Imaging and Assessing Mobile Technology for Development

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Edited by

Richard Musabe and John Sören Pettersson

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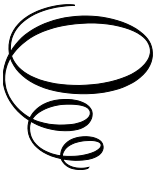

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FOREWORD

MOBILE TECHNOLOGY FOR DEVELOPMENT: AN INTRODUCTION

JOHN SÖREN PETTERSSON AND RICHARD MUSABE

1. Harvesting development?

The dissemination of inventions has been a research focus for decades. For international development, the idea of transferring knowledge and technology has been a natural area of focus. While the concept of 'transfer' has been qualified by increasing demands for imaging needs from the perspectives of the people planned to be affected by the transfer, it is also clear that certain technological developments are appropriated even if the hardware involved cannot be produced outside a few regions of the world. The remarkable spread of mobile telephony in the developing regions of the world at the beginning of this century was surprising because mobile telephony with small hand-sets represented the latest technology, and its adoption in a region supposedly built on an existing well-developed network of wired telephones. Since then, many digital services have blended into the mobile mix. All of these factors promise to bring under-served areas of the globe with effective means to exercise democracy, money transaction, waste management, electrification, agricultural development, and so on. However, the records show that harvesting development is often not as easy as getting millions of people to subscribe to mobile operators.

There is a need to spread ideas about applications of technology and also to evaluate the impact of such attempts against their goals, but also against their presumptions. In a literature review on "the maturity of the mobile communication technology for development (M4D) landscape", Van Biljon and Renaud remarked that "the unprecedented ubiquity and reach of mobile technology has created unique opportunities that warrant evidence-based research attention in order to navigate the challenges and optimise the benefits of mobile technology in supporting development" (2018, 16–17). The present volume focuses on M4D aspects of technology for development.

There are reasons to treat as a special focus area a technology that has become so widespread and where the technological development promises further capacity development as concerns the technology itself. Nevertheless, the question of how to harvest the potential for social and economic development is not answered by staring at the technology (Odumosu 2017; Wamala-Larsson and Stark 2019; Dini, Hatakka, Sæbø, and Thapa 2022). The contributions to this volume are inspired by questions (obstacles) related to the development of automated services, utilisation of services, awareness of services, dissemination of services, and the dissemination of knowledge of the underlying technology. Some chapters struggle with the matter of how to make users better understand the opportunities that have already been offered, while other chapters more or less explicitly air a preference for adaptation rather than adoption, or appropriation rather than adaptation, or indigenous development rather than appropriation.

There has been extensive debate on what decolonisation and self-determination should mean. Even the supposedly value-neutral science has exclusivist frameworks that cement the dominance of the Global North or West (Mogaji, Maringe, and Hinson 2020). An increasing stream of works by authors from the Global South points to the bias when development, technology, and innovation are traded the "international" way – the Western way. Examples with African perspectives include Mavhunga's (2017) collection of critical essays on *What Do Science, Technology, and Innovation Mean from Africa?*, Adamu's (2023) very recent problematising of "solutionism" and "saviourism" in human-centered computing for development discources, and the likewise recent *Digital Transformation for Promoting Inclusiveness in Marginalized Communities* from researchers at Midlands State University in Zimbabwe (editors Zhou, Mahlangu, and Matsika 2022). Other examples are brought up in the chapters of the present volume. Also, ICT as a pro-poor instrument in development can be questioned as it simultaneously opens a digital divide (a recent reflection is found in Musungwini et al. 2022, 96). The present book does not attempt to launch a specific model for digitally supported development. While the perspectives differ between chapters, the unifying theme is an underlying current of analyses of epistemological structures on the community and individual levels when development is supposed to rely on widely available communication technology.

When does development happen, and how much does it depend on digital technology? Van Biljon and Renaud argued that re-inventing the wheel by conducting an endless stream of small unconnected pilot projects will not further research (2018, 16). It would be tempting to also conclude that individual piloting does not lead to development and, consequently, the

lesson would be to study the many reports from all corners of the world that have documented previous attempts in order to find a gap to define one's own unique contribution, before even starting to think about making a contribution. Alternatively, it should perhaps be recognised that development on the ground, among "local manufacturers and consumers" as mentioned by Catherine Bishop (2021, 54) – that is, appropriation and the crafting of system-solutions that fit a *certain* community where the ambient society provides *certain* support and has *certain* needs for the moment – can hardly be done by learning "the lesson" once and for all. Instead, the editors of this book rather see a promising state in the ever-increasing number of on-the-ground investigations. Such studies reflect the willingness of new generations of entrepreneurs and students on all levels to experience such investigations, whether it is data collection for planners or service prototyping, or community organisation-building. These studies also indicate the readiness of groups at various levels of society to participate; this is especially reassuring when projects are conducted by local institutes, not least institutes of learning such as colleges and universities. This constant interaction is necessary in the development of conscious students as much as it is necessary in the development of appropriate policies, regional development plans, and technology-based systems (or "solutions" as IT people like to call their initially square wheels).

