Towards a Systemic View of Educational Technology in Developing Regions

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***Abstract*—This paper is aimed at educational technology specialists who work with multicultural and international projects in developing countries. Educational technology is increasingly portrayed as a cure for the developing countries' educational challenges. But as countries differ much from each other, and as developing regions differ in many ways from industrialized regions, naïve technology transfer just does not work. We propose a tentative framework for a systemic view of educational technology in developing regions. In that framework, we present 100 pedagogical, socioeconomic, and technical considerations that educational technology developers may need to re-think in projects in developing regions. We propose further research on developing the current framework into a proper analysis tool.**

I. Introduction

Soon after the birth of modern computing, educators started to consider ways of using computers for fostering education. The progress of modern, information and communication technology (ICT)-based educational technology spans from the 1960s new, simple programming languages, to the 1970s personal computers in schools, to the 1980s drill-and-practice software and learning games, to the 1990s Web-based tools and multimedia, and to the 2000s web 2.0 tools and trends.

ICT is often portrayed as a cure for the developing countries' ailing education, too (e.g., [1], [2]). A good number of successful attempts at improving education through affordable ICT equipment has been presented. An equally good number of attempts have failed, for one reason or another [2], [3].

There are a number of checklists for technology development in developing regions [4], [5], but we find that they are either not aimed at educational technology specifically, or lack a holistic view on the sociotechnical system. All educational technology initiatives happen in a complex network of actors, and the success of those initiatives depends on an in-depth understanding of that network. Well-functioning technical solutions may fail due to a poor understanding of the complete sociotechnical system in the actual location of implementation [6]. Pedagogically sound ideas may fail due to a poor sociocultural understanding of the educational context. Financially promising initiatives may fail due to a poor understanding of the economic characteristics of developing regions.

In this paper, which reports a work-in-progress, we propose a list of topics for a systemic view on educational technology in developing regions. Our list is divided into pedagogical issues, socioeconomic issues, and technical issues; and each of the categories is further divided into several sub-categories. We present examples of each category, based on research literature and our experience on educational technology in several African countries; Our work on educational technology in Africa started in the late 1980s. We believe that our list covers the crucial considerations of educational technology development projects, and we propose that further development of our systemic view would benefit international, multicultural educational technology development projects.

First, we present three considerations that are related to each region's unique socioeconomic context: Economic considerations, staff recruitment and training, and organizational and political considerations. Second, we present three considerations that are related to each region's technological, infrastructural, and environmental environment: Issues related to tools and equipment, to connectivity, and to system administration. Third, we present four considerations that are related to each country's educational context: Pedagogical, motivational, educational, and content-related considerations.

II. Socioeconomic Context

Socioeconomic and cultural factors affect learning outcomes on individual level and group level, and they also shape and characterize each educational system. The design of learning objects and equipment requires contextual understanding about the learners' immediate environment. The larger the planned roll-out is, the more need there is for understanding the whole educational system.

Firstly, *economic environment* underlies all educational technology initiatives. No technology roll-out is immune to economic factors, and ICT-based solutions strongly depend on economic matters. We present a number of aspects that should be taken into account. Secondly, the importance of well planned *staff recruitment and training* cannot be understated [7]. Every ICT-based educational initiative requires trained local staff—even those ones that are aimed at self-directed and independent learning. Especially important is a well-working plan for teacher training: We have earlier suggested a participatory approach [5]. Thirdly, organizational structures, processes,

Fig. 1. Economic context

Fig. 2. Staff Recruitment and Training

and procedures on various levels have developed with the rest of the society and reflect some characteristics of the society. We present a number of *organizational and political aspects* that are crucial for planning and implementing educational technology projects in developing regions.

A. Economic Environment

Economic issues are important for a number of reasons. Project self-sustainability depends on a secured, stable, long-term source of funding. Sustainable educational technology initiatives must, hence, ensure the project's financial viability. In terms of finances, we wish to underline eight issues that designers in cross-cultural design milieux, especially in developing countries, need to understand (Fig. 1).

