either enhance or hinder the development of effective computer skills (Ertmer, Evenbeck, Cennamo, & Lehman, 1994). Individuals who negatively perceived their ability to successfully perform computer-related tasks, despite the extent of computer experience, were less likely to use computers (Hsia, Chang, & Tseng, 2014). Likewise, they were more likely to avoid or give up on challenging computer-based assignments (Jegede, 2007). It is important to note that CSE is not related merely to technological learning, but to a broad array of academic outcomes. CSE is not only positively related to improved computer skills (Compeau & Higgins, 1995; Lang, Waterman, & Baker, 2009) and intentions towards future engagement with computing technologies (Kher, Downey, & Monk, 2013), but also to learning performance (Potosky, 2002) and scholastic achievements (Torkzadeh, Koufteros, & Pfughoeft, 2003; Wang et al., 2013).

In the educational context, consistent evidence show that self-efficacy serves as a mediator between various antecedents and achievement outcomes; peer support and e-learning outcomes (Chu & Chu, 2010), contextual variables and stressors on teacher burnout (Khani & Mirzaee, 2015), cognitive ability and task-related performance (Chen, Casper, & Cortina, 2001), achievement goals and study processing strategies (Liem, Lau, & Nie, 2008), and self-regulation and academic achievement (Ghonsooly & Ghanizadeh, 2013; Kingir et al., 2013). Despite the importance of this motivational variable, little is known about the mediating role of computer self-efficacy in the relationship between OLPC usage and learning outcomes among users. This research attempts to fill this gap.

We suggest that computer self-efficacy mediates the relationship between technological literacy attained as consequence of the contextualized OLPC education project and a specific learning outcome, functional literacy. Therefore the following research question and hypotheses are raised:

RQ2: Does computer self-efficacy mediate the relationship between technological impact and learning outcomes?

H3: Technological knowledge is positively associated with functional literacy.

H4: The association between technological knowledge and functional literacy of rural Indian children during the C-OLPC education project (test group only) will be significantly mediated by computer self-efficacy.

Method

Study Context, Design and Implementation Strategies

In India, free education is provided compulsory to all children between the ages of 6 and 14. However, government-run primary schools continue to suffer from poor quality education due to high daily absenteeism rates of teachers, insufficiently qualified human and material resources, inadequate infrastructure, and scarcity in teacher training (Makwana, 2011; Pillai, 2014). For example, our fieldwork found that most schools were not equipped with the chairs, tables and adequate learning materials, often requiring students to sit on the ground. These were some of the contextual realties under which this study was implemented.

This study was conducted in the Muktheswar district of Uttarakhand, a hilly and predominantly rural state in the northern Himalayas, which has witnessed literacy rates gradually improving from 72% in 2001 to 79% in 2011 (School Education Government of Uttarakhand, 2015). Building upon this momentum, state and district level education ministries have expressed enthusiasm for using technological tools for learning. However, no concrete policy measures have addressed the provision of technology access in rural schools to enhance education quality and learning outcomes (UNESCO, 2007b; V. Sethi, personal communication, May 17, 2010, 2015).

To resolve the access issue and to facilitate long-term sustainability, we donated fourteen OLPC XO-1 laptops, as part of the C-OLPC research study to a local non-governmental organization (NGO)-collaborator, the Unified Development and Academic Activities Network (UDAAN) Foundation. UDAAN assisted the principal investigator in obtaining necessary governmental and administrative permissions and establishing contact with the schools, and was also involved in conducting computer training for teachers, and providing data-collection services in local Hindi language.

We conducted this study in nine remote regional primary schools. Schools were at least five kilometers apart, with limited modes of transportation between them. As encountered in the prior 2011 study, the contextual conditions of the rural schools, chosen for the research fieldwork, were challenging. None of the schools had internet access. Five participating schools did not have any electricity, with the remaining four having very limited and often inconsistent power supply. Alternate power sources in the form of solar chargers were installed in all schools (funded by the research project) with teachers briefed on their use and maintenance. Despite these measures, it is worth noting that harsh and unpredictable weather conditions often impeded regular charging. While noting that the infrastructural challenges were far from ideal for the introduction of innovative technology, we focus here on the three Community factors, identified by the TCM model, of unbiased gender access, local language use, and teacher training. The contextualized design of the present C-OLPC study implemented strategies to address these three factors.