When the focus is on advanced, general-purpose technology in an available format (yes, the handset, but the relaying telecom towers and the battery chargers are not to be forgotten), it is worth recalling the rather slow electrification process during the decades around 1900 in the "developed" world (the industrialised world). As the economics historian Paul David (1990) described in an often-cited article, in the United States there was a 30-year lag before factory layout significantly deviated from steam-engine logic, despite the much greater distributional freedom that electrical power allows compared to mechanically distributed power. This partly explains why "future technological progress is consistent with low current productivity growth" as three of the foremost researchers in the field concluded when analysing the productivity figures related to artificial intelligence in OECD countries and emerging economies (Brynjolfsson, Rock, and Syverson 2019, 41; Brynjolfsson and Hitt 2000). Might we think that mobile technology for development is now mature? After all, the impactful adoptions of mobile phones in Kerala, India, which led to a dramatic increase in fishery market performance, occurred already between 1997 and 2001 (Jensen 2007). However, for several reasons, the answer to the above question is "no". The infrastructure spread has not favoured sparsely populated areas and informal settlements, and rural areas in general are underserved. Policy development,

but also service development, are still needed. Another reason for the "no" is a more positive observation, namely that the last few years have seen the proliferation of several new types of affordable digital technology, and people have only just started figuring out productive service designs.

2. Trends

Several studies have already depicted the development of M4D and of Information and Communication Technology for Development (ICT4D), and that will not be repeated here. However, as this collection of chapters have sprung out from one of the M4D conferences – the M4D 2022 in Kigali – some notes on what have been salient at different conferences can be made. If we start with the M4D in Senegal 2014, we can see that from that conference stems a book where the chapters "initiate evocative conversations on how mobile technologies can contribute to expanding mobile participation practices" (Wamala-Larsson, Hellström, and Scharff 2015, 12). In Mozambique, in 2016, there were some contributions connecting to radio and TV technology; the M4D 2018 conference in Uganda included some papers on how utilities can be backed by subscription schemes via mobile services, as well as by apps where citizens can report dysfunctions and illicit use. The M4D 2020 did not take place, as the COVID-19 pandemic prevented the possibility of running a conference on site and it was postponed to 2022, when Rwanda saw the first blended M4D conference. The Zoom presence for several dozen participants over three days went very well and, via two cameras and two large screens at the venue site, they blended in well at the conference. The IT maturing effect caused by the pandemic was thus noticeable. Among the presentations it was noticeable that the Internet of Things and drones, often blended with machine learning, are now imaginable as "mobile technology". Of course, drones are always mobile, and IoT sensors often travel with cargo, but it was the realisation of the affordability of these technologies for food chain, livestock, and crop management, combined with their reliance on mobile phone networks to make use of farmers' photos and senor data, that made such presentations appropriate at a conference that focuses on affordable communication technology.

While technology is a prerequisite, in this volume, based on selected contributions to that conference, we will balance some imaginations with some assessments. The focus will not be on the "new" M4D, even though we acknowledge that it is time to set up demonstration farms with IoT and machine learning, as pointed out by Ronald Katamba from Uganda in an interview (Pettersson and Rehema 2022, 145), and books are now published

on *Applying Drone Technologies and Robotics for Agricultural Sustainability* (Raj, Saini, and Pacheco 2023, with examples from India and Zimbabwe; see also FAO and ITU 2022). Instead, the chapters selected for this book adhere to the theme of knowledge dissemination and knowledge development, as mentioned already. One chapter was invited to report from the African Center of Excellence in Internet of Things, hosted by the University of Rwanda in Kigali, to illustrate the efforts to build native technological competence on an advanced level. That chapter simultaneously demonstrates the growing pan-African collaboration in the academic infrastructuring project. The following section provides an overview of the book by presenting the chapters one by one.

One trend that this volume does not focus on is sustainability, at least not in the number of references to UN's Sustainable Development Goals (SDGs). Sustainability is important in ICT4D, as can be seen from the special issue on this topic opening the 2023 volume of the journal *Information Technology for Development* (Andersson and Hatakka 2023). However, those articles already do a good job of analysing SDG in relation to ICT4D, which leaves room for a book on competence of use and development of availing information technology.

3. Chapters in this volume

In Chapter 1, **Service-learning and appropriate technology in ICT education**, Simon Pickin, Ángeles Manjarrés, and Simon R. Munyaneza discuss combining the ideas of appropriate technology and service learning in university-level computing education. The application example draws on mobile technologies. The authors provide some current lines of research in these areas and a concrete example, where the first prototype of an application developed and deployed by a Rwandan public-sector organisation was built according to this approach in the context of an MSc thesis. In over a decade of use, this application has provided an invaluable service to millions of Rwandans.

Also, Chapter 2 discusses how university students should be connected to real-world problems. Here, however, a bold vision – a hyperbole to some, perhaps – is presented of digital infrastructures that can provide immersive learning experiences to ensure that universities in resource-constrained regions can offer education that would attract students who would otherwise try to study abroad. In the wake of the COVID-19 pandemic, we are currently experiencing a mixture of old and new ways of providing education and conducting teamwork. Simultaneously, more digital technologies, such as machine learning, cloud computing and edge computing, Internet of

Things, and drones, are becoming viable targets for solutions in resource-constrained areas. Based on their experiences of Namibian-Finnish resource sharing at different levels of education, Vuyelwa Ruwodo, Antti Pinomaa, Lannie Uwu-khaeb, and Erkki Sutinen present a sketch called **Interconnected bases for a physical metaversity in Africa**. Their concept exceeds that of virtual reality and presumes that a functional instance of a "metaversity" also has a physical appearance in the concrete community within which it operates. The authors argue that interconnected bases are needed to provide the talents of the future with research, development, and innovation competences at the global level and, at the same time, the grassroots level competence and comfort needed in real-life contexts.