In most countries, educational institutions compete with each other for resources, students, projects, and funding. In developing countries the *competitive environment* is somewhat unique, though, as some national HEIs receive ample funds from the government as well as from large international donors, whereas private HEIs often fund their operations through tuitions and project-oriented small donor support.

Seeking for *secure income* causes special pressure to project budgeting, and a good number of demonstrations are often needed to encourage educational institutions to commit to the usual high *initial investments* [8]. Often infrastructure needs to be built from scratch—including proper classrooms, electricity, telephones, lavatories, and everything else [9]. Also *operational costs* may be substantial, as Internet fees in many countries run sky-high and the salary levels of competent IT staff may be similar to industrialized countries.

The *prices of computing equipment* in developing countries may be as high as twice the prices in industrialized countries [10]. Banks in most developing countries do not easily issue international credit cards, which might exclude *online purchasing* as a procurement option. While importing goods, one must be able to work with sometimes heavily fluctuating *foreign exchange rates*. Importing equipment also has its own special characteristics, as the *shipping and handling* fees, insurances, taxes, tolls, and tariffs may pile up to a significant sum of money. Often the deal is that a U.S. or EU-based organization donates used computers if the recipient institution pays the shipping costs, and sometimes that ends up as a bad deal.

B. Staff Recruitment and Training

At the preparatory phase of educational technology projects, one has to hire staff and usually train staff for their jobs. When one reads exciting and inspiring success stories about educational technology, those stories often revolve around enthusiastic and capable individuals or user groups [11]. But staff recruitment for educational technology initiatives sometimes requires special care due to the limited *availability of staff* that is both pedagogically and technically competent [8]. *Recruitment channels* often rely on informal networks, although many large projects require an open, public recruitment procedure. *Hiring policies* vary greatly between institutions, and a completely transparent evaluation of job applicants is highly recommended. Specific attention needs to be paid to *language skills*: foreign experts often lack the necessary language skills in developing countries' official languages.

In terms of competence, prospective staff members' skills and knowledge may vary greatly [8, p.23]. Due to an overabundance of various kinds of degrees, diplomas, certificates, and degree-granting institutions, it is not very easy to assess applicants' real competence based on certificates only. It is important to evaluate the applicants' *practical experience*, and not only their theoretical knowledge. Also an assessment of *generic IT knowledge* is often recommended. An explicit *training plan* may help to minimize staff turnover. One should also prepare for a high number of part-time staff members.

Similar to elsewhere in the world, *commitment* of staff can be increased through a number of items, such as salary levels, promotional possibilities, clearly stated paths for further (sponsored) education, and possibilities for extra income through consultancy [7]. However, in order to discourage employees from taking second full-time or part-time jobs, clear guidelines must be set for part-time work and consultancy outside. The international brain drain takes many of the best talents abroad, too [8, pp.18–19]. Unfortunately, apart from hiring from one's immediate network of friends and colleagues, there are few ways of assessing the *work ethic* and *accountability* of staff members beforehand. Turning bureaucratic career ladders into well-planned incentive structures has been suggested for attracting qualified and motivated faculty [8, p.23].

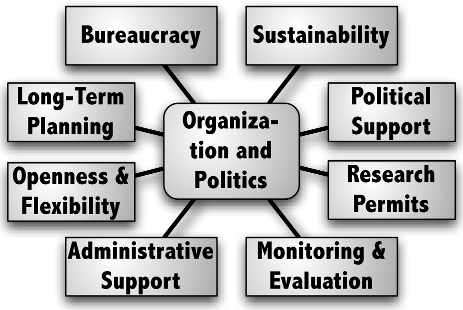

Fig. 3. Organizational and Political Context

C. Organizational and Political Aspects

Developing countries are often accused of excessive and complex *bureaucracy*. But we have found that bureaucracy is usually not as much excessive or complex as it is unfamiliar. It might be wise to employ a local partner who knows how to deal with the red tape on the organizational level and on various governmental levels. *Research permits* and work permits ought to be cleared early in advance: obtaining the necessary permits has in some cases taken a year. Schools and other educational institutions are often particular about proper permits—mostly to protect their own back.