Strategy for ownership: Unbiased gender access. The strategy employed in this C-OLPC implementation to support equal access was to sensitize teachers of gender biases. However, urging them to allow girls and boys to use the laptops equally evolved in to a strategy to maintain gender segregation in laptop use. We note that whilst some teachers assiduously implemented this strategy, others proceeded to allow mixed gender groups. In such instances, we observed that boys, as seen earlier, dominated laptop use. After the initial weeks of implementation, this strategy was consistently applied by all teachers who divided students into groups by gender, prior to each OLPC session.

Strategy for needs: Local language use. The current C-OLPC implementation aimed to translate technical information to local language for improved comprehension and familiarity in an educational system where teachers and learners were accustomed to reading and writing in the local Hindi language. Basic translations of on-screen options and keyboard symbols, such as the power symbol, battery check, selection menu and spacebar, were provided in the local language on charts placed in every school. This approach facilitated students' ability to grasp the meaning of particular icons and program instructions. Additionally, students and teachers were provided with individual reference documents for use in class that included translated information about selected OLPC programs, meanings of various selections and usage instructions.

Strategy for training: Teacher training. The C-OLPC project designed a technology training curriculum for teachers. Prior to engaging school teachers, UDAAN confederates attended a week-long training workshop conducted by the principal investigator on operating the OLPC laptops, equipping them to guide and conduct computer training with teachers. UDAAN trainers familiarized themselves with all the programs on the laptop and ran practice training sessions with peers. The next stage involved identifying various psychological barriers of teachers, interviewing them about their needs and expectations, and possible anxieties. We noted that none of the teachers had prior access to any form of computing devices in the schools for teaching or administrative purposes, while four of the eight participating teachers had experience using Pentium laptops at home. None of them had previously interacted with OLPC laptops. We found that those lacking technological familiarity faced greater anxiety, whilst all expressed a preference for one-on-one instruction, as opposed to a group training workshop.

Training sessions were conducted when teachers were available, not requiring them to commit extra time beyond school hours. Simplified instructions were provided sans the use of technical jargons, in an attempt to assuage teachers' fears about the complexity of these devices. These extensive training sessions, an average of six hours per teacher over a fortnight, were aimed at building capacity and confidence in their abilities to use the OLPC laptops.

A specific OLPC-subject syllabus was created collaboratively with teachers to integrate with the pre-existing curriculum. These weekly curriculum guide-sheets matched appropriate OLPC programs with corresponding mathematics and language subjects already existing. This provided teachers with structure and guidance in adopting OLPC-based activities alongside textbook-based teaching. Finally, regular weekly technical support by local UDAAN confederates would address problems encountered, and teachers were assisted with troubleshooting techniques as well as device maintenance.

Participants

We recruited 205 fourth and fifth grade students from nine primary schools in the rural regions of Uttarakhand State, India. In schools, children from grades four and five studied en masse in a separate classroom space, while lower-primary graders studied separately. Course materials and teachers were common between these grades. These were reasons why only fourth and fifth graders were chosen for the study – to allow for simultaneous use of the OLPC laptops among a larger group of children in a compatible learning environment. In these remote schools, average class sizes ranged from five to fifty students. However, the class sizes did not correspond to the number of teachers available; one classroom had one teacher to fifty students, while the teacher-student ratio of another school's classroom was one to five. Given these differences, although we conducted the study across 29 classrooms in nine schools, the number of OLPC laptops distributed to the schools depended on the student counts per class session. Only children from test groups shared the devices at an approximate ratio of one to four pupils per laptop.

Selection of participating primary schools was guided by the criteria that all participating children were from similar socio-economic and socio-cultural backgrounds, had no previous exposure to any form of computing technologies in schools, specifically the OLPC laptops, , and were taught using similar language curriculum structures for English and Hindi lessons. The NGO partner confirmed that children and families in the study region had access to computing technologies at cyber-cafes and UDAAN's digital e-learning centers. Thus, computers were not foreign to the study participants, who would have had varying frames of reference to these technologies.

We checked that none of the participants had prior exposure to the OLPC laptops. Given that there was a basis to believe that participants had some level of technology knowledge, questions on technology literacy were asked to participants from both test and control groups. However, questions pertaining to computer self-efficacy, as covered in the second research question, were only limited to the test group since assessment of self-efficacy in this study dealt with beliefs associated to actual usage behaviors.

