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InfoInternet for education in the Global South: A study of applications enabled by free information-only internet access in technologically disadvantaged areas

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This paper summarizes our work on studying educational applications enabled by the introduction of a new information layer called InfoInternet. This is an initiative to facilitate affordable access to internet-based information in communities with network scarcity or economic problems from the Global South. InfoInternet develops both networking solutions as well as business and social models, together with actors like mobile operators and government organizations. In this paper we identify and describe characteristics of educational applications, their specific users, and learning environment. We are interested in applications that make the adoption of Internet faster, cheaper, and wider in such communities. When developing new applications (or adopting existing ones) for such constrained environments, this work acts as initial guidelines prior to field studies.

Keywords: Agenda 2030, applications, education, ICT4D, low bandwidth

Introduction

We use InfoInternet as an umbrella term for the technical activities of the Basic Internet Foundation,[1] which has the general goal to provide free and affordable access to basic information in areas with no or scarce Internet infrastructure. A multi-tenant deployment plan is being executed,[2] through pilots in rural areas from Africa, Myanmar, and India. InfoInternet (see the section entitled "Background on InfoInternet" for a more detailed presentation of the technology) is meant to initially help in three main social environments: health, education, and small businesses for empowering women. Women and youth are prioritized, as the population most vulnerable in a society. This paper focuses on the *education* aspect; in particular, on studying *educational applications* enabled by InfoInternet for the intended communities.

The map of Internet speed provided by Akamai[3] shows that the countries in the Global South[4] (Mitlin and Satterthwaite 2013) have least coverage, as well as the lowest speed. These countries also have the largest population growth, as well as the poorest. For children that live in poverty (ca. 20% of world's children live in 'extreme poverty')[5] it is often difficult to focus on learning (even when they have access to schools) due to multiple traumas they have suffered. Causes for these traumas include poverty, domestic violence, parents with mental illness or under addictions, lack of homes or living in refugee camps, and war. The first goal in the *2030 Agenda for Sustainable Development (SDGs)*[6] is the elimination of poverty, while the quality of education is number four.[7] InfoInternet addresses communities that have both these problems, with the belief that better education would help solve the other problems as well. Four-hundred-and-twenty million people would be lifted out of poverty with a secondary education, thus, reducing the number of poor worldwide by more than half.[8]

By offering free access to digital information in schools, InfoInternet aims to improve the accessibility, breadth, and quality of education in the Global South.

Our interest in supporting ICT-based education[9] for this vulnerable population is motivated by the fact that the *participation in the digital society and the access to information* is a human right (Watch 2016). Providing free and affordable access to information has the potential to reduce the digital divide (Society 2017), bring about social change (Franquesa and Navarro 2017), and become a catalyst for the SDGs.

Besides the above social advantages of InfoInternet, the technology behind it also has the advantages of providing a local and rapid infrastructure allowing for high capacity access to local content and free access to basic information from the Internet. A disadvantage is that full Internet access, including heavy bandwidth content, needs to be paid for, thus reducing the access to video and high-resolution picture-based educational content, which are being considered as more accessible for people with illiteracy, learning disabilities, or attention deficit disorders. The section entitled "Limitations of InfoInternet" gives more details, whereas (Datta et al. 2019; Noll et al. 2018b) offer more discussions about InfoInternet.

Structure of the paper: Our methodology, detailed in the third section, uses Informed Grounded Theory (Corbin and Strauss 2015; Thornberg 2012) to learn from existing studies about education and children in the Global South areas. We identify the users' characteristics and needs in the section entitled "The intended users of InfoInternet", and the educational environment and how it would be affected by InfoInternet in the section entitled "Educational context of InfoInternet". We proceed to the section entitled "Applications on top of InfoInternet" where we analyze educational applications to extract characteristics that are

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representative for the users and learning environments presented in preceding section. The knowledge synthesized out of existing literature need to be verified and confirmed through more studies in the field.

Related works are detailed in the section entitled "Methodology", grouped in four main categories, investigating areas of research relevant for our work, namely: ICT for education, ICT for Development, misinformation, and educator training. Our present work is particularly related to works that study the digital inclusion in rural schools, where Madon et al. (2009) and Sánchez (2010) are reference points for how we approach the topic. However, there are no studies (neither theoretical nor field studies with users) that look at ICT-applications for education that would be enabled by the Internet. An even greater focus of our present study is on the InfoInternet, which is seen as a form of Internet that could reach the Global South more easily and would be more accessible to local communities.

Contributions: Our contribution to the general topic of digital inclusion is that of investigating the existing applications for education, as well as identifying characteristics for future applications, that are enabled by the introduction of InfoInternet in local communities from the Global South.

We work with *two sources of variability*:

(I) one coming from the specific needs of disadvantaged children (like long distance to school or need to do domestic work);
(II) another coming from the special characteristics of InfoInternet, identified in the section entitled "Background on InfoInternet" (like low bandwidth, slow response time, or special kind of content).

We also identify what kind of applications are likely to make the adoption of the InfoInternet:

- *larger*, i.e., spread more easily and widely to other areas,
- *faster* in terms of time, and
- *cheaper* in terms of resources, knowledge and training, or support from government or industry.

Background on InfoInternet

The technical part of InfoInternet works with developing and deploying the networking infrastructure, whereas business and social activities are conducted to ensure its adoption. The research in this paper relies on the fact that the studied communities have access to a network infrastructure such as the one put in place by InfoInternet, with the restrictions of limited and/or unstable network connections.

Relevant technical aspects of InfoInternet

In this section we briefly describe the technological aspects of the InfoInternet infrastructure that are relevant for the present paper, i.e., within the educational sector, and the business model InfoInternet is based on.