Political support to educational projects is very important [12], [11]. One Laptop Per Child (OLPC) foundation is a great example of the importance of political support. In Nigeria, the foundation opened a great deal of possibilities through the right political connections—and lost them as the government changed [13]. In addition to wider political support, strong *administrative support* is a sine qua non of any initiative in educational institutions. Without strong and broad support, it is difficult to build *sustainability*—social, economic, environmental, and self-sustainability—in a project [5].

The institution's *openness and flexibility* [8] to alternative approaches to education strongly influences whether a technological innovation remains as a tacked-on addition to education or becomes an integrated, transformative part of education in the institution. Institutions can be encouraged to change their rules and regulations to allow new types of course arrangements, which many educational technology initiatives necessitate. The new pedagogical instruments and arrangements often require new types of grading, timetables, facilitation, and regulations.

Long-term planning should be encouraged in technology-oriented initiatives everywhere [11]. The contingent environment of developing countries, combined with the volatile funding situation of also foreign partners, makes flexible long-term planning even more important. Also, only time reveals the true commitment of various stakeholders, the real utility and usability of innovations, and how robust and long lasting the equipment really is. Hence, proper *monitoring and evaluation* scheme is imperative [5]. Projects should always include in their vision the question "If, after 15 years from now, we look back at our project, what impact did it make?" Logical framework analyses are encouraged due to their ability to look further than a single technical intervention.

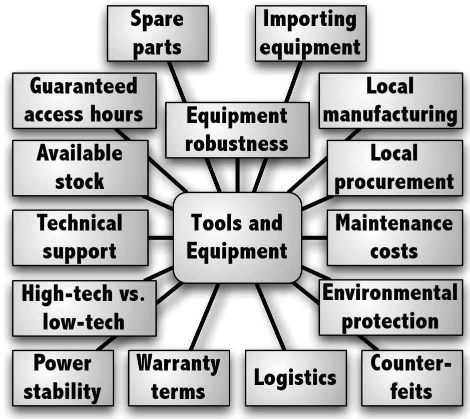

Fig. 4. Tools and Equipment

III. Technical Context

Similar to any other technology project, educational technology initiatives everywhere must take into account a large number of technical factors that underlie procurement, installation, maintenance, and disposal of equipment [14]. Those factors differ, to some extent, between regions and cultures, and they need to be properly addressed throughout the project life cycle. In this section we have divided technical issues in three broad categories.

Firstly, in developing countries issues concerning tools and equipment extend beyond the corresponding issues in industrialized countries. ICT equipment is particularly prone to fail and malfunction if some aspects of the environment do not meet the equipment's operational parameters [15]. Secondly, connectivity is an integral part of much of modern educational technology, and understanding of the contextual aspects of connectivity is necessary for project success. Thirdly, system administration is a combination of human aspects, technical aspects, and organizational aspects—each of which is dependent on the broader sociocultural and technical environment. We present a number of aspects that we have found to be central to well functioning system administration in developing countries.

A. Tools and Equipment

Usually the first task in the implementation phase is procurement of tools and equipment for the initiative. Some of the equipment can be manufactured locally, some can be purchased from local vendors, and some must be imported. Each of those methods of procurement has their pros and cons. Equipment that is *manufactured locally* varies in price and quality, ranging from unusable to excellent [16]. *Importing equipment* for the project's needs also requires some planning. Bureaucratic procedures, shipping and handling, taxes, hidden fees, tolls, necessary permits, and sometimes bribery may cause delays and additional costs to the project (Fig. 4).