Schools were selected based on a cluster random sampling amongst primary schools at the district level. Test groups that received laptops with C-OLPC implementation (n=126) and control groups that did not receive laptops (n=79) were randomly assigned to different schools. The students comprised 40% girls and 60% boys ranging from ages 9 to 11, with an equal percentage of fourth and fifth graders. Eight teachers from test schools were involved in C-OLPC training sessions, while four teachers from control schools did not receive such training.

Procedure

A longitudinal quasi-experimental design involved pre- and post- experiment measures conducted with both test and control groups. The shared usage of available laptops is based on past research about the value of a shared-learning model in lieu of popular claims supporting individual ownership of the OLPC laptops (Author, 2011a; Zheng, Warschauer & Farkas, 2013). Due to a need to re-use the 14 OLPC laptops acquired for this research, the quasi-experiments were conducted in two time phases. Participating schools at both phases were selected using the same selection criteria, hence with similar school and student characteristics. Phase 1 was conducted during academic semester from June 2010 to October 2010, and phase 2 from November 2010 to March 2011. Teacher training commenced in test schools a month prior to actual implementation of the C-OLPC education project (refer to Figure 2).

To facilitate responses to the questionnaire, all data were collected in the local Hindi language. The questionnaires were designed in English, and then translated by the local team to

Hindi. A reverse Hindi-to-English language translation was generated to check for translation errors. Survey questionnaires were pre-tested for comprehension with fourth and fifth graders from a non-participating primary school in the district. Pre- survey measurement was conducted with all participants (n=205) a week before laptops were distributed to the test group (n=126), with the post-measurement survey administered at the end of each study phase.

Lessons in the control group continued as per the regular academic curriculum; without any exposure to computing devices. The C-OLPC implementation was incorporated into school-hours, where children used the laptops for an hour daily during a six-day school week, over a period of five months. Teachers claimed that this arrangement had not disrupted their daily teaching, instead generating interest toward an innovative complement to existing didactic method of instruction widely adopted in rural Indian schools.

Five pre-installed programs in OLPC laptops were selected with the guidance of three teachers from participating schools; ‘Tam Tam Mini’, ‘Speak’, ‘Write’, ‘Memorize’, and ‘Record’. The teachers identified programs that were relevant to school subjects, namely mathematics and English and Hindi languages. Teachers were consulted for information on relevant learning activities that students engaged in, which included vocabulary and oral activities in English and Hindi, and simple mathematical additions and subtractions, among others. Feedback from teachers guided the design of weekly curriculum guide-sheets. The relevance of selected programs to pre-existing curriculum made it easier to develop weekly curriculum guide-sheets that complemented extant learning activities. For example, a basic media-function of the ‘Record’ program lets users capture pictures. Given the program capacity, the curriculum guide-sheets included a learning activity that required students to take pictures in the school vicinity and practice talking about the image with peers or make presentations in classes. A similar strategy to target students' verbal communication skills was already in place, where they used picture cards and textbook images. Programmatic details of the instructional design process and implementation can be found in prior publications (Authors, 2012, 2011).

Principals of participating schools were briefed on the project requirements and requested to confirm their interest in participating in the study. All ethical procedures related to research involving human subjects were followed. The purpose of the research and protections from possible risks were explained verbally to all participants. Teachers and students were informed that participation was voluntary and that they would be able to withdraw from the study at any time. Study information sheets were sent to parents informing them of their child's participation and rights. Informed consent was obtained from legal guardians or parents of all individual participants included in the study. Individual names have been withheld for reasons of confidentiality. At the end of the study, all participants were given a token of appreciation.

Instrument

Children's responses to statements were reported on a 7-point semantic scale designed based on feedback from pretesting. Items for all the instruments had a maximum possible score of 7 with higher scores representing greater values for confidence or knowledge. There were no reverse-coding. A composite measure based on their average score was used as the indicator of each measure. Cronbach's alpha (α) for internal consistency was used to determine internal consistency estimates of reliability of the study scales. The composite reliabilities across the variables were greater than the acceptable alpha of .70 (Nunnally, 1978).

Computer self-efficacy (CSE) scale, developed by Murphy, Coover, and Owen (1989), was later modified by Durndell and Haag (2002) into a simpler three factor categorization - basic-level computer skills, advanced-level computer skills, and mainframe computer skills. We measured CSE composed of items regarding children's confidence in their capability of accessing and using basic computer skills. These included questions such as, 'I feel confident that… I can use a laptop; I can use the laptop to write a few sentences; I can move the cursor; and I am able to open the laptop.' The five CSE items were averaged to create a composite index (M = 2.88, SD = 1.53, Cronbach's α = .84).