The architecture of InfoInternet, designed for low-cost local infrastructure and rapid deployment, consists of (see Figure 1):

(I) a local core network with local content,
(II) a local network,
(III) a centralized core, and
(IV) the backhaul network/network termination (achieved through, e.g., a radio link or a satellite connection).

This architecture fosters high-capacity access to local content, free access to basic information from the Internet, as well as paid access to other bandwidth-heavy content, like video.

The HTTP Archive[10] shows that an average web page has doubled in size from 1.09 MB in 2012 to 3 MB in 2017, divided into scripts ca. 19%, and images ca. 60%, while video in 2017 accounted for ca. 24% of the whole web size. On a satellite link of 1 Mbps, a web page of 3 MB would load in 24 s blocking the capacity for all users. Because of this, InfoInternet (Noll et al. 2018a) makes the local network and local content accessible through high capacity WI-FI hotspots, also using caching techniques. However, when non-local content is requested, applications need to be developed taking into consideration a low-capacity backhaul or a limited payment plan.

The business model suggested by InfoInternet adopts the freemium style (Anderson 2009; Seufert 2014), where access to basic information is free and full Internet access (e.g., to videos, games, full websites) is paid, e.g., through specific data plans offered by the mobile operators. InfoInternet pilots demonstrated that the free services take ca.2.5% of the bandwidth, leaving the rest for commercial operations. This percentage can be covered by the businesses through various schemes like tax or other state supported funding programmes. Thus, InfoInternet is not proposing a diluted or in any way an inferior mobile service.

Related projects and initiatives

From the related projects already identified previously by InfoInternet, we mention here Free Basics from Facebook,[11] a partnership between Facebook and several companies to bring affordable access to selected websites. However, their model is criticized for violating net neutrality.[12] In contrast, non-discriminating access to basic information and net neutrality are part of InfoInternet. Moreover, InfoInternet is not dependent on specific operating systems nor apps on the users' devices. Besides, InfoInternet can integrate with relevant companies like WaveTek Nigeria LTD,[13] research programmes like EU's Next Generation Internet,[14] social initiatives like Internet For All,[15] academic projects like Gram Marg from IIT Bombay,[16] or business fora like Digital Impact Alliance.[17]

Limitations of InfoInternet

Textual information requires a certain level of literacy from its users, e.g., (Medhi et al. 2011) shows that textual interfaces are unusable by first-time low-literate users, and error prone for literate but novice users. However, in applications for medical treatment at home or online banking, illustrations proved (Medhi et al. 2011) to be more effective and preferred by the users. *Low resolution pictures* can be delivered by InfoInternet and thus considered for similar needs in educational applications.

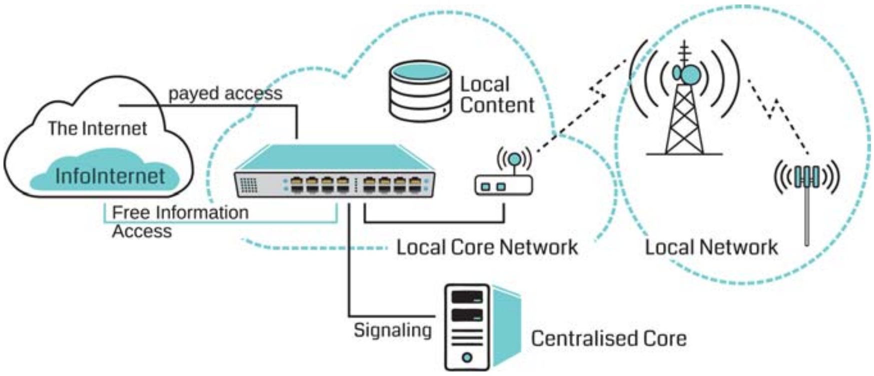

Figure 1. InfoInternet deployment architecture.

Limiting streaming videos can be an important shortcoming for education, especially for ICT, since many lectures and tutorials are made available in this form. Moreover, children with different attention and reading disorders have better learning results when video alternatives exist. InfoInternet does not put restrictions on this type of content, providing free access to videos on the local content server as well as freemium access to any other content.

Devices relevant for InfoInternet and their usage

InfoInternet supports all types of devices as long as they can be connected to the Internet (e.g., tablets, smartphones, PCs).

As hardware, tablets seem to be the most preferred device to be used for education. This preference is motivated by cost, adaptability and scalability but also for supporting a new kind of learning called ‘here and there’, that allows for more flexibility when it comes to the physical space and time where learning can happen (Haßler, Major, and Hennessy 2016; Martin and Ertzberger 2013).

Methodology

We follow an Informed Grounded Theory methodology (Thornberg 2012) in the constructivist style (Charmaz 2014) to investigate the various existing applications for education that are enabled by the Internet and networked communication in general. We particularly focus on applications relevant for InfoInternet and extract what exactly it means to be ‘*InfoInternet ready*’. Our focus on areas from the Global South and children living in remote areas without communication infrastructure, introduces another variability line.

The constructivist grounded theory builds gradually the research criteria and concepts in an incremental, systematic fashion as they become apparent during the process of analyzing the data. For a thorough introduction and definitions one can consult Charmaz (2014), Corbin and Strauss (2015), and Morse et al. (2016). In short, one can see grounded theory as providing methods and guidelines for collecting and analyzing qualitative data to construct theories from the data. This is opposed to more traditional methods that study users where normally a researcher outlines a theory, and then goes to collect data, analyze it, and then determine whether the initial theory is validated or invalidated by the data. More recently, the constructivist approach to grounded theory assumes that neither data nor theories are discovered, but are constructed by the researcher while interacting with the users. The informed grounded theory adopts the constructivist view but instead of delaying the use of literature until the end of the process, it encourages the investigation of relevant literature in the beginning, and all along the way to help in developing the theories. Quoting from Thornberg (2012, 249) ‘Informed GT is not about forcing data into pre-existing concepts and theories nor replacing constant comparison and systematic coding with prejudiced and insensitive theoretical interpretations of data.’ Instead, a series of principles in using literature are being described (Thornberg 2012, 250), often enhancing the methods of the constructivist grounded theory.