Similar, when planning for *local procurement*, some issues must be taken into account. First, *equipment prices* for brand names can often be higher than in industrialized countries [10]. Second, *warranty terms* are often poor or nonexistent [17], [10]. Third, *technical support* by manufacturers and service providers is limited [14]. Fourth, *counterfeit products* are common, and they are often very hard to spot [17]. Fifth, *available stock* is often limited to the most common basic equipment. Sixth, *spare parts and tools* may be hard to obtain. Nevertheless, local procurement supports local entrepreneurship, and is, in that sense, preferable to self-imported equipment.

The issue of *high-tech vs. low-tech* is an important one, as many types of low-tech may often offer exactly the same benefit as a high-tech piece of equipment does—but for a fraction of the cost. One might ask, for instance, whether Ethiopia's Plasma TV project offered the best educational value for the money—as compared to, for example, teacher training or textbooks [3]. There again, robustness, reliability, and durability are characteristics often linked with low-tech, but, ironically, high tech often works more reliably: For example, landline telephones in many African countries work very poorly whereas mobile phones work sometimes reliably.

In many countries with less developed road and rail infrastructure, *logistics* can be costly and difficult to organize, and poor roads and transport equipment sometimes damage equipment [14]. Due to frequent *equipment failures* caused by the harsh environment [15], *maintenance costs* can be significantly higher in developing countries than in industrialized countries. Usually we consider 20% of equipment to be out of order at any given moment, and plan the amount of equipment accordingly. *Power problems* are common in developing countries. Power stability is affected by, for example, rolling blackouts (load shedding), thunderstorms, deteriorated power grid, and poor electrical infrastructure.

In projects that involve computer labs or other kinds of shared equipment, computer / student ratio is an important issue. That ratio, however, is not sufficient for guaranteeing enough hands-on time. Instead of computer / student ratio, we are nowadays more concerned about *guaranteed access hours* per week per student.

Environmental concerns are easily overlooked by educational technology projects everywhere. In industrialized countries, where e-waste recycling is well organized, e-waste is not a big issue, but in developing countries projects must institute their own e-waste collection procedures [18].

B. Connectivity

Many technical solutions for education require some kind of connectivity; usually access to the Internet. For example, podcasting, video lectures, and content management systems all need varying amounts of bandwidth in order to be viable. Although many developing countries have, in principle, a fiber-optic connection to the rest of the Internet, in reality some adaptability is required (Fig. 5). In Africa, for instance, *Internet penetration* varies greatly between countries: from Niger's 0.7% and Somalia's 1.0% to Morocco's 33.4% and Seychelles' 38.4% [19]. *Government monopolies* play a significant role in the availability and pricing of Internet connectivity [20]. In our experience, governmental telecommunications companies also lack in service orientation and *technical support*.

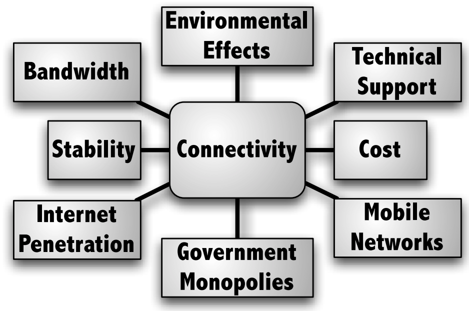

Fig. 5. Connectivity

Availability of the Internet is, interestingly, not always tied with the power grid, as in many areas *mobile networks*, GPRS, 3G, and even 3.5G, work fine. A good number of educational solutions have also been based on simple short messages. Mobile phone coverage and services, of course, vary greatly between countries and between rural and urban areas, and in most cases, mobile coverage does not yet guarantee Internet connectivity. VSAT satellite connections are more expensive but are available nearly everywhere. Long-distance wireless solutions are currently being developed for rural areas [21].

