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Abstract
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Community-centered, Project-based ICT4D Education in the Field

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Abstract. The growing demand for user-centered, sustainable, collaborative and ecosystem-aware ICT4D programs and projects brings requirements for education of a new generation ICT4D professionals. This paper presents a post-graduate field-based course in ICT4D that teaches how to co-create and deploy community-centered ICT services. The course has been jointly organized and deployed by Vrije Universiteit Amsterdam and Universiti Malaysia Sarawak for a mixed group of computer science, information science and artificial intelligence students from VU and UNIMAS. The course design, experiences, outcomes and evaluation are presented in this paper.

Keywords: ICT4D education · Community Service Education · Information System development life cycle · Context · User-centered approach · Ecosystem awareness · Sustainability.

1 The need for skilled, hands-on ICT4D professionals

”Design with the User”, ”Collaborate”, ”Understand the Existing Eco-system”, and ”Build for Sustainability” are the new imperatives, set by the international donor community for the ICT4D practitioners community. Formulated as the new ”Principles for Digital Development” [20] these requirements mark a trend towards more agile, user-centered, and innovation-oriented approaches in ICT4D projects and practice (e.g. [19,5,10]). The trend results from the concerns about high failure rates in donor-funded ICT4D projects, especially where projects target the poorest populations and regions [11].

However, bringing agile, collaborative, user-centered approaches into practice in poor low-resource development environments is a challenging endeavor. Low resource, development regions may have a lack of (physical, digital, energy) infrastructures. There may be high illiteracy rates, low purchasing power or a variety of other complex social, economic, cultural and environmental factors [12, 1]. In recent years, new, user-centered approaches to ICT4D and Digital Development have emerged that

use state-of-the-art concepts, theories and methods from e.g. agile Information Systems (IS) engineering [6,8,13,2]. These approaches can guide operational, socio-technical ICT4D developments in challenging and demanding development contexts. However, bringing with these frameworks into practice requires field experience and social, technical and organizational skills. Where do ICT4D professionals obtain these skills and knowledge?

Currently, ICT4D education at graduate or post-graduate levels is oriented at social, economic, development or policy studies (see e.g. a recent textbook on ICT4D [15]). However, these ICT4D curricula do not train ICT4D professionals for field-based information systems/requirements engineering under complex, real world conditions. Technical studies such as computer science, artificial intelligence and information science have traditionally focused on technology development for the ”wealthy”, connected world, and have not yet included ICT4D in their curricula. Recent trends in ICT4D policy and technological innovation are demanding a new type of ICT4D education, that caters for social, technical, practical and organizational knowledge and delivers professionals with hands-on skills and a reflective attitude.

In this paper we present design and implementation of a new type of community-centered, project- and field-based ICT4D education. The paper is structured as follows: in section 2 we discuss the theoretical framework to be used for course design. In section 3 we outline the course objectives, structure and assessment criteria; in section 4 we illustrate this with a case of a field-based post-graduate ICT4D course which was deployed in June 2018 at the Universiti Malaysia Sarawak; in section 5 we discuss the evaluation and the outcomes and give recommendations and perspectives for further adjustments and deployments.

2 Theoretical frameworks for practical and societal ICT4D education

In terms of course design, an appropriate theoretical framework for designing and rolling out community-oriented, field-based ICT4D education is (Community) Service Learning (CSL) [3]. CSL is designed to connect theory and practice and meet challenging social problems while educating students for a life as responsible citizens [3,7]. CSL uses an experimental learning methodology that integrates meaningful community service with instruction and reflection to enrich the learning experience, learn civic responsibility, encourage civic engagement and strengthen communities for the common good [16]. Moreover, CSL is useful for field-based operational ICT4D, as it combines two different (but related) goals: (i) an educational goal based on learning-by-doing and reflection (ii) a societal goal to serve the community, by co-creating meaningful solution.

For the course content, we used ICT4D 3.0 as theoretical framework. This framework matches the Community Service Learning philosophy, fits a learning-by-doing approach and offers a methodology how to ”do” socio-technical development in the field [2]. The framework is displayed in Figure 1 as an intention-strategy map [17]. It

consists of five components that cover the complete information system (IS) engineering life-cycle : (i) context analysis, (ii) needs assessment, (iii) use case and requirements analysis, (iv) sustainability assessment, (v) engineering, deploying, evaluating. ICT4D 3.0 differs from policy-oriented frameworks, as for example ICT4D 2.0 (e.g. [14]), in its practical, hands-on, grassroots approach.