Technological literacy (TL) was operationalized as children's technological familiarity with terms, signs and basic operation of the OLPC laptop. The items specifically focused on computer-related knowledge included questions such as, 'I know… how to use a laptop; what a keyboard is; the meaning of different symbols in the laptop; and how to type a sentence on the laptop.' The eight TL items were averaged to create a composite index (M = 3.31, SD = 1.29, Cronbach's α = .76).

Functional literacy (FL) as a measure of knowledge operationalized children's basic reading, writing and numeracy skills, tested using items such as, 'I know…the multiplications table until 20; how to add 3-digit numbers mentally; how to read fluently in English; how to spell difficult words in English; and how to describe a picture in Hindi very well.' The eight FL items were averaged to create a composite index (M = 4.92, SD = 1.24, Cronbach's α = .72).

Analysis

A two-way within subject analysis of variance was conducted to evaluate differences in the effects of OLPC usage learning outcomes. Using Sobel's (1986) mediation test procedure, we conducted test of mediation effects.

Results

Pre Scores Comparison of Test Group Vs Control Group

A one-way analysis of variance (ANOVA) was conducted to determine significant differences between the means of the test and control groups for the technology and functional literacy measures using the pre-stimulus scores. Specifically, we wanted to determine the equivalency of the two independent groups (test versus control groups) at the beginning of the quasi-experiment prior to administering the OLPC stimulus. The ANOVA was found to be significant, $F(1, 203) = 26.61, p < .001$. The test group which had access and usage of the OLPC showed a lower level functional literacy when measured against the control group. The means and standard deviations of the two groups are reported in Table 1.

The ANOVA test for significant differences between the means of the test versus control groups for the technological knowledge using the pre-stimulus scores showed that the two independent groups (test versus control) at the beginning of the experiment were also significantly different, $F(1,203) = 4.10, p < 0.05$. Refer to Table 2 for the means and standard deviations of the two groups.

Changes in Technological Literacy - Test Group Vs Control Group

An ANOVA analysis was used to analyze significant differences when comparing the achievement in the technological literacy between the test and control groups. The tests showed significant results, $F(1, 203) = 54.75, p < .001$. The test group which had access and usage of the OLPC showed a greater increase in technological knowledge in comparison to the control group. The strength of the relationship was strong, as assessed by $\eta^2 = .21$. Thus, Hypothesis 1 is supported. The means and standard deviations of the two groups are reported in Table 3.

Changes in Functional Literacy - Test Group Vs Control Group

A one-way analysis of variance (ANOVA) was conducted to test for significant differences between the means of the test group (with OLPC) versus control group (without OLPC) when comparing the functional literacy gains (post – pre). The ANOVA was significant, $F(1, 203) = 43.69, p < .001$. The test group which had access and usage of the OLPC showed a greater increase in functional literacy in comparison to the control group. The strength of the relationship was strong, as assessed by $\eta^2 = .18$. Thus, Hypothesis 2 is also supported. The means and standard deviations of the two groups are reported in Table 4.

Direct Effect of Technological Literacy on Functional Literacy

The hypothesised model was analysed using multiple regression techniques. First, the change in functional literacy was regressed against the change in technological knowledge to test for direct effects of the experiment. In other words, we hope to predict the changes in children's functional literacy from measuring their technological knowledge. The regression equation for predicting the dependent variable of functional literacy from the technological knowledge independent variable was significant:

$$(Change\ in\ Functional\ Literacy = .43 * Technological\ Knowledge - .14)$$

The hypothesis test of interest evaluated whether the independent variable of technological knowledge had a direct effect on the dependent variable of functional literacy. As the 95% confidence interval for the slope, .34 to .53, does not contain the value of zero (refer to Table 5). Hence Hypothesis 3 is empirically supported. Accuracy in predicting the change in functional literacy was moderate as approximately 28.9% (*R-square* = .289) of the variance of the functional literacy was accounted for by its linear relationship with technological literacy.

Mediation Effect of Computer Self Efficacy

We conducted Sobel's mediation test procedure to determine how computer self-efficacy affected the relationship between technological and functional literacies. A significant mediation effect was found: Sobel test statistic, 6.18 ($p < 0.01$, one-tailed). This result suggests that children's computer self-efficacy mediates the association between technological literacy and functional literacy. A summary of the hypothesis testing results of the mediation is presented in Figure 3.