In Chapter 3, on the other hand, William Tichaona Vambe and Tineyi Herbert Pindura report and reflect on focus groups conducted with students from a South African university after the 2020 lockdowns with its hasty adoption of digital technology in distance teaching and learning. Their chapter, titled **Post-pandemic reflections of university students' perspective on the e-learning in South Africa**, includes reflections on where the South African education sector is coming from, where it stands now, and where it ought to be. They note that most students prefer blended learning when compared to pure face-to-face learning and pure online learning. Bandwidth constraints led most respondents to use mobile phones instead of laptops to connect during the lockdowns, but the reasons for returning to campus later were varied. Vambe and Pindura emphasise that frameworks for blended or online learning must consider where students are coming from in terms of network connectivity and their digital literacy. There can be a huge gap between urban and rural capacity.

Chapter 4, by David T. Risinamhodzi, Courage Matobobo and Prince D. N. Ncube, entitled **Students' mobile security awareness: Insights from the Eastern Cape**, takes the discussion on reliance on mobile phones further. The authors note that very few studies have reported on mobile security awareness in rural universities. Their study assessed students' knowledge of mobile security best practices at a rural university in the Eastern Cape province of South Africa to serve as a basis for future interventions to improve mobile security and protect the university network. The authors propose a model to significantly improve mobile security awareness among users in the university community, and thereby assisting the users to apply security best practices to their usage of mobile devices.

Several contributions to the M4D conference series over the years have dealt with food production and distribution. From the 2022 conference, one of the papers focusing on agriculture was selected for this volume. Like the other chapters in this book, Chapter 5 adheres to the aspect of information

dissemination, in this case the **Use of mobile phones to enhance households' access to agricultural information in Nyamira North, Kenya**. The starting point for its author, Samwel Auya, is the observation that weak economies have rendered most governments in developing countries like Kenya incapable of fully providing requisite agricultural information to households engaging in farming. To bridge this gap, mobile phone network operators in Kenya, as in other developing countries, have launched services where households can use mobile phones to access agricultural information. Auya reports from a study that sought to determine the level of perceived utility among households of such mobile information. The use of mobile phones to access agricultural information has enhanced household production in the perception of the farmers, but simple handsets, language barrier, and high costs are notable challenges facing households from using mobile phones to access agricultural information.

In Chapter 6, **Conceptualising digital resilience factors for mobile payment services**, Muftawu Dzang Alhassan and Martin Butler conduct a systematic literature review to investigate the convoluted questions of how people perceive risk and are willing to use mobile payment services after fraud. Mobile payment fraud has been on the rise for many years, while individual and societal gains from mobile money are enormous. The authors argue that ensuring user continuity of mobile payment services is imperative after fraud events have occurred. Their study identifies factors that can help mobile payment service providers effectively manage the immediate environment of victims of mobile payment fraud, and may also enable technology developers, service providers and governments to promote intended benefits and support resilience at the individual level.

Chapter 7, **Decolonising community-based media**, returns to the question of appropriate technology and indigenous technology. In this chapter, media researcher Brian Semujju and technology researcher Jude Mukundane explain why they ended up with different sorts of "towers" (viz., audio towers vs. FM radio towers) for local, "community-based" communication. Each author also reflects on the problem of trying to localise what is inherently foreign technology. The authors assert that "There is need to assess the relevance of community-based media from the perspective of the independent communities they stand to serve." Content in community media is a key issue, not only technology, even if the latter may possess obstacles if it requires the maintenance by extrinsic expertise. In addition, the chapter reveals the lack of government support in policymaking and procedures to support relevant local media forms.

While local-community capacity building seeks appropriate content through appropriation of technology, as discussed in Chapters 5 and 7 for

example, there is also a mindset in which building capacity goes via higher education, as exemplified in Chapters 1 and 2. For the final chapter in the book, we invited the acting director of one of Africa's *centres of excellence* that has been developing in the last decade, to simply report on the motives behind the efforts and the struggles they are facing. Damien Hanyurwimfura has compiled a **Case Report: the "African Center of Excellence in Internet of Things" in Rwanda**, which is presented as Chapter 8. Hanyurwimfura demonstrated the centre's facilities during the M4D 2022 conference in Kigali, and master's students and teachers presented several studies at the conference. It is obvious that the limit for what is "mobile technology for development" is rather mobile in itself. The IoT is a facilitator (often through so-called "edge computing" protocols, although we leave the technological details out of this introductory text) for the use of ever-cheaper sensors and actuators. These make data collection and processing through "traditional" mobile networks and even handsets an affordable reality for villages and farmers, as well as utility service providers and their customers. Appropriate development of systems for applications throughout the developing world (actually, throughout the world) requires the indigenous development of educational and production capacity. Chapter 8 ends with a discussion of the centre in a larger context, not least the ambient discussion of innovation systems. The chapter cautions that innovation systems build on collaborations and that it takes time to develop the connections needed.

We should also mention the Afterword, **A view from the back seat**. Using the "back seat" as a metaphor, the Afterword puts the contributions to this book into a new perspective. Several chapters battle with the question of the extrinsic technology's place in community-sourced development, and also with the concomitant values to the adoption of educational structures, especially university-level education and the perceived need to compete on a global ranking, which easily puts all new universities in the back seat of the vehicle of progression. Tunisian-born Sana Rouis Skandrani reflects on the place of North Africa in the development of Africa. She uses the back-seat metaphor to ponder other situations that puts her in the rear seat of events, at a distance from the steering wheel.

The contributors to this volume are presented before the Index section.