Even where the Internet is available, *bandwidth*, *cost*, and *stability* of Internet connectivity are crucial issues for many educational solutions. Satellite-based Internet is expensive. For example, a dedicated (1:4) 1024kb/512kb satellite connection for Africa costs slightly below $4000 per month (BADR-6 satellite). In many cases the Internet connection is intermittent, and there is no way to find out how long the downtimes will take. All mobile connections, Wi-Fi/Wi-Max connections, and satellite connections are vulnerable to *environmental effects*, especially rain fade. A great number of educational solutions can, however, be tailored to cope with limited connectivity or be designed to need no connectivity at all.

C. System Administration

A great amount of technical expertise is required during the analysis, design, development, and implementation phases of educational technology projects. Many technical decisions have to be finalized early in the process, and changes may be difficult to do later. Hence, the project staff should involve, from early on, an expert on local technical context, who can advise the other team members on local technical issues [22]. After all, often the technical issues in developing countries vary greatly from those in industrialized countries [15], [16], [17]. In addition, during the everyday operation of educational technology, systems need active maintenance to ensure smooth running, and the system administrators need to be well knowledgeable about the local sociotechnical environment (Fig. 6).

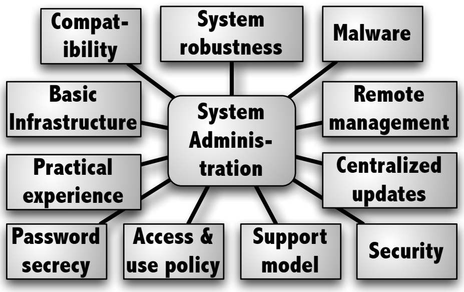

Fig. 6. System Administration

The issues one has to deal with in developing countries start from very basic concerns. One cannot assume that the *basic infrastructure* works flawlessly. Hence, things like power quality, building quality, wiring, roofing, and other similar issues need to be ensured. *System robustness* is more important in developing countries than in anywhere else. In many industrialized countries, if a system goes awry, it is often quite easy for system developers to go and fix things, or even fix the system remotely. In developing regions, *remote management* may not be possible [16] and there may not be enough local expertise to do a re-installation and re-configuration.

Spyware, adware, viruses, and all other kinds of *malware*, are a nuisance everywhere in the world, but in developing countries, few people have their virus protection software up-to-date. Not only with virus database updates, but also with other kinds of programs, much care must be put on the design of *centralized updates*, as centralized update mechanisms are, in our experience, particularly sensitive to problems.

Aspects of *security*—data security, physical security, network security, and system security—require more thought than they do in many industrialized countries. Security also involves security from inside: Tampering with systems has been reported as a problem in ICT4D projects [16]. Proactive planning and attitude change may work towards minimizing misuse of equipment and services. The types of misuse may range from quite innocent (such as letting friends and family members use the project computers for their own tasks) to questionable (such as using an expensive pay-per-megabyte Internet account for private things) to borderline fraud (such as using the project printing resources to run a small printing business). Hence, *policies* are needed for using and accessing equipment and resources, enforcing those policies needs to be done rigorously, and assessment and evaluation of those policies must be done externally to the responsible unit. A properly planned and managed *support model* for update and maintenance has been argued to be a key element in one-to-one computing projects, for instance [4], [5].

Furthermore, in many types of systems, stringent *password security* needs to be at place, along with regular, forced password changes. In our earlier research, we found out that 38% of the student respondents knew the passwords of some other students, 39% sometimes used other students' accounts, and 59% sometimes used other students' printing quota (which indicates password sharing) [23].