For the work in this paper we used data and knowledge gathered by the Basic Internet Foundation over a long period of time, and thus did not need to interact directly with users this time. We used insights from studies done directly both with children as well as students at university level in the Global South. These insights and studies were mostly not peer-reviewed, but either available on the websites of the respective projects/pilots[18,19] or received directly from the field scientists who performed them. Since its start in 2010, the Basic Internet Foundation has run a series of pilots in villages in the following continents and countries: Africa (Tanzania, Kenya, Ethiopia, Rwanda, Ghana, Uganda, Mali), Myanmar, and India.[20] Besides villages, in 2011 InfoInternet access was also established for the region and University of Lisala in Democratic Republic of the Congo (DRC). A pilot was run also in Europe, in a small town called Bottrop, from Germany, where it provided InfoInternet to a community with about 60 children with special social and psychological needs (e.g., due to violent family backgrounds) and up to 40 grown-ups looking after them.[21]

Moreover, in the tradition of informed grounded theory, we study existing literature and initiatives relevant to our topic to enlarge our understanding on how access to Internet-based content will impact the quality of education in marginalized regions. We identify the needs and the context of use specific to underserved communities with respect to information technology and Internet infrastructures. We look at the research done on digital inclusion (Madon et al. 2009; Sánchez 2010) in rural schools around the world and use it as starting point. We also consider how access to Internet might influence the education in these communities. We use this research to understand better the needs and the dynamics of such communities and their influence on the adoption and use of InfoInternet in schools. We thus also base our work on the data collected by the previous research efforts that we cite, and rely on the conclusions that those authors drew.

Relevant literature

Relevant fields of study from which we reviewed literature useful for this work include the following.

ICT for education is essential for allowing children to become contributors to the creation of technology, instead of only consumers (Crompton, Burke, and Gregory 2017; Unnikrishnan et al. 2016). Free access to information through InfoInternet would inspire and encourage various initiatives to reach the Global South schools, such as: Code Club[22] (Smith, Sutcliffe, and Sandvik 2014), Hour of Code,[23] Teach Kids Code[24] (Corneliussen and Prøitz 2016), or intuitive programming languages like Google's Blockly (Trower and Gray 2015; Weintrop and Wilensky 2017) or MIT's Scratch (Maloney et al. 2010; Resnick et al. 2009) and other educational programming languages (Armoni, Meerbaum-Salant, and Ben-Ari 2015; Weintrop and Wilensky 2017).

ICT for Development (ICT4D) is a large field (Avgerou 2008; Heeks 2002, 2008; Unwin 2009), and the work in this paper fits particularly in the education part (Selwyn 2013b, 2016), which ICT influences both positively (Pegrum 2014) and negatively (Selwyn 2013a). The work of (Hilbert 2012) introduces the concept of 'Cube Framework' which models the transition toward information societies as an interplay between technology, policy, and social change. InfoInternet participates in all three aspects of the 'Cube Framework', through: (I) building a communication infrastructure, (II) working in three socioeconomic areas, and (III) proposing policies together with local governments and companies.

Earlier ICT4D efforts focused on the expansion of the telecommunication infrastructure. This is still needed in some parts of the global south where InfoInternet is active. However, ICT4D 2.0 encourages to use the power of low-cost devices such as mobile phones or tablets, and web 2.0 technologies to help improve access to educational content, which is what InfoInternet sees as devices, moving away from the traditional personal computers. The use of mobile devices has been shown to be effective in improving the quality and equality of education in underdeveloped countries (Kim et al. 2012; Valk, Rashid, and Elder 2010) due to their increased accessibility and flexibility.

Misinformation is characterized as 'unintentional mistakes', as opposed to *disinformation* which is 'false information spread deliberately to deceive' (Mintz 2002). InfoInternet would be used for obtaining information by the child through 'surfing' the web. This is vulnerable to disinformation and misinformation. Disinformation is most often spread through social media and news channels and forums (Benham et al. 2012). As such, we expect *misinformation* to be the main problem for InfoInternet in education (Graham and Metaxas 2003; Leu, Forzani, and Kennedy 2015). For this the children need to be trained to detect such mistakes, like everyone else (Azpiazu et al. 2017; Derman-Sparks and Edwards 2010; Kumar and Geethakumari 2014), under the guidance of tutors or teachers. *On-line risks*, like Cyberbullying or online safety for children Pinter et al. (2017) is also a relevant aspect that needs to be considered.

Educator training. All school ages are expected to be affected by InfoInternet, and thus teachers for all levels need to be trained into using and making most out of new resources available through InfoInternet (Gestwicki 2015; Gordon and Browne 2013). In the same school often there are notable differences between classes at the same level and even between individuals in the same class. Moreover, since InfoInternet will penetrate also the community and family, some resources would also contribute to the e-learning process of children at home (Gestwicki 2015).

The intended users of InfoInternet

Unconnected communities in the Global South

According to the Internet Society (Kende 2015), the majority of the Global South population does not have adequate Internet access, i.e., is slow, unreliable, and often offline; only ca.30% having 3G coverage in 2013 and a small minority having 4G, where smartphone subscriptions in Sub-Saharan Africa were only ca.25% of the population in 2016. This implies that the digital world cannot be reached by everyone fairly and thus an access gap is created between citizens who can afford a digital device and an Internet connection and those who cannot. The later represents the general user group of InfoInternet.