Discussion

The objective of this study was to prioritize local contexts during an OLPC implementation designed to improve learning outcomes for students in the study context. We discuss the importance of the three factors identified in the theoretical TCM model as validated by the empirical evidence presented in the C-OLPC education project – teacher training, unbiased gender access, and local language use – as critical contextual factors to produce beneficial educational outcomes. We are nonetheless adopting a prudent approach in generalizing findings broadly to all developing countries; however we feel that the theoretical conceptualization provides a basis for consideration in other educational technology interventions. Support for hypotheses 1 and 2 suggest that children's usage of OLPC laptops in a contextualized implementation design in rural Indian primary schools did indeed lead to positive learning outcomes, both in technological and functional literacies.

A second objective was to assess the impact of technology introduction while countering extant techno-determinist approaches that are increasingly criticized by scholars for being counterproductive to educational reform efforts (Barrera-Osorio & Linden, 2009; Warschauer, Cotten, & Ames, 2012). We first demonstrated that technological knowledge was associated positively with functional literacy, since H3 was supported. We situated the experiment in social cognitive theory to demonstrate, as seen in support for H4, that computer self-efficacy mediates the relationship between technological literacy attained as a consequence of the contextualized OLPC education project and a specific learning outcome, functional literacy. This finding reiterates prior research that literacy is contingent upon CSE beliefs (Adetoro, Simisaye, & Oyefuga, 2010) with research suggesting that students' perceived self-efficacy significantly improves 21st century literacy achieved via educational technology (Ait et al., 2015; Kurbanoglu, 2003; Streatfield & Markless, 2008). From a theoretical perspective of SCT, the factors identified by the TCM model allow for developing self-efficacy via self-regulation (Bandura, 2003), particularly through enactive and vicarious processes of using the learning tool in a shared environment with peers (Bandura, 2009). From a practical perspective, teachers, curriculum developers, and policy makers can note the importance of cooperative learning environments. This shared usage of device has implications not only for learning outcomes as demonstrated, but also significant cost-savings, an important institutional factor in the implementation of technology in education (Author, 2011b).

This research suggested that giving primacy to mere deployment of OLPC laptops has limited relevance to children, both in use and outcome. This is consistent with recent claims in the ICTD field that technology-based development projects can address the needs of users if they "aim to design solutions suitable to diverse local contexts" (Islam & Grönlund, 2016; Warschauer & Newhart, 2016, p. 187). The results, therefore, demonstrated the role of contextualized technology in rural Indian classrooms alongside an understanding of user psychology that influence learning impact.

Certainly, caution must be exercised for the fact that this study uses the quasi-experimental design, which typically lacks the element of random assignment to treatment or control groups While the study only controlled for the amount of treatment; when the OLPC laptops are given to students, for what duration do students use it, and so forth, there are limitations in the design. The study overlooked the need to include control variables to capture relevant group differences that may have potentially influenced the outcome. While every effort was ensured to provide rigor and control that exist in experiments, such quasi-experimental studies conducted in the field are often compromised from obtaining an absolute cause-and-effect answer (Gravetter & Forzano, 2012). Given that the experimental methodology consists of only two treatments, i.e. *time* and *group*, future studies can adopt a multiple-treatment design, e.g. *teachers' ICT capacity*, to provide a more convincing demonstration of a cause-and-effect relationship between the variables, other than the technological intervention itself. In addition, the steep learning curve associated with low-cost computer use by students, and the disruptive impact of computing technologies on prior ways of teaching, means that gains might not be fully realized in just five months after their introduction, or that gains may regress after the initial spurt, further warranting more longitudinal research to test this hypothesis. It is worth noting that the generalizability of findings may be limited to the rural contexts with similar contextual settings.

Central to this study was our emphasis on contextual factors that guided the C-OLPC implementation strategies. We note that an empirical investigation of the relative influence of these factors was not accomplished in this research; to reiterate, teacher training was not isolated as variable in measuring impact. However, interviews with teachers [and the implementation team] provide insights into ways that various activities sparked reactions in classrooms.

The project managers maintained that better trained teachers were more capable of facilitating learning in classrooms. The active participation of teachers in guiding, assisting, and monitoring laptop use was crucial in directing how children learnt. Recent implementations endorsing informal, unguided computerized learning environments have often discounted the discussion of assisted-learning as a necessary element in learning achievement (Szewkis, et al. 2010). In these cases, educational tools were considered as replacements for class instructors, potentially prompting teachers to reject their use. Our research, on the other hand, supported claims on the centrality of teachers in educational contexts through the provision of technology training efforts. This claim needs to be examined empirically in future research.

