Comparing Paradigms for AIED in ICT4D: Classroom, Institutional, and Informal

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Abstract. The landscape of technology in the developing world is changing significantly, primarily due to the rapid expansion of mobile computing devices. These changes make it important to re-evaluate practices for internet and communications technology for development (ICT4D). This paper examines three alternative paradigms for educational technology in the developing world: traditional classroom systems, institution-wide systems, and informal learning systems. The advantages and disadvantages of each paradigm are considered in terms of barriers to adoption at the student, teacher, and institutional level. Consideration is also given to educational technologies that serve as models for each type.

Keywords: Educational Technology, Barriers to Adoption, Informal Learning, Ubiquitous Learning

1 Introduction

As access to Information and Communications Technology (ICT) expands through the developing world, educational technology has the potential to play a pivotal role for supporting development. However, successful paradigms for incorporating ICT into developing world education are less clear. Educational technology in the developing world has an uneven history that includes numerous wasted investments in underutilized computers and limited learning benefits (Patra et al., 2007; Woolf et al., 2011). Moreover, the landscape of ICT in the developing world is changing drastically due to the rise of mobile handsets and wireless Internet access (International Telecommunication Union, 2012). These changes offer new opportunities, but also present new obstacles.

Research on advanced intelligence in education (AIED), such as adaptive learning systems, intelligent tutoring systems, and computer-supported collaborative systems, needs to outline the tradeoffs between different application contexts (e.g., classroom, institution-wide, and informal) to help select appropriate system designs. In this paper, these tradeoffs are framed as factors that mediate adoption of ICT, as indicated in Table 1. These factors are based on known barriers to information and communications technology that were identified from recent review papers (Gulati, 2008; Lowther et al., 2008; Bingimlas, 2009). Different paradigms have advantages and disadvantages for each factor.

Table 1. Factors Impacting Adoption of Educational Technology

System	Requirement/Possible Barrier	Description
Learner	Basic ICT skills	Computer literacy and familiarity with basic interfaces
	Independent access to ICT	Web access or computing outside of school
	Motivation to use ICT	Student interest and persistence in use
	Peer support	Peer help or collaboration
Teacher	Basic ICT skills	Computer literacy and managing applications
	Beliefs about utility of ICT	Values and expectations for an ICT design
	ICT-integrated curricula	Pre-made curricula and syllabi that incorporate an ICT intervention
	Match to pedagogical views	Match of teacher pedagogy to an ICT design
	Peer support	Communities of practice and peer views
	Time constraints	Class and preparation time available
	Training (e.g., in-service)	Training with a given ICT design
School or Institution	Administrative support	Administrative needs, reactions, and leadership toward ICT use
	Curriculum flexibility	Flexibility to modify teaching to use ICT
	ICT hardware availability	School web access and computing hardware
	Technical support	Technical staff to set up and maintain ICT
	Internet reliability	Stable, reliable internet connections

This paper considers three paradigms that have shown promise in the developing world, discussing successes and potential challenges. These paradigms will be framed in terms of the context where they are utilized: under *classroom* control, around the entire *institution* (e.g., through a central learning management system), or outside the educational system in an *informal* learning context. While these are not the only approaches (nor are they exclusive), each offers distinct strengths and challenges. Each paradigm will be briefly discussed, with attention to the barriers to sustainability noted in Table 1 and also to promising implementations that embody each approach.

2 Traditional Paradigm: ICT Under Classroom Control

The traditional paradigm for educational technology in the developing world has been classroom-centric (Gulati, 2008). The typical design sets up classroom computers or shared computer labs with educational software. In this context, educational technology is a tool that teachers use to improve learning for students. Classroom-based tools are typically tailored to domain (e.g., Algebra I) and require less flexibility than a general learning management system (LMS).