Citizens unable to access digital tools are often confined to the *lower or peripheral edge of the society*, both economically and geographically. As a result of this inaccessibility, such groups are denied full involvement in mainstream economic, political, cultural, and social activities. This usually also implies restricted access to or exclusion from critical services such as health, education, and other public services, and therefore limited opportunities for development and welfare (Watch 2016). From a technological point of view, InfoInternet provides the network connectivity and deploys the infrastructure necessary to furnish this. However, there are other aspects of InfoInternet such as business models, expert advice and coordination for the integration of the technologies within the local communities, and Public Relations, that come into play to support the participation of our users in the digital world and diminish the digital gap.

Children from these poor communities are *the primary users regarded in this paper*. The adult part of population will only be mentioned as part of the context in which the children are growing up. Their characteristics and needs are strongly influenced by the socioeconomic context they are surrounded by (we give more information about this in the section entitled "Educational context of InfoInternet").

Bellow we identify the characteristics and needs related to education of the unconnected communities, based on their socioeconomic status, their access to technology and/or educational resources, or more generally to study support (e.g., from the parents or community).

Characteristics

- Little knowledge of what a digital device can do and how to operate it, as there is little technology accessible in these areas (a TV and an occasional smartphone) (Unnikrishnan et al. 2016).
- Lack support from parents, because of illiteracy or little understanding for why their children need to learn technology.
- Irregular school attendance, e.g., due to domestic work load.
- Have less knowledge (in school subjects) than expected for their age level in more developed countries (Gordon and Browne 2013).
- Some children have psychological problems caused by a challenging home environment, which affects, e.g., their attention span, curiosity, and motivation for learning.

Needs

- Access to remote and flexible learning for children that cannot attend school regularly or within the school time schedule.
- Access to digital content translated to the child's language and relevant for their own age and individual capabilities.
- Easy access to digital devices and Internet.
- Guidance and help with differentiating good/appropriate from misleading or flawed information.
- Interaction with people with the will and competence to share their ICT knowledge (friends, family).
- Technology use should be supervised/guided by adults, so that educational uses would outweigh the entertainment ones.

Other stakeholders

While the main stakeholders that we consider here are children from unconnected communities, the larger scope of InfoInternet is to help all sorts of users forced to work in different contexts than the classical office space. These are individuals that work in professional isolation, freelancers that would like to work from remote places, commuters, or researchers involved in projects meant to help these communities. The researchers from the Community Lab of the Faculty of Computing and Informatics (FCI), at Namibia University of Science and Technology, mention that having a mobile lab, equipped with Internet and electricity will be very useful for their research work within the community setting (Winschiers-Theophilus and Peters 2017).

Educational context of InfoInternet

An effective use of ICT has three dimensions: motivation, possession, and digital skills (Sánchez 2010). *Motivation* refers to the willingness of individuals to use technology and to include it in their home, work, or educational efforts (Kumar et al. 2017). *Skills* refer to the abilities to use the technology. *Possession* is the dimension most relevant for InfoInternet, as it includes physical access to Internet and computers (or Internet-enabled devices). By offering free access to basic forms of information from the Internet, InfoInternet enables a baseline in the possession dimension. However, the other dimensions are of equal importance as they influence the adoption of InfoInternet. The communities need time to discover or be taught the benefits of information technologies. They need to experience the positive effects and, even more, to adapt ICT use to their needs.

InfoInternet in schools

Schools play an important role in social and symbolic integration. With InfoInternet the schools begin to play a new role, that of diffusion of technology and equitable access to information to children and transitively to their families. Traditionally, school contributes to equalize social differences, offering children an equal baseline to start from in a society.

In rural communities with high levels of poverty, the school is a fundamental space for reducing the economic divide. Various technologies that are not available in home or other community spaces, are often accessible through schools (Sánchez 2010). For example, in India, when starting school the student receives a tablet, thus ensuring that the student gets access to electronic information.

The teachers role

Though school is one of the main places providing access to Internet, the teacher does not seem to be a fundamental agent in transmitting ICT knowledge to children, being surpassed by other members of the communities (Sánchez 2010). However, teachers do act as *gatekeepers*, generating conditions for children to learn in the school how to use the ICTs. We thus need to consider the *role and position* the teacher could have in supporting the adoption of InfoInternet, both for children and pedagogical reasons.

Many of the pedagogical theories on learning, motivation and socializing have a built-in philosophy on *adaptive learning*. This is because the reality in schools shows notable differences between the learning needs of each individual, e.g., in the same school often there are different learning needs and capabilities between classes at the same level and even between individuals in the same class. The role of the teacher is to be aware of these differences and to *adapt the content to the variety of levels and needs*. Moreover, teachers also know the importance of the cultural and social context in the learning process. In this perspective, as emphasized by sociologically oriented theories (such as Bernstein's theory of code (Bernstein 2000; Sadovnik 1995) and Berger and

Luckmann's theory of primary and secondary socialization (Berger and Luckmann 1966)), teaching should take into account the student's language, values, way of conduct and cultural ballast. As such, a main requirement for developing apps and content for schools is to *bring along the teachers* and their expertise and to make sure that the content is flexible enough to support diversity and be relevant for the community.

Technical support and mentoring for teachers is observed to result in better adoption of technology. For a new InfoInternet-based app or infrastructure deployment, one should first study in what measure the teachers see the InfoInternet as a positive tool for improving learning conditions, accessing resources for teaching, and for improving educational results. An unfortunate example is the statement from Patrick Muinda from the Ministry of Education and Sports in Uganda (Society 2017) informing how schools were equipped with all the technology necessary, but the computers were left unpacked as the teachers were lacking the digital skills and knowledge to take them in use in the classroom. The teachers did not want to embarrass themselves in front of the children. We observe that the more technical support or/and mentoring teachers get regarding the use of computers and InfoInternet as tools and resources for supporting the teaching activity the better the adoption. There is a wide range of support for teachers and administration as part of InfoInternet, as direct support for end users is the core of the InfoInternet principle.