Of theoretical relevance, research found that interactions with supportive others, namely teachers, have the ability to influence the development of efficacious beliefs and successive action (Sivandani, Koohbanani, & Vahidi, 2013), beyond access to technology alone. Along these lines, Bartimote-Aufflick and colleagues (2015) suggested that strategic intervention of teachers in technology context can raise student self-efficacy. Likewise, Martino's (2010) study on integrating OLPC in Uruguayan schools emphasized a need to support "innovative structural changes" (Lowther et al. 2007, p. 56) in classroom dynamism, namely by encouraging teachers to collaborate with students as they acquire technological skills for classroom learning. Such a focus on a teacher-student-technology triad not only facilitated teachers' willingness to challenge traditional classroom practices, but also resulted in students' increased motivation to engage in learning activities. Hence, children's increased interactions with better trained teacher, confident in taking role as facilitators and mentors when teaching with educational technologies (Author, 2009), could potentially impact computer self-efficacy beliefs that mediate children's learning outcomes. This relationship between teachers' facilitation role and computer self-efficacy also calls for further scientific research.

There is considerable attention being generated yet again about another technological intervention in education, viz. MOOCs (Massive Open Online Courses}. We consider it worthwhile to replicate this study to examine whether a contextualized design produces better results than mere technology introduction in educational contexts connected to the internet — it is recommended that evaluation of the effect of teacher involvement and training on learning processes finds a role in MOOCs research.

Extant evidence suggested that boys tend to dominate ICT-based activities in the classroom (Burn & Pratt-Adams, 2016; OECD, 2007; Volman et al., 2005). Furthermore, such gender-based differences are also found to influence learners' attitudes towards ICT use (Tømte, 2011). Yet, as Vekiri (2012) pointed out, it is important to prepare teachers to manage gender equality issues in ICTE while equipping them with the necessary ICT-skills. Hence, the point of the C-OLPC implementation was not only to improve technical skills, but also address socio-cultural barriers to the integration of technology in teaching. Our attempts to encourage teachers to be additionally mindful of the need to maintain equality in overall OLPC use led to strategies to actively segregate boys and girls. One teacher recalled her proactive approach:

> *We make sure that every child in a group gets a chance by assigning turns to every child. There is a lot of equality in how the kids should get to use computers. If one child shuts down the computer today, another child will do it another day. If one child types one sentence, another child will type the next sentence.*

While we believe that the overall objective of improved learning outcomes was achieved as a consequence of this forced gender segregation, we are hesitant to endorse this strategy because of concerns about possible unintended consequences. In a socio-cultural structure that already prioritizes males over females, segregation at the school level might further exacerbate the imbalance, with limited resources being allocated to one particular group. Further, segregation reinforces existing beliefs in gender differences, particularly in terms of academic ability and potential. We recommend deliberation within the educational system, discussion with local stakeholders, and further research to develop alternate strategies to ensure equal access to technological innovations by the genders.

The use of local language, however, was a factor that garnered mixed responses. While teachers and students found the project's translated information kit useful in the initial stages of OLPC adoption, according to another teacher, "the biggest challenge of teaching computers is English instruction… speed is slower as a result of English language not being easily understood." Despite this drawback, teachers recognized that, "in a way it is an opportunity, as we can now teach English through computers." Further highlighting the significance to learning impact, a teacher stated that, "laptops are making English learning easier and faster. The kids are making better sentences and taking more interest." While noting the enthusiasm about a foreign language, we recognize the cultural imperialism, demonstrably evident in other spheres such as science and commerce, that technology exhibits, and urge technologists to develop advanced capabilities across a variety of language groups.

Conclusion

It is important to note that, despite the moniker One-Laptop-Per-Child, the financial reality of the situation demanded alternate implementation strategies that may not be particular to this specific instance — in other words, shared usage might be a reality for technological projects in a number of developing countries — another instance in which context matters. We conclude on an optimistic note; advances in technological inputs in educational environments of developing nations can produce improvements in learning outcomes. The factors that determine such an effect hinge as much on a supportive and contextually appropriate learning environment, as they do on the technology.