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CHAPTER ONE

SERVICE LEARNING AND APPROPRIATE TECHNOLOGY IN ICT EDUCATION

SIMON PICKIN, ÁNGELES MANJARRÉS
AND SIMON R. MUNYANEZA

1. Introduction

Recognising the important role of ICTs in the Agenda 2030, accreditation bodies such as ABET (https://www.abet.org/) and organisations that provide curricula recommendations such as the ACM and IEEE stress the importance of integrating ethical-civic competences and sustainability in undergraduate curricula. Service Learning (SL) is a pedagogical methodology that combines formal and informal learning with providing a service to the community (Jacoby 2014). SL is an eminently suitable vehicle for the acquisition of these transversal competences in both undergraduate- and postgraduate-level engineering studies, due to its active, constructivist and experiential nature which greatly facilitates raising awareness among students of the impact, and of the potential for social transformation, of technology development and deployment.

Appropriate Technology (AT), in its essence, describes low-cost technology that responds to basic needs and which, by design, is well-adapted to the deployment context. Regarding Information and Communication Technology (ICT), mobile telephones provide a convenient platform for Appropriate ICT (A-ICT), primarily due to their high penetration. According to International Telecommunication Union (ITU 2022), in 15 years, the ratio of "mobile-cellular telephone subscriptions" per 100 inhabitants in the "developed" and "developing" countries[1] has gone from 4:1 to almost parity while the ratio of "active mobile broadband subscriptions" has gone from

[1] Terminology as used by the ITU, though the distinction between "Developed regions" and "Developing regions" was removed from the UN M49 Standard in December 2021.

over 20:1 to under 2:1. Moreover, elsewhere ITU states that "Ninety-five percent of the world population now has access to a mobile broadband network" (ITU 2021, 10).

We observe that SL objectives in engineering studies are complemented and enhanced if the development and deployment used in these studies follows the principles of AT. In tertiary computing education, the curricula areas which most lend themselves to the use of SL pedagogy and AT principles are undergraduate degree projects and master's degree theses, due to the number of student hours they entail and to the fact that they are subject to relatively few curricula restrictions.

We report on a successful use of AT-based SL in which a prototype application that was designed and implemented in the context of an MSc thesis was then further developed and deployed by a Rwandan public-sector organisation, having a significant impact on Rwandan society. We note in passing that Rwanda was exceptional (in 2018) among developing countries in having well-developed online public services, according to ITU (2021). Since a version of this application has now been deployed for more than a decade, we can draw some conclusions about the sustainability of the technology and about the long-term impact that AT-based SL can have on the community partner.

The rest of this article is structured as follows: in Section 2, we provide definitions of the concepts that are crucial to this article, SL and AT, briefly discussing the history of AT, its relation to sustainable development and the use of AT in the field of ICT. In Section 3, we discuss technologies that are well-suited to forming the basis of A-ICT projects. In Section 4, we present our work on promoting A-ICT based SL, in particular, using these technologies. In Section 5, we present the highly-successful Rwandan public-sector application which began life as a SL-oriented MSc thesis in AT and in Section 6, we draw our conclusions.

2. Service Learning and Appropriate Technology

2.1 Service Learning

SL is defined by Barbara Jacoby (2014, 1–2) as "a form of experiential education in which students engage in activities that address human and community needs, together with structured opportunities for reflection designed to achieve desired learning outcomes." Jacoby adds that "some definitions clearly state that service learning must be part of the formal academic curriculum". *Community engagement* is perhaps a more commonly used term in the African context (Preece 2017, 49–74), though definitions

of both terms vary. Generally-speaking, service learning has a more precise meaning. In particular, most service-learning experts stress the distinction between service learning and volunteerism / community service. Jacoby (2014, 2–3) indicates that the former has "no intentional link to reflection or learning" while the latter "may lack academic credibility". In addition, experts differentiate between service learning and internships / fieldwork, which Jacoby affirms do not necessarily address human and community needs due to a focus on learning.

SL, the concept and the term, is already widely-implemented in universities in the American and Asian continents (Salam, Iskandar, Ibrahim, and Farooq 2019). Interest in Europe is growing, particularly since the Bologna process and specifically in the Spanish university sector (Heras-Colàs, Masgrau-Juanola, and Soler-Masó 2017, 87–88), where one of the authors of the present article is based. It is important to point out here that the current worldwide interest in university-level service learning extends to engineering faculties (Natarajarathinam, Qiu, and Lu 2021). International service learning refers to service learning projects with an international dimension, usually involving students from universities in high-income countries (HICs) travelling to low or middle-income countries (LMICs) to carry out service-learning projects.

The university sector is often said to be insufficiently engaged with the real needs of society; academics should "come down from their ivory tower" in the popular image. Without diminishing the importance of collaboration between the university sector and the private sector, the ivory-tower narrative tends to view the private sector as sole spokesperson for society's needs in any university-society dialogue. However, building a more complete view of these needs in the short, medium and long term, would also involve listening to the voice of other civil society actors (who, incidentally, should also be given the opportunity to contribute to defining the strategic lines of research of the public sector). Given that SL community partners are generally public-sector or third-sector organisations, by providing a framework for collaboration with these actors, SL also provides a means for their voice to be heard in the university sector. In fact, SL also furnishes the multi-stakeholder framework and collaborative networks suitable for carrying out R&D in AT, and for the promotion of social entrepreneurship based on AT.

2.2 Appropriate Technology

The concept of AT is particularly relevant to sustainable uses of technology. In its original meaning, as coined by Schumacher in 1973 (Schumacher

2011), the term refers to technology that responds to basic social and ecological needs, while being low-cost, small-scale, decentralized, with low environmental impact, drawing on community and local knowledge, and facilitating the participation of users in its conception and implementation, thereby contributing to the empowerment of local social organisations. It is a technology focused on specific problems and contexts, based on the knowledge of the culture, resources, needs and values of the target communities, with the aim of maximizing the possibilities of adoption and sustainability. It seeks to avoid the assumption that technological development in more marginalised communities can be achieved by simply providing more universal access to technological solutions designed for high-income populations.