Influence of InfoInternet on learning results

We consider, based on existing studies (Ciampa 2014; Crompton, Burke, and Gregory 2017), that once children and educators get access to relevant information through the Internet, their motivation and skills will increase. Already only with the technological infrastructure in place one can see positive results in *cognitive and digital skills* development. The evaluation of the 'One Laptop per child' (OLPC) programme (Kraemer, Dedrick, and Sharma 2009) in poor communities in rural Peru (Cristia et al. 2017) offers proof in this respect, even without any follow-up from the tutors or teachers. Other evaluations from use of OLPC in Tanzania show that the initial interest in digital technology drops if it is not supported by network access. This is where the InfoInternet solution is needed. Once the adoption and motivation is assured, as we can see from comprehensive studies (Crompton, Burke, and Gregory 2017; Haßler, Major, and Hennessy 2016), mobile technologies can viably support children with their learning tasks and bring positive outcomes on learning achievements.

However, one should not start from the premise that technology by itself brings improvement in the quality of education, both when it comes to teachers and students. Even if in the OLPC the laptops came loaded with 200 books, the children used them mainly for activities that had little effect on education, e.g.,: word processing, calculator, games, music or recording sound and video (Cristia et al. 2017). Another three years study in US schools (Vigdor, Ladd, and Martinez 2014) shows that the increased availability of computers at home, together with high-speed Internet, are associated with significantly lower math and reading test scores in the middle grades and less frequent computer use for homework. Computing devices could also *crowd out studying effort* by offering new forms of recreational activities.

Even more, the introduction of broadband Internet could result in widening racial and socioeconomic achievement gaps. The authors of the US study interpret these findings by that home computer technology is put to more productive use in households with more effective parental monitoring, or in households where parents can serve as more effective instructors in the productive use of online resources. Students might use the computers and Internet mainly for different recreational and entertainment purposes if not guided and monitored by both parents and teachers.

Meaningful integration into curricula

For computers/technology and Internet to be effective, they need to be *linked to specific curricula goals and learning activities*. Access to Internet and computers is however a prerequisite for children and educators to be able to access learning resources, and for building the computer skills of the children, which are so much necessary in the global work market today. Mobile technologies, when paired with appropriate pedagogical tools and methods that are used meaningfully within teaching and learning environments, can yield several benefits, such as:

(I) decrease school drop-out,
(II) increase the interest for STEM (Science, Technology, Engineering, Mathematics) (Cominsky et al. 2017; Ge, Ifenthaler, and Spector 2015) subjects and careers,
(III) improve general proficiency of children in STEM (Grant 2015).

Other educational programmes and projects are necessary to complement the InfoInternet initiatives. These should help with ICT knowledge building, creating of a curricula that integrates InfoInternet and ICT into the learning activities, and encourage and motivate both students and teachers to use computer technology as tools to support their school activities.

InfoInternet for community supported education

Education is not limited to the school areas and is not only the responsibility of the teachers; the entire community and the environment in which the children are growing up influences the development of a child (Gestwicki 2015).

Family members also play an important role; as they gain computer competence, they often support their children in the same direction. The study of (Sánchez 2010) notices that even though parents have low education (or are even illiterate) their willingness to help their children with school tasks is considerable (88%). This is especially the case in poor communities where *children often cannot attend school* (Antle 2017) because, e.g.,:

- children are required to contribute to domestic chores,
- the school is not easily accessible because of the long distances, sometimes combined with adverse weather,
- the community does not even have a school building.

Special needs could be addressed by *alternative educational applications* supporting remote and individual learning. Connectivity and/or Internet access is usually a prerequisite for such applications.

Volunteer programmes like 'Computers Are Free for Everyone (CAFFE)' in Bangladesh (Ahmed, Haque, and Doyle 2015), 'Code Club' in UK (Smith, Sutcliffe, and Sandvik 2014), or 'Lær Kidsa Koding' in Norway, are examples of alternatives that can *supplement the institutionalized education*. Such initiatives could foster local job creation and ICT related entrepreneurship for youth and women (Margolis and Fisher 2003) and provide this vulnerable segment with job relevant and lifelong learning skills and new professional and life opportunities.

Through public locations, e.g., community centres, market places, health centres, besides schools, InfoInternet intends to provide information for everyone in the community. The intention is to introduce InfoInternet progressively, so that knowledge and expertise gathered in one sector will contribute to quicker results and development in the other sectors. It is an advantage to have several points of InfoInternet access and several kinds of people that are exposed to it (e.g., from health care, from education, from social care) because the number of users will also increase. Thus the entire community can contribute to knowledge sharing and support each other in the process of building digital skills. When people get together in groups, like in centres, the user that learns quickest, will give the other users pointers and suggestions (Kumar et al. 2017).

We have seen that aggregate content, including broadband content, on a village server can have positive effect on the whole local society, because it will:

- bring preferred content free of charge, and
- add the community aspects to the digital layer of information, meaning that communities can contribute to the content, can vote on it, and encourage each other to participate at reaching learning goals.