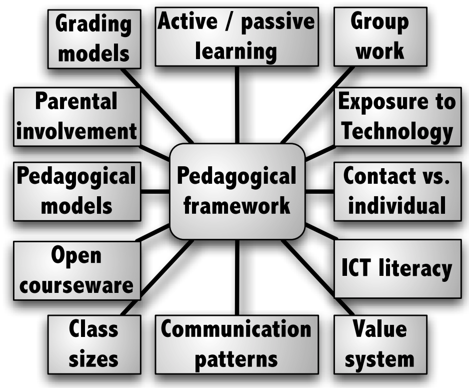

Fig. 7. Pedagogical considerations

It is important to ensure that there is enough *practical experience* at the grassroots level of operations. In many countries, Linux and Macintosh systems are rare, and more time has to be invested in staff training if those systems are in use. In addition, especially when planning Linux or Macintosh based systems to be embedded in existing systems, one should prepare for sorting out incompatibilities.

IV. Educational Context

Understanding and mastering the educational dimensions of the design context is the most important success factor in any educational technology initiative. Especially in challenging educational settings, educational technology initiatives must take into account important issues concerning differences in pedagogical practices and in the context-dependent motivational and cognitive characteristics of teachers and learners.

Firstly, the choice of *pedagogical approach* involves a range of practical decisions that require expert planning. We present a number of pedagogical issues, which often differ remarkably between industrialized and developing countries' educational systems. Secondly, the *motivational and cognitive characteristics of students* include a wide range of issues, which must be understood and well-considered in any successful educational project. Thirdly, the project must be well aligned with the broader *educational context* and its local, regional, and national actors and elements. Fourthly, educational technology is usually just a tool for delivery of educational *content*, which must be well designed to suit the particular context [24].

A. Pedagogical considerations

Pedagogy—or the strategies, methods, and practices of teaching—is at the heart of every educational technology project, either implicitly or explicitly [5]. An explicit investigation and evaluation of pedagogical choices in an educational technology project strengthens the project considerably. We have listed twelve aspects of pedagogy that are important for the success of educational technology initiatives (Fig. 7).

When planning the initiative's pedagogical dimensions, it is extremely important to be familiar with a rich variety of pedagogical practices, and to be able to recognize, which pedagogical practices are feasible in that specific project. The choice between *active and passive learning* models defines the extent to which the learning environment will assume a student-centered, constructivistic approach, and how much of the teaching will be teacher-driven, instructivistic, or "traditional" teaching. In our experience in developing countries, local teachers and learners have usually been exposed to only one learning model—typically a teacher-driven one—in which case a too radical and sudden switch to a student-centered, open learning environment, will not be easy to implement.

Students' attitudes towards *group work* differ greatly between regions. For example, in Africa it is very important to be sensitive to the group work tradition that is inherent in a high number of African cultures [25, 31]. Group work tendencies may have both negative and positive impacts on teaching and learning [26], and may cause unnecessary extra work to an unaware educator. Individual coursework, which is aimed for students who are used to working in groups only, should discourage copying and free-riding. Many cultures do not encourage competition between students, especially if striving for improved individual performance is considered to be self-centered. There again, a "leave no-one behind"-attitude and a positive group spirit can be an intense motivator. Utilizing group work in constructive ways demands well-planned pedagogical approaches. In addition to group work dynamics, *value systems* at large affect a wide range of pedagogical and organizational elements. One should analyze whether certain dynamics carry over to virtual learning, too.

In many cases teachers' and learners' *exposure to technology* is limited, and they might have never used a computer before. Also the general *ICT literacy level* might be very limited. For example, in one rural primary school in Tanzania, which was selected to host a one-to-one computing pilot project, the teachers had practically no computer skills at all before the project started. *Parental involvement* is an important element of educational projects on the K-12 level [5], and if a research component is involved on the K-12 level, parents must be involved from the beginning and their consent to research must be established. However, safeguards against nepotism, favoritism, and various kinds of pressure need to be taken when parents are involved.