Not all projects that can be classified as AT will exhibit all of the above attributes and, moreover, in some fields, the original AT definition may need updating and the AT meaning of some of these attributes clarifying; for example, the attribute "small-scale" in the field of ICT. Notwithstanding these caveats, Schumacher was a pioneer in introducing ideas of sustainable development, today so ubiquitous on international agendas, long before the foundational 1987 Brundtland Commision definition of this concept.

2.3 Which technology for sustainable development?

Technology is often presented as a universal panacea: it is not necessary to question the causes of crises since every problem, even global warming, will have a technological solution. While it is certainly true that technological advances have caused profound social transformations, improving the quality of life of enormous numbers of people, and it is recognised that technology can play a central role in the Agenda 2030, at the same time, one needs to be wary of excessive techno-optimism and techno-centrism, often accompanied by a hidden or not-so-hidden commercial motive. Not all technology is beneficial or in keeping with the spirit of the Agenda 2030. For example, when the idea of biofuels was first widely promoted, it was not obvious that it would displace food crops in parts of the world suffering from hunger; as a World Bank report (World Bank 2007) stated, "the grain required to fill the tank of an SUV with ethanol... could feed a person for a year". The techno-optimistic position tends to ignore the limits of technology and its possible negative impacts on social cohesion and inequality, or simply makes "feel-good" hypotheses that lack supporting data, such as the idea of "decoupling" (Safu-Adjaye, Blomqvist, Brook, and Brand et al. 2015,7). While recognising that ICT in education could increase access to education, it could also accentuate inequality, creating a comprehensive,

face-to-face education with personal interaction and in-person exams granting VIP degrees for the elite, and an impersonal, automated, all-online education with very high student to teacher (or computer operator) ratios that is focused on learning specific professional skills for the rest of the population.

As pointed out by Miller (2020), "contemporary philosophers of technology widely reject the VNT" (Value-Neutrality Thesis). Affirming otherwise by pointing to different uses of any given technology is not a sufficient argument to the contrary; by design or not, technology embodies values regardless of how it is used and, moreover, it tends to form its own context of use. Given the longevity of many technological artefacts, the values they embody can have "long-term implications that surpass their designers and builders". This lack of value neutrality shifts part of the responsibility for the consequences of a technology from its deployers and users to its developers in research centres, educational institutions and engineering companies, who need to reflect on its ethical implications.

How to avoid negative technological impacts? To use a biblical analogy, though it may well be true that "by their fruits shall ye know them", in the case of technological development, by the time the fruits arrive, it is generally too late to do much about it if they are poisonous. The adage "prevention is better than cure" is a more appropriate one for this situation and, along these lines, Appropriate Technology constitutes an attempt to ensure positive impacts of technological development while reducing the risk of negative impacts.

2.4 Appropriate Technology for sustainable development

The concept of AT arose in opposition to the idea that the path of industrialisation followed by Europe and North America could be reproduced and accelerated in other parts of the world, that all that was needed was the direct transfer of the means of industrial production to different geographical and social contexts, this being the prevailing wisdom until the late 60s. The origins of the fair trade movement were contemporary and arose from similar considerations. Awareness of the need for a new type of technology that is intentionally designed to conserve natural resources and promote social equity was an important movement that triggered major shifts in focus in development programmes.

As stated by Bishop (2021, 50-51), though the 70s witnessed a boom in AT in LMICs, in the 80s the AT movement was partially discredited, due to the well-publicised failure of some AT initiatives but also due to it being out of tune with the neoliberal zeitgeist and "Reaganomics", which was not

exactly characterised by its emphasis on sustainability issues. AT was also criticised for not practising what it preached, often remaining within the framework of technology transfer from "developed" to "developing" countries.

The concern for sustainability in the last decade has led to a resurgence of interest in AT (Bishop 2021, 54), accompanied by the emergence of related approaches such as frugal technology (Leliveld, and Knorringa 2018), and that inspired by indigenous / autochthonous knowledge (Briggs 2005; Tharakan 2017). The former emphasizes minimizing the cost and use of resources while the latter aims to use knowledge from indigenous societies independent of, and often prior to, the advent of modern scientific knowledge systems.

The new incarnation of AT seeks to learn from previous failures, taking advantage of the knowledge accumulated in recent decades in development and sustainability studies, in particular, regarding the monitoring of the impact of AT projects and consideration of the cultural, social, and political processes in the deployment environment. Defining objectives and assessing impact can now be guided by the UN Sustainable Development Goals (SDGs) and the Human-Rights Based Approach promoted by UN development agencies (UN 2003). Projects now also pay more attention to crucial but previously-neglected aspects such as marketing, local supply-chain development, and the creation of job opportunities. Finally, AT is no longer conceived for LMICs but for any community, with an emphasis on the marginalised in all parts of the world. It seeks to avoid an "aid" approach and instead be a model of international and intercultural collaboration for innovation across diverse sectors (agriculture, health, education, etc.).