For remote learning, the InfoInternet provides local info-hotspots, which are InfoInternet local technology centres situated in public spaces where children can go easier and at different times than at school. Such a *local info-hotspot* is meant to offer access to educational material for free, on the location. The children can connect to the WI-FI hotspot through the provided hardware, such as tablets, or/and their own devices. The local info-hotspot would also provide content from local storage, in various forms, e.g., videos previously retrieved from the Internet would be stored and served on location. Such local stored content could be educational material adapted for remote learning needs. The local info-hotspot functionalities are not putting a significant burden on the mobile infrastructure, thus the free availability. However, because the maintenance of the local info-hotspot is done by the community, the complexity and variety of the available technology and features will be dictated by the existing relevant technical competence in that community.

The example of maintenance has been demonstrated through the Gram Marg project in India, where the local IT person:

- takes the responsibility for the community, and
- has the possibility to earn his daily living through providing Internet access and other services, such as online shopping.

The hardware implementations can be of various kinds fitted to the specific field requirements of the respective area (e.g., energy through solar panels to power up Wi-Fi hardware, tablets, smartphones and other connected things). Such concerns are studied in other projects (like DigI) which we build on.

Facilitating other educational programmes and initiatives

InfoInternet is intended to reach the most remote areas, where people have no or little money available to use on telephony or Internet communication. The communities that InfoInternet reached so far have only one to two dollars per month available for communication Noll et al. (2018b). The coast goal of two dollars is reachable through only buying cheap equipment like tablets, as it have been shown through the Gram Marg project. This financial restriction can also be overcame through sharing of devices in the community centres or schools. In consequence, InfoInternet must not be tied to one single kind of device, but should be useful on anything with browser-like functionality (e.g., phones, laptops, PCs; often old models). InfoInternet would cater also for future developments, when sensor-based devices, like Internet of Things, will be taken in use to support learning. The local hotspots can serve as hubs for such a sensor-based communication. The introduction of InfoInternet will allow further digital education projects to come into the community. These are projects that rely on the existence of some kind of access to Internet.

Adapting existing applications such as CETA (Marichal et al. 2017), which is a mixed-reality environment, augmenting the Cuisenaire roads, a milestone in manipulatives for mathematics learning, and inspired by a popular commercial game called Osmo. The application was adapted to work with low-cost tablets delivered to schools in Uruguay through the OLPC programme. This tangible interaction environment is especially interesting for InfoInternet as it focuses on using the limited features of the low-end tablets as an already existing technological infrastructure put in place by other programmes.

Sensor-based Platforms as built in projects like (Putjorn et al. 2017), funded by Thailand's government, require connectivity. This platform supports science learning among primary school children in underprivileged Northern Thailand. This platform does not rely on traditional mobiles, tablets and desktop devices, but on devices that can be created out of low-cost components (e.g., created locally, as part of a ICT programme in the school), and adapted for different school sciences.

Learning by Making is another project (Cominsky et al. 2017), funded by the US Department of Education, with the goal to develop a high-school curriculum aligned with the Next Generation Science Standards (NGSS) integrating all four aspects of STEM. The project has already developed a one year course approved as a college preparatory Science laboratory course. This is especially relevant for InfoInternet because the developed platform is optimized for use by students in high-needs rural communities with low Internet bandwidth.

Augmented Reality (AR) finds novel applications in combining physical world with digital information when building learning platforms (Bacca et al. 2015; Huang, Chen, and Chou 2016; Jeřábek, Rambousek, and Wildová 2014; Kamarainen et al. 2013; Yilmaz 2016). In a second stage of InfoInternet, when access to digital devices and digital skills will be more spread, we envision a digital education seemingly integrated in the local culture and environment. In this sense, the applications and devices could also support learning outside the physical classroom, in the local environment. Integrating with, and basing the education on the natural environment, would support local community building and make children aware of the local values, making them capable to contribute to its protection and development. In this envisioned environment, InfoInternet will offer the possibility to put the local in a global context and augment the local based knowledge with information available elsewhere.

The children could be provided with a digital toolbox, consisting of different cheap electronic components put together locally at schools. These devices would contain sensors and technology that could involve all senses of the child and link the physical world and information browsing to provide contextual and location-specific information. Such applications have been explored in more developed countries like Finland (Alakärppä et al. 2017).

Applications on top of InfoInternet

We analyze the characteristics of InfoInternet-friendly educational applications correlated with the previously described (A) intended target group, (B) educational environment, and (C) the specifics of the InfoInternet technology. We are interested both in existing applications that can be adapted to InfoInternet, as well as future applications designed to work well on top of InfoInternet.

Content type

Free and open content is encouraged, as our users have low purchasing power. The content producer/distributor could use Creative Commons licences. One can find a list of such existing applications in the 2016 the State of the Commons report.[25]

Shareable content is recommended so that it can be displayed on, and transferred between, mobile devices or computers in schools or at home. In the case of India, the state requires all educational material to be provided in electronic formats (e.g., pdf, epub) that can be taken by the children with their devices. The content should also be thought to be accessible for people with low digital competence and low literacy. Mobile apps like SHAREit or Zapya,[26] allow to get content from a hotspot, carry it home, and then share it with other users locally.

Allow adaptation and contribution so that local communities can also create and adapt the content for their needs and in their own languages/dialects. It is not enough to only translate into a language, but also make the content suitable and relevant for the social and cultural context in which it is introduced, for otherwise it will not be used.

One application that covers well these criteria comes from the African Storybook Initiative[27] (Stranger-Johannessen and Norton 2017; Welch et al. 2015), aiming to support and promote literacy in the languages of Africa, using digital storybooks distributed by means of web browsers and native mobile app.

Education types

Educational applications pertain to one of three main types of education: formal, informal and semi-formal education (Grant 2015).

Formal learning is initiated, led and evaluated by a teacher or a trainer (schools and MOOCs are examples). For this case, an application should be developed together with the teachers and fitted with the curricula.