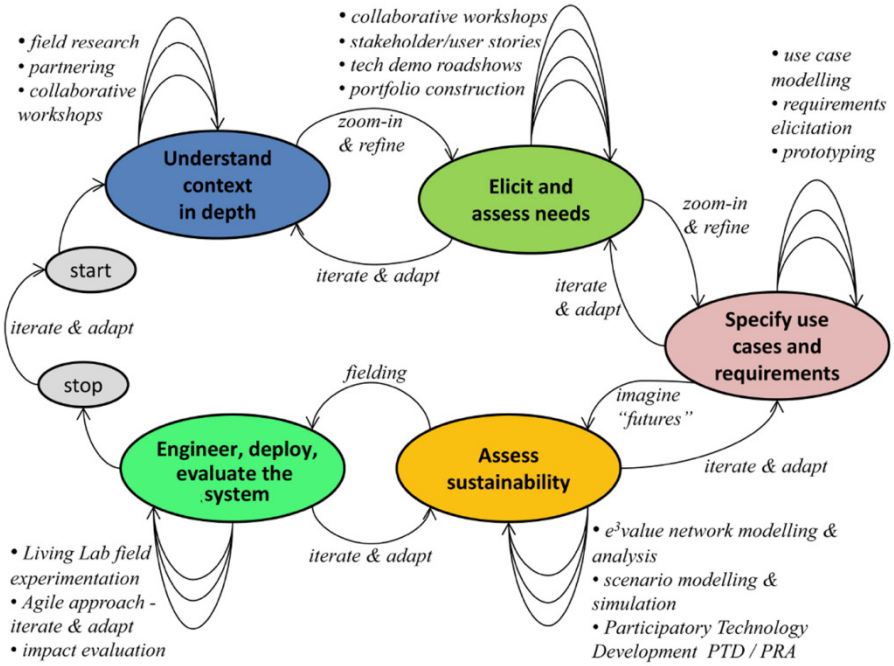

Fig. 1. ICT4D 3.0 Framework how to build ICT services in low resource environments using a collaborative, adaptive, iterative approach [2].

3 Designing a post-graduate course: ICT4D in the Field

Based on the theoretical frameworks (i) CSL for education, and (ii) ICT4D 3.0 for course content, we designed a post-graduate course in ICT4D. This consisted of setting course objectives, defining content, methodology, admission criteria and assessment method. The course design is evaluated by its implementation.

3.1 Course objectives

Based on the above considerations of section 1, we formulated the course objectives as:

– to make the next generation of information and computing scientists aware of the

potential role of ICTs for the developing and emerging world, with a strong appreciation for the highly diverse and complex contexts (in contrast to a one-size-fits all-approach), social-cultural factors and human needs that must be addressed;
- to equip students with relevant field research and development methods and skills to develop technologies in a (poor) rural/suburban community/developing region;
- to acquire and reflect on the experience of carrying out a full life-cycle of a realworld software development project in the field, learning to be able to deal with unfamiliar and complex contexts, and engage with communities with their specific contextual constraints, needs and goals.

3.2 Course structure

Based on the time available (a 6 ECTS course equals one month of full time education), the course takes 4 weeks for field research and designing, modeling, engineering, testing and deploying an information system, that must serve local community's needs.

The course comprises lectures, field visits to (rural or sub-urban) communities where the envisaged users live and work. Interviews and focus group discussions, user test and feedback sessions are part of the course assignment(s). The course starts with lectures in which important topics are reviewed: (i) use case, context and requirements elicitation and analysis; (ii) conceptual modelling of information systems; (iii) selected technical aspects of ICT4D projects; (iv) value modelling and economic sustainability analysis; (v) guidelines and protocols for interviewing and focus group discussions with local communities. Based on meetings with user groups and context analysis in the field, students form teams (of 4-6 persons). Each team selects a relevant use case to elaborate, build a prototype, test with the users, evaluate, improve and deploy. Sustainability analysis and value modeling are part of the assignment. Students work in self-organizing teams, dividing tasks and working closely together. Users must be involved to make sure their needs and (business) requirements are met. The course involves reflection and open dialogue. The constraints and opportunities of the real world context are taken into consideration. The students interact and receive daily feedback from the lecturers. At the end of the course the results of the project are presented by the student teams to the users, local experts and other stakeholders, during an official symposium.