Classroom-centric ICT has many advantages when compared to other approaches. First, the classroom setting gives the teacher a significant degree of control over students to mandate and manage the use of the system by students. In a classroom setting, basic ICT skills are not typically a blocking issue as students often learn controls quickly and students with more advanced ICT skills may even help the teacher (Gulati, 2008; Ogan et al., 2012). As such, the high availability peer support mitigates deficits in basic ICT skills. Students also do not need to own personal computing devices. The motivation of students, while still important, is less critical than in other contexts. Research has found that liking a system does not necessarily correlate with learning gains, provided students still use the system as intended (Moreno et al., 2002). In a classroom, most students will do assigned work even if they do not find it interesting.

Second, the primary buy-in occurs at the teacher level. At least for initial evaluations, this mitigates many barriers related to teachers. Given that teachers have very different attitudes to technology (Lowther et al., 2008), the ability to pair up a system with technologically-receptive teachers greatly increases the likelihood of successful usage. Teacher beliefs about ICT, match to pedagogical views, and these teachers' basic ICT skills are likely to be better than average. One barrier not mitigated by this approach is peer support, as few teachers will be using the system. Additionally, scaling up to widespread use will hit these barriers once the supply of early-adopters is exhausted. Persuading uninterested teachers to adopt technology is unlikely, unless institutional entities encourage its use. So then, while this paradigm is useful for pilot testing and establishing a foothold, there may be limits to its scale.

The clear point of failure for a classroom-centric approach is institutional factors. If buy-in is primarily at the teacher level rather than the administration level, there is no assurance that the larger institutional context will offer a sustainable environment for that educational technology. If educational technology is a low priority, teachers may be pressured to focus on other matters and technical support may be unavailable. Inflexible mandatory curricula may also make it impossible to work technology into classrooms. Alternatively, curricula dedicated to computers may focus exclusively on digital literacy (e.g., learning about computers) rather than using computers to learn a broader range of topics.

Most importantly, ICT hardware depends on financial support. Investment in computers must be made at the institutional level, but developing world schools often lack the funding to support heavy investment into purchasing, managing, and replacing hardware. Low ratios of students to computers can make meaningful computing curriculum infeasible. Accessing and financing reliable Internet may also be out of the control of the school system. Many developing world areas still have unreliable electrical and Internet infrastructure, which can easily fail and derail any instructional plan relying on web connectivity (Woolf et al., 2011). So then, the primary barriers to traditional classroom ICT are at the school and institutional level. Thankfully, strong focus has been placed on overcoming hardware barriers for ICT in schools. Irregular electricity can be mitigated by using laptops, as their batteries make them immune to short power losses. Irregular Internet can be sidestepped by installing from disk media or only depending on Internet infrequently, rather than during classroom time. Pilots of Cognitive Tutor in Latin America installed software on desktops and did not note significant roadblocks due to the unreliable Internet available (Ogan et al., 2012). By implication, web-based tutoring portals are poorly-suited for the developing world classrooms. This is unfortunate, since educational technology in the developed world has moved strongly in this direction.

Two approaches have been used to overcome hardware barriers: cheaper devices and shared computing. The One Laptop Per Child program spearheaded the "cheaper hardware" approach, driving down the base cost of computers overall (Patra et al., 2007). However, this approach encountered two problems. First, even with lower costs, many schools cannot afford a laptop for every child. Second, studies on ICT interventions in the developing world find that students *prefer* to share computers (Ogan et al., 2012). As such, a number of systems have adapted to this landscape and offer one mouse or keyboard per child (Alcoholado et al., 2012; Brunskill et al., 2010), collaborative turn-taking, and other methods of individual input into a shared learning environment such as mobile devices (Kumar et al., 2012) or wireless clickers (Zualkernan, 2011). Individual inputs are inexpensive compared to computers, greatly reducing hardware costs. Additionally, these techniques complement cheaper computers since they have a multiplier effect. Computer sharing also offers greater pedagogical flexibility, since interactions with other students enable social constructivist designs that would be difficult in a single-user system.