Appendix A: Figures

Technology-Community-Management Model

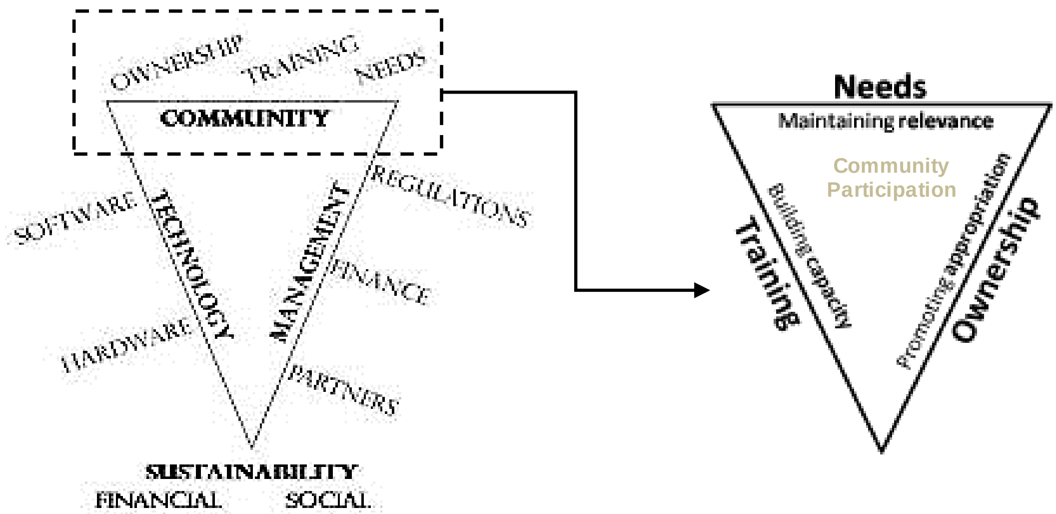

Figure 1. The Technology Community Management model

1

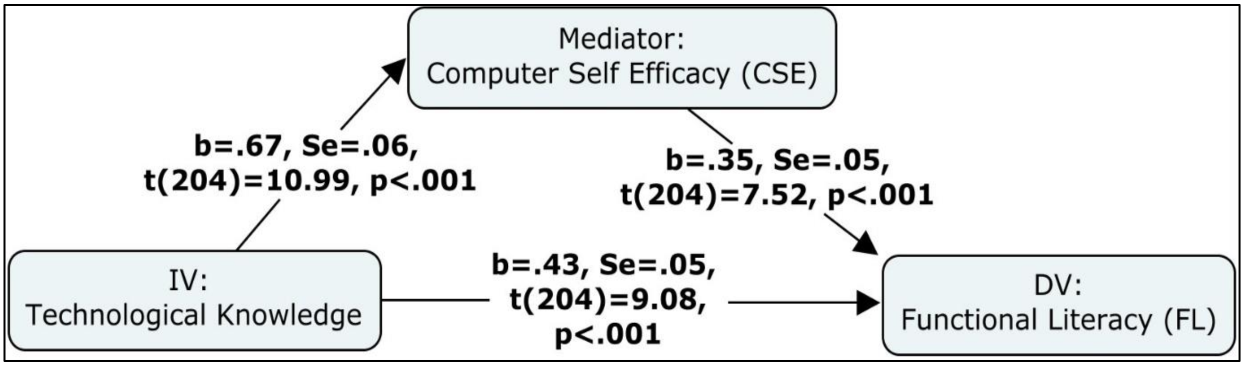

Figure 3. Summary of hypothesis testing results of the mediation effects

Appendix B: Tables

Table 1. Pre-test technological literacy levels between groups

Group	Mean	SD	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	3.46	1.38	3.15	3.77
Test	3.00	1.67	2.71	3.30

Table 2. Pre-test functional literacy levels between groups

Group	Mean	SD	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	5.22	1.32	4.90	5.54
Test	4.16	1.50	3.91	4.41

Table 3. Change in technological literacy between groups

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	1.089	.196	.702	1.475
Test	2.940	.155	2.634	3.247

Table 4. Change in functional literacy between groups

Group	Mean	SD	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	-.02	1.32	-.334	.304
Test	1.35	1.50	1.095	1.600

Table 5. Coefficients of regression

Model		Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-.14	.14		-1.01	.316	-.42	.14
	Change in Technological Knowledge	.43	.05	.54	9.08	.000	.34	.53

a. Dependent Variable: Change in Functional Literacy

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