2.5 Appropriate ICT

The new incarnation of Appropriate ICT (A-ICT) can find inspiration in many of the projects of the ICT4D field, which has progressed tremendously since its inception at the end of the last century. Consolidated methodological frameworks and tools are used for the conception, design, implementation, monitoring, and impact evaluation of technological development interventions involving, for the most part, participatory approaches that promote acceptance, operability, and long-term maintenance. Today the ICT4D field has virtual communities (e.g., ICTworks), conferences (e.g., ICT4D and M4D) and journals (e.g., *Information Technology for Development*). Noteworthy developments in recent years are the increasing focus on the SDGs and the definition of a set of "principles for digital development" by some ICT4D practitioners (Principles for Digital Development 2012). Critical reflection

in this area, such as the critique by Schelenz and Pawelec (2022), is another important source of knowledge for AT. Indigenous Technologies could also have some role in A-ICT; while the technological basis of an ICT project clearly cannot be indigenous – one will search in vain for an indigenous Hertzian communications technology, for example – ICTs can serve as a support to automate and computerize indigenous processes, and to formalize and preserve indigenous knowledge (Tharakan 2017).

3. Technological basis of A-ICT projects

Clearly, some technologies are more suitable as the basis for AT projects than others. We contend that in the ICT field, new disruptive technologies could provide an excellent basis for the development of A-ICT projects. Here, we look at the case of two such technologies: Artificial Intelligence (AI) and decentralized computing (DC).

3.1 Artificial Intelligence as a basis for A-ICT projects

Intelligent technologies can address complex modelling problems in the presence of incomplete or contradictory data and changing requirements. There is growing interest in the role that AI can play in achieving the SDGs on the part of international organisations, such as UN Global Pulse (2012), United Nations High Commissioner for Refugees (UNHCR) (Salah, Pentland, Lepri, and Letouzé 2019), the UNICEF Global Innovation Centre (UNICEF 2018), the World Wide Web Foundation (World Wide Web Foundation 2017), the ITU (n.d.), the FAO (Elbehri and Chestnov 2021), and even the World Economic Forum (World Economic Forum 2018). Manjarres, Pickin, Artaso, and Gibbons (2021, 39–42) suggest a set of principles, paradigms, and methodological and technical tools for the development of AI4Eq (Artificial Intelligence for Equity).

Numerous examples of successful applications of AI in the prevention, prediction, monitoring, and evaluation of environmental and humanitarian crises (famines, ecological disasters, epidemics, conflicts), in the identification of vulnerable groups, discrimination of different kinds, deprivation of basic services, in the planning of social protection services and emergency aid, or in support of participatory democracy processes have been reported (UN Global Pulse 2012). However, Big Data for humanitarian purposes also present particular challenges, especially related to privacy. Privacy is particularly important in contexts in which privacy problems can become personal security problems, e.g. the rush to deploy a digital identity backed

by biometrics in Afghanistan could now facilitate repression by the Taliban (Guo and Hikmat 2021; WhyID 2021).

As another example, the FAO and the ITU discuss in a 2018 report how the cheapening of drone technology has led to an explosion in the use of aerial imagery in agriculture around the world, and consequently in the use of AI imaging techniques in agriculture, even in conditions of scarce resources (Sylvester 2018).

3.2 Decentralised Computing as a basis for A-ICT projects

At the beginning of the 21st century, interest arose in decentralized peer-to-peer (P2P) technology leading, among other advances, to distributed hash tables (DHT), unstructured P2P systems with Gnutella-type hierarchy, and the successful File Exchange System BitTorrent. A little more than a decade later, the "distributed ledger technology" (DLT) / blockchain technology, smart contracts, decentralised autonomous organisations, and the so-called decentralised web emerged.

What makes DC interesting as the basis of A-ICT is that, in principle, it allows a community to pool its computing resources to create a system that does not need any central server or central authority to function. Administration and maintenance are integrated into the application itself and, therefore, automatically distributed among the devices of all participating users. This aspect makes it possible, in particular, to use computer applications that are non-profit but sustainable over time. In the case of centralised, non-profit computing applications, the work of administration and maintenance falls to volunteers, usually the founding users, whose initial enthusiasm tends to wane over time. If, as is often the case, other users are unwilling or unable to take over these tasks, the usual result is the abandoning of the project. This phenomenon has often been observed, e.g., in time-banking applications.

A prominent objection to the use of DC concerns "freeloaders" and the so-called "tragedy of the commons"[2]. However, the study of long-lived, commonly-owned real systems has revealed the main flaw in this argument, and its biased reading of history: it does not distinguish between restricted access common to a group of users and open access. Ostrom, winner of the

[2] Though the idea is much older and was prevalent at the time of the enclosure act in 19th century Britain, this title of an article by Garrett Hardin is used to name the idea that each user of a common resource will act in function of his or her own interest until the resource is exhausted and that, as a consequence, systems of ownership other than purely private property (or involving government intervention) are doomed to failure.

2009 economics Nobel Prize for her work in this line (Ostrom 1990), characterised the tendency to misapply theoretical arguments of this type with the adage "an organisation of resources that works in practice can work in theory".

The critique of the "tragedy of the commons" thesis does not mean that a decentralised system does not have to contemplate "freeloaders". However, in the decentralised virtual world, there would appear to be a spectrum between common access and open access, and the computing attributes that characterise the position on this spectrum need to be clarified. Elucidating these issues could be decisive in determining whether a project tends to increase or decrease inequalities, i.e. whether or not it is consistent with an AT approach.

In recent years, the brightest star in the DC firmament has been DLT/blockchain technology. Its potential as appropriate technology or, at least, as socially-useful technology, has recently been the subject of much attention (see e.g. Cunha, Soja, and Themistocleus 2021; Goldstein, and Tillemann 2020; Galen et al. 2018; Blockchain for Humanity Awards 2021), including in EU bodies (De Filippi, Hakami, Brekke, Martínez Vicente et al. 2020; European Commission 2020) and within international organisations, e.g. UNICEF Office of Innovation (2021), World Food Programme Innovation Accelerator (2021), UN Innovation Network (2018), FAO – Food and Agriculture Organization (2018), Start Network (2018), World Bank (Stanley 2017), GSMA (2017). Though it is still early days for judging whether this potential will be fulfilled, it is advisable to be wary of the tendency towards techno-optimism that is common with new technologies.