3.3 Assessment

Assessment of the student work is based on four deliverables: (i) a personal (individual) reflection about the course and the student's role in the process, and what he/she learned from it. Each team delivers a: (ii) a working information system/app, tested and validated by key users, documented and available as Open Source (group work); (iii) a group presentation/pitch during the end conference; (iv) a technical report containing the following items:

- Context description;
- High level system design and user scenario;
- A justification of the project (short);
- Interviews typed out (not necessarily literal), containing relevant info (e.g. all user and business requirements, key points, important details etc.);
- A use case and analysis report according to the structured narrative format including a stakeholder analysis, a system architecture, information concepts (activity diagram, class diagram, user interaction diagram, deployment diagram), summary of requirements in MoSCoW [4] method terms; fidelity.
- A sustainable value model/multiple scenarios using the *e*^{3}*value* method [9] for quantitative and qualitative assessment of sustainability;
- Report of user tests (preferably two cycles);
- A reflection of the (iterative) process, and user interactions with the group (how were the interviews);
- A discussion section on the outcomes and what aspects of the project need further research.

To be admitted to this course students must dispose of technical (programming, modeling, requirements engineering) skills and social/communication skills. Moreover, a specific attitude is expected as well: openness to other cultures, willingness to collaborate in an interdisciplinary team, a hands-on mentality, a social orientation and a reflective nature.

4 The case of ”ICT4D in the Field” in Sarawak, Malaysia

The post-graduate course ”ICT4D in the Field” was designed, implemented and evaluated as a joint educational program by Vrije Universiteit Amsterdam (VU) and Universiti Malaysia Sarawak (UNIMAS). The initiative was built on previous experiences. VU was already offering a (6 ECTS) classroom-based ICT4D course in the master tracks of computer science, information science and artificial intelligence, without field work, and running an interdisciplinary research program on ICT4D since 2009. UNIMAS was engaged since 1999 in ICT4D research projects to connect remote communities in Sarawak: eBario and Long Lamai [18]. Both universities were committed to implementation of Community Service Learning in their educational curricula.

In June 2018 eleven master students computer science, information science and artificial intelligence from VU joined a group of ten computer science students from UNIMAS in Sarawak, Malaysia for a one month ICT4D project-based field course, by a joint VU/UNIMAS lecturers team. The course was hosted at the UNIMAS campus. The students followed classes, did group assignments and participated in community visits. The course was organized according to the framework ICT4D 3.0, starting with a general context analysis. This led to the definition of three student projects in which each project proceeded with the next steps of the framework (see Figure 1).

4.1 Context analysis

The project started with a joint context analysis by all students and lecturers, to become familiar with local environment and eco-systems. The visited a banana plantation and a small banana factory, talked to inhabitants of a sub-urban community or *kampung* PJ and visited a community primary school. Focus groups discussions and interviews with users led to a list of project ideas. Three mini-ICT4D student projects were selected, based on (i) relevance for the community and (ii) technical feasibility for an ICT4D student project. The projects, dubbed BannaTree, Appong and EDUCOMX are briefly described in the following paragraphs. The full reports are available at https://w4ra.org/student- papers/.

4.2 BannaTree student project

During the context analysis field visits the students learned that the government of Sarawak wants to increase income and standards of living of banana contract farmers by providing support to banana chips factory and improving work conditions of the farmers.

Elicitation of needs: According to the interviews with farmers and other experts, banana crop yields are poorly planned. The farmers plant and harvest bananas called *pisang sekaki*. The bananas are sold to small local factories where they are processed as chips and packed for (international) export. Lack of information on timing and amount of expected crop yields leads to planning problems for the factory, waste of bananas for the farmers and supply inconsistencies for the banana chips export. To improve co- ordination and logistics between farmers and chips factory, the students proposed an information system with a mobile users interface: the BannaTree application.