Informal learning is happening unorganized and unplanned, and is being initiated by the individual itself. Participating in a hacker space, in community activities like Code Clubs, reading technical books at home, DIY (Do-it-Yourself) kits and activities, are examples.

Semi-formal learning shares characteristics with both formal and informal learning (Eshach 2007). The earlier mentioned African Storybook is semi-formal, as the storybooks are created by educators to be used to improve the literacy of the many children in sub-Saharan Africa that are out of school or that reach fourth grade without learning to read. However, these books are intended to be used without guidance, by the child alone or together with the parents, or also in schools and libraries. The project is working with teachers, librarians, and literacy development organizations in Eastern and Southern Africa to overcome the shortage of children books, particularly in local languages.

Technological limitations

As a general guideline, applications should be created (or adapted) with restricted resources in mind.

> **Scarcity of devices** or low-end and old hard/software versions (Franquesa and Navarro 2017). Devices sold in Global South emerging markets have mostly low-end specifications, characterized by slow computing power, small screen sizes with low resolution, and short battery life (Sambasivan et al. 2017). These can be devices running outdated operating systems, often bought second-hand upon

being discarded from other areas. Smartphones are falling significantly in price, but due to requirements of charging once per day have not reached the rural markets. However, thanks to programs like OLPC and the development of cheap tablets and smartphones, digital devices are more spread in schools.

The content delivered to these devices should not require high computing/processing power and should be suitable for sharing between different kinds of devices and follow the progressive enhancement principle (Gustafson 2015). In schools, a shared computer will still improve the learning activities if this can be used to retrieve information and learning resources from the Internet. The information could then be shared with the students through analogue means.

Bandwidth restrictions or low mobile data allowances. Data costs can be a substantial proportion of monthly expenses, e.g., 5% in Nigeria and 11% in Uganda. According to an Internet.org report,[28] in order to reach half the world, an app's monthly mobile data consumption should be no more than 250MB (Sambasivan et al. 2017).

There is increased interest among the web community in technologies related to creating apps that work over unstable or poor connections (Firtman 2016). Today's web technologies (e.g., Service Workers or Progressive Web Apps) (Ater 2017) allow for building such applications, but require sometimes extra resources, which companies are not willing to invest if they do not see the revenue. Though there are companies that are interested in expending/invest in emergent markets, most of these are interested in engaging these communities in the digital world as mare consumers/users. Supporting consumerism is not what it is desired for a healthy society.

Since InfoInternet aims at providing access to information, it fulfills the requirements of low data amounts, and opens for a business model where aided/subsidized usage will pay for the usage of low content. It also supports models where the government puts constrains on those using ISP or mobile licenses on non-profit content, being held as education, agriculture and e-gov services.[29]

Off-line use and local storage are an advantage, as in the African Storybook where users need not be online to read the stories; they are able to download stories on their device, or print them. It is also possible to create or adapt a story offline, and then upload it when Internet is available.

Intended use

Besides technical aspects, the design of the applications should also consider the social and cultural needs of the users. Thus, prior to technical developments, user research needs to be conducted in the regions of interest to know the existing social, cultural, political, and religious norms, and how these influence the applications. These will help to make the applications relevant for the needs of the respective community.

Users should be well identified. Types of users relevant for educational applications include:

- teachers,
- children being alone (e.g., studying at home),
- groups of children (collaborating and communicating),
- parents, or
- persons trained in a community centre.

Context is a defining factor. Identify whether the application is to be used in schools, library, at home, on the play-ground, in a community centre. *In a community/playground setting* collaboration and group activities should be leveraged. The authors of (Robinson et al. 2017) have created a framework to help with sharing of technological resources. The framework *Better Together* splits core components of a service onto separate phones to support richer mobile interactions. For example, some devices have particularly good cameras, while others offer a large storage capacity or a fast Internet connection. The toolkit is open source and can be extended, adopted to other needs. *In an out-of-school context* the content should support individual and remote learning.

Conclusions and further work

About half of the population of the Earth is not connected to the Internet. Thus, they suffer from the digital divide. When Internet enters a market it is mainly provided through mobile networks which are solely revenue oriented. Thus, content on the Internet is typically revenue generating content, such as movies. As a consequence non-profit content such as health, education, agriculture, or e-gov services are not promoted in the mobile Internet. InfoInternet promotes the free access to information under a sustainable business model, combining both of them with 2.5% of the bandwidth for basic information, text, pictures and local video, whereas more than 97% of the mobile network capacity can be used for commercial services.

Out of the three societal areas that the InfoInternet is intended to impact, we focus on education. In particular, this paper is intended to help those that build educational apps for InfoInternet (or similar), giving them guidelines for:

(I) how to understand their users (in the section entitled "The intended users of InfoInternet"),
(II) their educational environment (in the section entitled "Educational context of InfoInternet"), and
(III) the technological challenges of the networking infrastructure (in the section entitled "Background on InfoInternet").

We draw our findings from studying existing literature and using the knowledge from the currently running InfoInternet projects in villages from Africa (Tanzania, Kenya, Ethiopia, Rwanda, Ghana, Uganda, Mali), Myanmar, and India. Though in this paper we build on the technological platform of the InfoInternet, other similar initiatives could benefit from our studies, or can be applied to similar areas that have more restricted access to Internet, fitting the socioeconomic profile that we describe here.

The paper at the outset pointed out the possibilities offered by InfoInternet and how they could harnessed for educational purposes. Low bandwidth content, such as textual information and low-resolution images, can be retrieved for free, while access to more heavy content needs to be paid for through, for example, state supported funding programmes. The educational applications need thus to serve mostly content that does not require high bandwidth. This limitation is however not absolute, as the local storage possibility offered by InfoInternet, through the local hotspots, allows for sharing of information purchased elsewhere or paid for collectively, making it cheaper. The existence of several Wi-Fi hotspots, such as community centres, besides schools, allows for more flexibility in education. Children who cannot attend school at regular hours (because of, e.g., household chores), could still access the learning material provided by the teachers, in their vicinity, after the school hours or on the weekends. Education is thus extended beyond the school buildings and the whole community can participate by sharing knowledge and helping each other.