One important pedagogical consideration is the ratio of *contact versus individual* learning. In developing countries, even at tertiary level the students' need for close contact and affective support is high. This needs to be considered when planning the ratio of face-to-face, distance, and blended learning modes in the learning environment. *Class sizes* may range from very small to very large [9], and one must appreciate the different contextual dynamics of various class sizes. Similar, proper analysis of *communication patterns* among students and teachers is crucial for successful design of learning environment. For example, there are differences between regions in the readiness of university students to make a conversation, pose questions, or actively participate in the classroom. It is sometimes culturally improper to question the lecturer, to interrupt the lecturer and ask for clarification, to strongly state one's *real* opinions, or to tell the lecturer that some things were not clearly understood. Again, one should analyze the extent to which these characteristics carry over to online interaction.

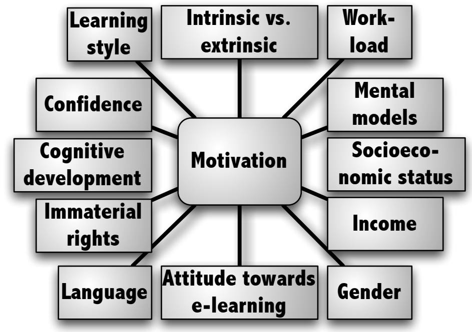

Fig. 8. Motivational aspects

We have found that the institution's *grading models* can influence the available pedagogical alternatives quite much. Some institutions impose strict, fixed models of grading, which state that every course must consist of certain fixed parts, and those parts are graded separately. For example, it may be decreed that every course must contain a certain number of assignments, a midterm exam, and a final exam, and that the final grading must be done using a particular formula.

B. Motivational and cognitive aspects

Understanding students' motivational and cognitive factors greatly improves the success potential of an educational technology project. Hence, it is important to study and analyze the motivational patterns of students. One should, for example, investigate whether the students' motivations to learn are mainly intrinsic—in which case the learners are interested in the topic or activity itself, or if the students' motivations to learn are mainly extrinsic—in which case they study in order to gain an external reward. This distinction between *intrinsic versus extrinsic motivation* has been found to be an important factor in learning outcomes [27]. It is important, but not always straightforward, to support an intrinsic motivational state. In addition to teachers' and students' motivations, the other partners' motivations must also be appreciated, as they may range from altruistic to nationalistic to private and tribal.

Similar to motivational patterns, we see *learning styles* as a very important consideration in educational technology research and development. Learning styles are traditionally classified into deep learning and surface learning [28]. Intrinsic motivation is confirmed to be connected with deep-level learning strategies and constructivistic pedagogy, whereas extrinsic motivation is connected with surface-level learning and instructivistic pedagogy. Certain learners have a tendency towards surface-level learning styles, such as rote memorizing, and certain teachers encourage that tendency [8, p.23]. That tendency, along with a lack of other cognitive and metacognitive learning skills, constitute a major challenge especially in

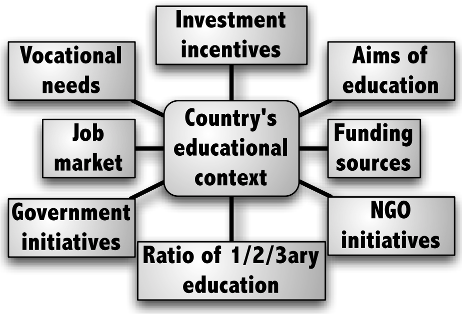

Fig. 9. Educational context

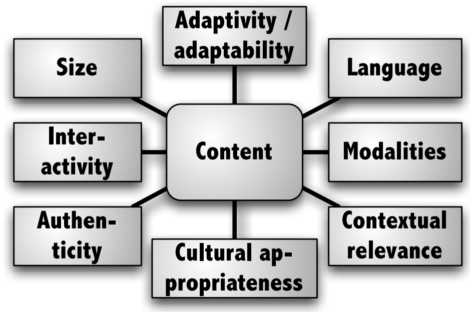

Fig. 10. Content

university studies, which require exploring, critical thinking, and problem-solving abilities. A related epistemological aspect is the *cognitive development* level of students [29], which describes whether a student understands the complex and to some extent relative nature of knowledge, or whether a student believes that there is one right answer for every question.