MultiLearn+ offered one model for such a multi-input system, presenting a math game split into four quadrants on a laptop screen and supplying each student a numeric keypad (Brunskill et al., 2010). To prevent dominance by a single student, MultiLearn adapted the difficulty of questions based on student performance. This system relied on installed software, with no Internet component. At present, a laptop with educational technology designed to be shared by four or five students may be the best model for ICT in a primary or secondary school classroom. Such a system might use Internet to update the system, but cannot assume Internet will be available during a classroom session. While significant work has been done in this area, there are still many questions over the relative advantages of different presentation devices (e.g., laptop screens, projectors, voice narrative) and input devices (e.g., mice, keyboards, voice recognition, game controllers, clickers/remotes). In particular, shared mobile computing might be a transformative technology in the future. For example, Kumar et al. (2012) presented a mobile learning tutoring system based on voice recognition and suggested the potential for shared computing through voice identification. While this particular paradigm may encounter technical hurdles, computer sharing for mobiles is an important avenue that needs further research.

3 Institutional Paradigm: ICT Around the School

In a related paradigm, the institution controls a learning management system from the top down. The institution may be a school, district, or even a national system. Learning management systems (LMS) primarily provide a container and delivery platform for static media, though assessments, adaptive learning systems, collaborative systems, or tutoring systems may be incorporated. These systems can support both traditional and online classes. Worldwide, this is more common within higher education. Ubiquitous systems, which connect a variety of devices to a central system, also require an institutional paradigm.

Institutionally-centered systems have similar pros and cons with respect to student barriers, since an instructor usually guides a group of students. One advantage is that, since students interact with a shared central system, remote peer support is possible (e.g., a forum, Wiki, or social media). Unlike classroom-centered systems, institutional systems typically require each student to own a personal computing device. This is because primary use cases of LMS and ubiquitous learning are web-based homework and remote collaboration. However, teachers are the most affected by this paradigm, who will often need to redesign their curricula to fit the system. While an opt-in single classroom paradigm hides teacher barriers by excluding the most resistant or inadequately-prepared teachers, institution-wide adoption hits these barriers head-on. Institution-level barriers are also still an issue. While buy-in by the institution should increase administrative and technical support, hardware costs remain an issue. Since an LMS requires both servers and personal computing hardware, centralized institutional paradigms are more hardware intensive and more costly as a result.

A few designs have attempted to overcome these limitations. EDUCA, a ubiquitous learning platform, provides an LMS and tutoring system capabilities that can be accessed asynchronously over the web through a desktop or a mobile device (Cabada et al., 2011). Entire learning modules are downloaded to the mobile device, as well as an adaptive system for personalizing learning. Since mobile Internet is more prevalent than wired Internet in the developing world, this helps students access the system without a home computer. However, as Mexico is an "emerging market," this approach still may not translate to less developed countries with worse wireless infrastructure. An alternative approach enabled mobile devices to communicate with the school network over mobile web or through "learning pills" transferred to the student's phone during class over Bluetooth (Munoz-Organero et al., 2012). However, both approaches require the student to own a web-capable phone and passes these costs down onto students. This approach seems better suited to higher education, where students can be responsible for the costs and ownership of mobile computing devices. However, as mobile web capability becomes commonplace, ubiquitous paradigms may also become relevant for primary and secondary education. In either case, any learning management system or large-scale institutional system for the developing world must support mobiles as first class, or even primary, devices.

4 Informal Paradigm: Technology Outside the School

A precise definition for informal learning is hard to pin down, as informal learning is often described in terms of how it differs from traditional schools. Within this paper, informal learning refers to education where students have no interactive human supervision and engage with learning materials based on their own initiative. The informal paradigm is attractive in some ways. School and teacher barriers are sidestepped, learning only student barriers. Computer-based informal learning was not previously a possibility in the developing world, but the spread of web-capable mobiles is changing this drastically. However, while informal learning offers strong appeal, it is likely a case of "the grass is always greener on the other side." First, while students' basic ICT skills were not a major problem in other contexts, studies have found that even setting up mobile Internet on phones can be an onerous task in the developing world (Gitau et al., 2010). So then, users probably need help from community centers or user groups to get started. Independent access to ICT is also required: students need a working phone or laptop with Internet capability. Informal usage also removes the constantly-available classroom peer group, limiting collaborative work and technical help. While students may naturally form study groups, the frequency and effectiveness of such emergent groups needs further study.