An important contribution is our identification (from the section entitled "The intended users of InfoInternet") of the specific needs and characteristics of the children and teachers, in the above-mentioned areas, who are our main users when it comes to Internet and technology use for education. However, as InfoInternet is meant to support the community as a whole and to cover as many areas of the Global South as possible, we situate our findings in this larger perspective.

We look at the role schools and teachers play in the adoption of technology for learning and we conclude that:

(I) technology and the InfoInternet needs to be meaningfully integrated with the learning environments they are introduced to and
(II) be accompanied by appropriate pedagogical tools and methods.

The educational environment is not restricted to the school building, but it expands to the level of the whole community and it is affected by the dynamics in these respective communities. Therefore, we look at how

- families,
- the communities in their whole, and
- other educational programmes outside school

could contribute to the goal of introducing technology and technology related curricula in education. We show that the adults in the community could especially be a resource in this sense, if they themselves are exposed to technology through, for example, community centres, market places, and healthcare centres. For this reason, InfoInternet Wi-Fi hotspots are established in several of such locations in the villages.

From identifying requirements related to technology in general, we narrow down our exploration to educational applications in the section entitled "Applications on top of InfoInternet". We pinpoint the characteristics that a InfoInternet-friendly application should have and group them in the following categories by:

(I) content type,
(II) education type,
(III) technological limitations, and
(IV) intended use.

For all cases we discuss aspects related to:

- the intended target group,
- the educational environment, and
- the specifics of the InfoInternet technology.

Besides guidelines for future applications, we also offer examples of existing applications that are representative of one or several of the above-mentioned criteria.

As future work, one could deepen any of the categories that we use for classifying the requirements for InfoInternet-friendly applications. In other words, one could work to either extend or implement our observations from the section entitled "Applications on top of InfoInternet". One could, for example, create technical guidelines for (i) developers, (ii) designers, or/and (iii) content creators, and then create applications that follow these guidelines and empirically test them with the intended target groups. One important consideration that we can share with future such initiatives is that the respective efforts need to:

(I) be sustained over longer periods of time,
(II) be well integrated with the respective communities, and
(III) involve the community in its whole, in order to be sustainable and long lasting.

For the empirical studies, one needs to consider the long-term impact of the introduction of InfoInternet applications in education, as well as that the adoption can change dramatically when the external stimulation and support disappears or simply because innovative initiatives take a long time to gain momentum.

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Notes

1. http://basicinternet.org/ Not to be confused with the Free Basics of Facebook.

2. DigI project 'Non-discriminating Access for Digital Inclusion': DigI.BasicInternet.org.
3. https://www.akamai.com/us/en/about/our-thinking/state-of-the-Internet-report.
4. The Global South is an emerging term, used by the World Bank and other organizations, identifying countries with one side of the underlying global North–South divide, the other side being the countries of the Global North. As such, the term does not inherently refer to a geographical south; for example, most of the Global South is within the Northern Hemisphere. The term was first introduced as a more open and value free alternative to 'third world' and similar valuing terms. https://en.wikipedia.org/wiki/Global_South.
5. https://data.unicef.org/wp-content/uploads/2017/09/Ending_Extreme_Poverty_A_Focus_on_Children_Oct_2016.pdf.
6. https://sustainabledevelopment.un.org/sdgs.
7. https://data.unicef.org/children-sustainable-development-goals/.
8. Policy paper 32/Fact sheet 44, *Reducing global poverty through universal primary and secondary education*, by UNESCO Institute for Statistics (UIS) and EFA Global Education Monitoring Report, 2017, available at http://uis.unesco.org/sites/default/files/documents/reducing-global-poverty-throughuniversal-primary-secondary-education.pdf.
9. Education based on Information and Communications Technology (in short ICT).
10. http://httparchive.org/interesting.php.
11. info.internet.org/en/story/free-basics-from-internet-org.
12. https://www.theguardian.com/technology/2016/feb/08/india-facebook-free-basics-net-neutrality-row.
13. WaveTek Nigeria Limited: http://www.wavetek.net/.
14. EU's Next Generation Internet (2016): https://www.ngi.eu/.
15. https://internetforall.one.org/.
16. Gram Marg project of IIT Bombay in India: http://grammarg.in/.
17. https://digitalimpactalliance.org.
18. http://its-wiki.no/wiki/Research_at_the_University_of_Lisala.
19. DigI project 'Non-discriminating Access for Digital Inclusion': DigI.BasicInternet.org.
20. An overview of all the villages connected to InfoInternet can be found here: https://its-wiki.no/wiki/DigI:Villages.
21. Together with Caritas Kinderdorf: http://its-wiki.no/wiki/Kinderdorf:Media.
22. https://www.codeclub.org.uk/.
23. https://hourofcode.com.
24. 'Lær Kidsa Koding' (in Norway): https://kidsakoder.no.
25. State of the Commons: https://stateof.creativecommons.org/.
26. https://www-shareit.com/ and http://www.izapya.com/.
27. http://www.africanstorybook.org/.
28. State of Connectivity Report 2015: https://fbnewsroomus.files.wordpress.com/2016/02/state-of-connectivity-2015-2016-02-21final.pdf.
29. E-government (short for electronic government) is the use of technological communications devices, such as computers and the Internet to provide public services to citizens and other persons in a country or region. https://en.wikipedia.org/wiki/E-government.

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