3.3 A caveat regarding excessive techno-optimism, the example of DLT/blockchain

Whether there has been an excess of techno-optimism regarding DLT/blockchain technologies, which could be said to be still in the "peak of inflated expectations" of the well-known Gartner Hype Cycle, is discussed in Pisa and Juden (2017). Their use in situations where other solutions would have been more adequate has stimulated the criticism that they are "a solution in search of a problem".

According to Walch (2017, Section IV), there is a rush to legislate about DLT/blockchain, e.g., in the US state of Arizona, without a consensus on the meaning of the basic terms. Walch (2019) argues that even the term decentralised, as used in "blockchain discourse", is not sufficiently well-defined to have the legal implications that some are considering giving it.

There are even free-market zealots that preach the replacement of nation-states with decentralised borderless "voluntary nations" that compete for citizens by offering a range of opt-in government services (see Tarkowski Tempelhof, Teissonniere, Fennell Tempelhof, and Edwards 2017), without there being any study of the effect that such a system would have on the well-being, equity, equality of opportunities, etc., of these "sovereign citizens". As stated by Scott (2014), the 'empowerment' of this view "does not stem from building community ties … it is imagined to come from retreating from trust and taking refuge in a defensive individualism mediated via mathematical contractual law."

A large stumbling block in the sustainability of DLT/blockchain is the huge and growing ecological footprint left by the use of the consensus algorithm based on proof-of work (PoW), popularly known as mining, of the traditional blockchain. Energy consumption of bitcoin mining is currently close to that of Sweden (Cambridge Bitcoin Electricity Consumption Index 2022) and it produces enormous quantities of electronic waste (De Vries and Stoll 2021). Blockchain advocates allege that blockchain uses mostly green energy, which is false, or that blockchain is well-placed to take advantage of the sporadic nature of green energy production and that conventional banking also uses large amounts of energy, which are mostly disingenuous arguments. Alternatives to PoW exist, in particular the next-most-popular candidate, proof-of-stake (PoS), but they are more complex and much less tested (and therefore, less secure), which explains the delay of Ethereum, the second biggest blockchain after bitcoin, in transitioning from PoW to PoS (Volpicelli 2021). Moreover, the effect of PoS on wealth-distribution and, more generally speaking, on equity is largely unknown.

Finally, there are questions about the nature of the blockchain ecosystem. Firstly, is there any point in using this technology in private blockchains as many are doing? Secondly, it would appear that most blockchain-based distributed applications interact with the main blockchains via a handful of proprietary APIs (Infura, Alchemy, OpenSea,…) so does it matter that the whole system, blockchain + broker is neither decentralised nor trustless?

4. Promoting A-ICT based service learning

To promote A-ICT based SL, we have worked in three complementary directions:

1. The supervision of Bachelor's-degree final projects and MSc theses on emerging technologies that have great potential as a basis for A-ICTs and future A-ICT based SL projects.

2. The supervision of Bachelor's-degree final projects and MSc theses, and the organisation of programming lab assignments, on using well-established technologies to develop A-ICT SL projects.

3. The development and implementation of an application to support the use of SL in universities, in particular international "virtual" SL and AT-based SL.

Below, we report on examples of work in the first two directions; more information regarding our work in the third direction can be found in Manjarrés Riesco, Pickin, Meana, and Rodriguez-Fernández (2020). This latter work attempts to address some of the well-known problems of SL in the field of engineering as discussed by Natarajarathinam, Qiu, and Lu (2021).

4.1 Exploring emerging technologies with a view to use in future AT-based service learning

To illustrate the first direction, we briefly present work we are carrying out on the potential of the DC technology mobile ad-hoc networks / opportunistic networks as a basis for A-ICT projects (we do not present work we are also undertaking on the potential of P2P technology or AI as a basis for A-ICT projects). This work has benefitted from a Shuttleworth Foundation Flash Grant.

We are developing an application for the Wifi broadcast of an audio and video stream generated by a common mobile device though an ad-hoc network composed of other common mobile devices with two main usage scenarios in mind:

1. *Alleviating humanitarian emergencies*, in situations in which the network infrastructure is not operational due to a natural or man-made disaster. The objective is to transmit video and audio streams through the ad-hoc network until they reach a device with Internet access, with a view to providing information to the world outside of the disaster area of the situation within it. Apart from the case of disasters, the application configured for the humanitarian situation could also be used in areas where the network is not out-of-service but where mobile coverage is very poor, as long as the area is not too isolated since the transmission relies on other mobile devices being in Wifi range, one example being a mountaineering accident.

2. *Bearing witness*, in situations in which the network infrastructure is not operational due to being deliberately put out of service by an oppressive regime, or in which communications passing via the network infrastructure

> are censored and/or could constitute a security risk for the parties involved in them. The objective is to transmit video and audio streams that provide evidence of human-rights abuses through the ad-hoc network until they reach a device outside the high-risk area that can act as temporary custodian of the evidence, or until they reach a device with safe Internet access so they can be sent to a permanent custodian of the evidence, e.g., via Tor and Secure Drop (SecureDrop 2022). According to Access Now (2022), Internet shutdowns (and throttling or partial shutdowns, e.g., using whitelists) are becoming more common; in 2020 there were 159 shutdowns in 29 countries, while in 2021 there were 182 Internet shutdowns in 34 countries. The authors also point out, however, that some countries (notably Algeria, Jordan, Ethiopia, India, Iraq, Mauritania, Sudan, and Syria) have used the rather heavy-handed tactic of shutting down the entire Internet simply to avoid cheating in school and university exams.