However, more so than any other factor, student motivation is an imposing barrier to the success of informal learning. In a traditional classroom, students can either do their work, sit idly, or incur punishment for performing off-task behavior. By comparison, informal learning environments compete with the Internet. Students need a high motivation toward the learning content to focus on an educational technology without a societal framework. No combination of teacher or school barriers may be more formidable than competing on a level playing field against the combined forces of the online media market. A pure informal paradigm may be an uphill battle. Informal learning technologies need find or create ecological niches that learners find useful and interesting.

One way to do this is to dominate a small ecological niche. One example of this is to preload devices with educational software. This paradigm relies on users trying out default programs first, rather than installing other programs. In less-developed areas, data may also be expensive enough to impose this barrier. A multi-week study on unsupervised use of preloaded educational games on mobile phones in India found that participants averaged of 2 hours and 23 minutes per week on the game, with 46 total hours per participant on average (Kumar et al., 2010). Possibly due to the game-based delivery, students had a fairly high level of motivation to learn. While off-task use was also present (e.g., downloading music), social dominance was a larger issue. Girls were particularly vulnerable, with brothers taking their phone and parents condoning this behavior. Additionally, software must be loaded onto devices at some point, so government or industry partnerships would be required for this to scale.

A second approach is to enhance existing niches, such as informal paradigms built around emergent communities of practice. For example, Mobile-ED offered a mobile gateway to a Wiki site where users could text a term and hear the web page read to them (Ford and Leinonen, 2009). If a term did not exist, users could dictate a definition that other users could use. Integrating web communities, which tend to be based on interests, and community organizations, which tend to be based on local ties, might drive sustainable informal learning, particularly on practical subject matter such as health, economic, or vocational competencies. Community groups can provide local motivational and technical peer support, as well as form connections with other user groups. By serving the shared needs of community groups, informal systems might benefit from grassroots support.

5 Conclusions and Future Directions

Classroom, institutional, and informal paradigms can each play a valuable role in developing world education immediately and in the future. While access to ICT is expanding, most of the developing world still has little computing hardware available. With that said, in raw numbers, the developing world has a strong demand for educational software that fits its needs. Primary and secondary school classrooms can benefit from shared computing applications today, through multiple-input laptops. In the future, single-display groupware or shared voice-input mobile devices might offer cheaper and equally effective designs. To make this jump, research on user interfaces for shared computing and group learning is essential. As technology evolves, regular research on these topics will be pivotal for keeping up with shifts in access and usage patterns.

Similarly, universities can immediately benefit from ubiquitous systems focused strongly on mobile learning. In the future, ubiquitous systems should be available at earlier grade levels as mobile computing expands and data costs fall. However, creating content for inexpensive mobile learning is non-trivial and many existing open systems, such as MIT Open Courseware (Abelson, 2008), are not well-suited for low resource contexts as they rely on rich media (e.g., streaming lectures). Research on methods to quickly convert existing content designed for high-resource computers (e.g., monitors, high bandwidth) to low-resource mobiles (e.g., small screen, speakers, low bandwidth) would be valuable. Techniques for rapid language and cultural localization may also be essential.

Finally, the role of informal learning in the developing world is still taking shape. Informal learning systems must target ecological niches created by technological and societal influences. While sustained engagement has been observed, social biases and gender barriers are reproduced in informal learning contexts (Kumar et al., 2010). Game-based learning and systems designed for community groups are two areas that may offer traction for supporting self-regulated education. Research on peer support and sustaining motivation for informal learning is essential, so that informal learning is both effective and equitable.

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