Language skills of teachers and learners bear a significant impact on learning, and those skills can be in some cases very limited. Correspondingly, for a foreign educational technology designer the local languages can be very challenging. The *confidence* of students with their own skills and capabilities may not always be realistic, and both overestimation as well as underestimation of one's strengths may hinder learning. *Attitudes towards technology* affect diffusion, adoption, and continued use of technology [30], and those attitudes may vary greatly between cultures. Various sources suggest that it is necessary to have local champions for technology, but the idea of champion is not well researched [12]. The *socioeconomic status*, which is a complex social, economic, tribal, and cultural construct, will need to be taken into consideration. Finally, *gender* and role expectations may be decisive to staff and student behavior [22].

C. Educational context

For many large-scale rollouts of educational technology it is necessary to integrate the new technology in the broader educational system [22]. Each country's educational system is different, though, and an integration requires in-depth knowledge about the broad context of education (Fig. 9). Many of the differing aspects are implicit, which makes it important to put explicit emphasis on finding out those aspects. For example, the *aims of education* differ between countries: Whereas in some countries the aims of tertiary education are those of a liberal education, in many other countries critical and pluralistic thinking is not encouraged, and professionalization and economic empowerment are emphasized instead. In many cases, a thorough understanding of the *job market*, *vocational needs*, and the *ratio of primary, secondary, and tertiary education* is also indispensable.

Funding sources of educational institutions differ between industrialized countries and developing countries, and between various kinds of institutions. It is especially important to be aware of the educational initiatives of various *non-governmental organizations* and *governments*—especially projects funded by UNESCO, World Bank, or bilateral aid—as those projects often have massive ramifications on the whole educational sector. In addition, it is important to understand how individual students fund their studies; it is often a combination of students' own investment, family, relatives, "sponsors," and government loans. There again, the *investment incentives* of stakeholders are sometimes relevant to planning of educational technology projects.

D. Content

Sometimes, in educational technology projects, tools and delivery modes of education are emphasized at the cost of the much more important educational content [5]. First and foremost is the *language* issue. It has been argued that content in local languages is one of the main considerations in educational technology projects in developing countries on the K-12 level [5]. But in addition to language, *cultural appropriateness* of educational content may make or break the project [31], [32]. It has been suggested that *authenticity* and *contextual relevance* of the content greatly affects educational technology projects in developing countries [31].

When planning the *modalities* of education, similar principles may or may not apply everywhere, and continuous research is needed to find out the best practices in various educational contexts (e.g., [33]). As students' starting levels and educational backgrounds may vary greatly, *adaptivity and adaptability* as well as *interactivity* hold great promise. In those cases where the end users' equipment may vary greatly (e.g., mobile learning), and in those cases where delivery modes or bandwidth are not known, *size* of content becomes an important issue.

V. Future work

This article offers neither generic guidelines nor design approaches for educational technology in developing countries. Our systemic view is a tool for analysis and planning; not a tool for design, development, or implementation. As each developing country context differs from each other greatly, there are no rough-and-ready solutions for such highly varying and complex sociotechnical systems as those frequently found in educational technology.

In the future, two concurrent branches of research on the topic are needed. On the one hand there is a need for deeper analysis of each of the ten categories in our list. That analysis should produce pieces of research that together contribute to a *broad and deep systemic view* of educational technology in developing countries. On the other hand, there is a need for situating the presented systemic view into design process models, such as the ADDIE model (analysis, design, development, implementation, and evaluation). That combination should produce *practical guidelines* for computer scientists, instructional designers, and other educational technology professionals about how to design educational technology from a systemic perspective. The comparatively resource-poor context of many implementations in developing countries leads to a bare-bones research and development approach where every element might be much more clearly exposed than in a resource-rich context where the environment is more level and constraints are less likely to be recognized. Thus, many lessons learnt in a developing country may be as valid for developed contexts.

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