Notice that the privacy and security requirements of the two usage scenarios are not the same. Regarding privacy, in the first scenario, human faces should likely be blurred, though it is debatable whether this should be done at source, since video streams coming out of a cut-off area affected by a disaster may find legitimate use in locating particular individuals or in providing testimony that the security or health of particular individuals is not under threat. In the second scenario, metadata that would enable the source to be easily traced must be removed from the stream, while the other metadata, such as global positioning information and time of emission, needs to be protected from tampering. Regarding security, in the first scenario security problems are unlikely, while in the second scenario the application is likely to come under a wide range of attacks. The application configured for either scenario is also vulnerable to malevolent use in situations for which it was not conceived so the possibility of taking countermeasures needs to be investigated.

As far as routing is concerned, again, the requirements of the two usage scenarios are not the same: in the first scenario the network is likely to be sparse even to the point where it may be of interest to incorporate aspects of delay-tolerant networks (Burleigh, Hooke, Torgerson, Fall et al. 2003) or opportunistic networks (Trifunovic, Kouyoumdjieva, Distl, Pajevic et al. 2017), while in the second scenario the network is likely to be dense and avoiding retransmission loops will have high priority. Different strategies for broadcast routing in Mobile Ad-hoc Networks (MANets) are discussed by Ruiz and Bouvry (2015).

4.2 Using well-established technologies for current AT-based SL projects

To illustrate the second direction, we discuss the supervision of MSc theses in AT at the Carlos III University of Madrid.

Erasmus Mundus 2009–2013 was a cooperation programme in higher education between the European Union (EU) and the rest of the world. The document that established the program speaks of "ensuring coherence and complementarity with development policy" as well as "with external cooperation programs" among other "relevant community instruments and actions." In addition, it included among its objectives "the sustainable development of third countries in the field of higher education". One of its actions was to offer joint MSc programmes from EU universities to students from countries outside the EU, including a generous scholarship scheme. The Erasmus Mundus *MSc in Network and e-Business Centred Computing* (NeBCC) was an inter-university MSc offered jointly by the University of Reading, UK, the Aristotle University of Thessaloniki, Greece, the Carlos III University of Madrid, Spain, and Trinity College Dublin, Ireland. In the first part of the NeBCC MSc program, the students attended lectures for one term in each of the first three universities while the second part involved the students carrying out an MSc thesis in one of the four universities.

Since the majority of NeBCC MSc students came from LMICs, the NeBCC MSc thesis provided a propitious context for developing AT projects designed to respond to the needs of communities in the home countries of the students, who could act as local experts and intermediaries within those communities. With this in mind, Simon Pickin supervised the following NeBCC MSc theses: in 2008, "The concept of appropriate technology in the context of web applications"; in 2009, "Developing a web-based e-government application for the government of Ethiopia" and "Mobiles for data collection in rural areas: an appropriate technology study" (oriented to the Honduran context); and in 2011, "Developing a web application for supporting digital inclusion in Brazil" and "Information technology planning and design framework for e-Government of Nepal". Although the academic results and the assessment of the experience by the students were very satisfactory, in most cases the deployments suffered from the lack of a follow-up. However, this was not the case for the first of these MSc theses which we present in the following section. Before doing so, we briefly sketch the second of these MSc theses which did suffer from this problem.

4.3 Government videoconference scheduling in Ethiopia

In 2009, Ethiopia had just deployed a videoconferencing system via satellite to communicate the local governments of small towns and villages with the state government. The student, who until moving to Europe to study the NeBCC MSc worked in the Ethiopian public ICT agency, knew the system and was aware of the need to add a scheduling tool with user profiles, permissions, and a profile-based priority system for the reservations. With the implementation deployed at that time, if a videoconference was already scheduled, not even the country's president could override it in order to schedule a higher-priority conference. For his MSc thesis, the student specified the required functionality and implemented it by adapting and extending a Free/Open Source Software (FOSS) scheduling tool. The AT character of this application is clear since it integrated remote villages into the e-government system, required a relatively simple local infrastructure (the tool had a web interface), and was based on free software. However, though the student implemented an excellent solution to a basic and pressing need, his lack of involvement in the continuation of the project due to his moving to a different job and country after finishing the MSc contributed significantly to its lack of deployment (to our knowledge).

5. Publication of school exam results in Rwanda

5.1 Context in which the system was first developed

Simon Munyaneza wrote his MSc thesis entitled "The concept of appropriate technology in the context of web applications" supervised by Simon Pickin, then a lecturer at the Carlos III University, in 2008. In the context of this thesis, Simon Munyaneza chose to develop a prototype web application for the publication of school exam results in Rwanda. As a long-term resident of Rwanda and as head of the IT department of the Rwanda National Examinations Council (RNEC), he was well-positioned to understand the needs of the target community as well as to have knowledge both of the infrastructure available to develop and deploy the system and of that available to the target community for accessing it once deployed. On finishing the NeBCC MSc degree he returned to his post at the RNEC and ensured the continuation of the work on the exam-results application that he had begun in his MSc thesis. The application was brought into service nationally in Rwanda in 2009 and a version is still in service at the date of publication of this article.