Analysis of use cases and requirements: The information system and information processes were modeled by the students according to the users and business requirements they collected. To understand the complete use case and elicit the exact requirements for the system they modeled the complete work process and information flows. Many discussions were held with key experts and users to check the validity of the requirements. Much attention was given by the students to stakeholder analysis, and to understanding their operational goals. The proposed model was discussed with the banana farmers, representatives of the banana factory, fertilizer experts, the agricultural department and a key expert from UNIMAS. The discussions led various times to changing requirements and two major redesigns of the system in one week.

Engineering, deploying, evaluating:. The first working prototype of the BannaTree application was delivered in the third week of the course to two local experts. See https://github.com/aoelen/banna/blob/master/README.md for source codes and documentation.

Sustainability analysis and reflection: The students became aware of local ecosystems and the complexity of (sometimes opposite) interests from various stakeholders on this use case. The requirements changed several times, as users changed their ideas. This made time to finalize and fine-tune the application a stress-full activity for the days before deadline. The team learned about the complexity of the use case and discussed their own roles as reflective practitioners. The project was ready in time, but the final delivery test to the banana farmers was unfortunately cancelled due to time constraints. Long-term impact and sustainability could not be evaluated in a real world setting due to the time constraint. An important lesson learned here is that more time than the available 4 weeks is needed for a project with a high level of complexity. The learning experience for the students was positively evaluated.

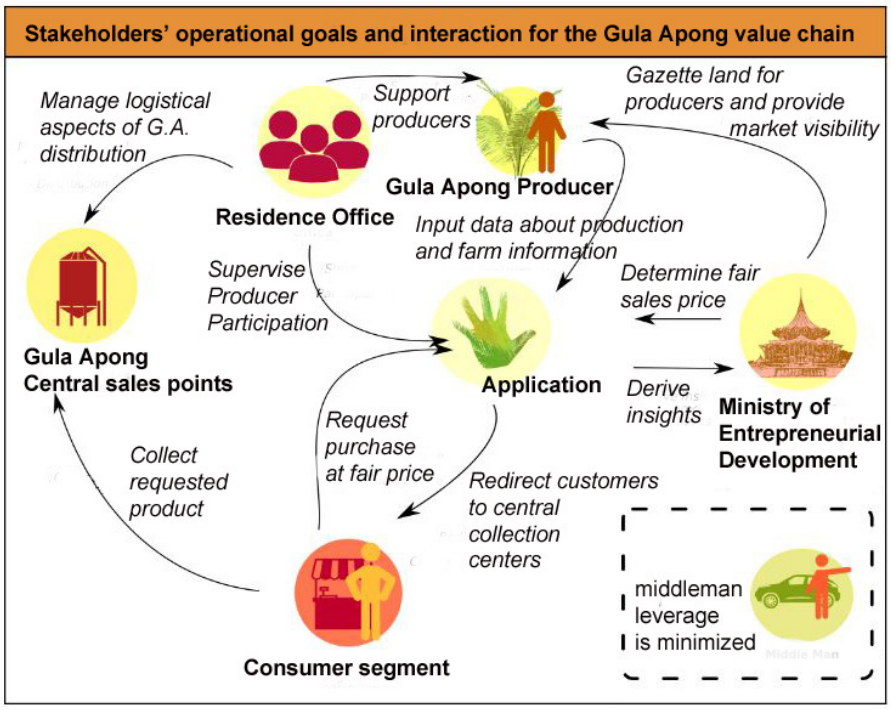

Fig. 2. Use case analysis for the Appong student project

4.3 The Appong student project

The second use case, dubbed Appong, consisted of a need of (independent smallholder) sugar palm farmers, to increase the sales of their product: Gula Apong.

Elicitation of needs: From interviews with the *kampung* inhabitants, in the first course

week, the students learned about Gula Apong, a traditional Malaysian sweet/sugar, produced from the Nipa palm by family farms in the mangrove forests along the estuaries of the Sarawak river. The Nipa juice is collected manually and produced (boiled) locally, in the forest. This work is challenging: there are ants and snakes in the forest. When the tide is high, the mangroves are a dangerous place for the farmers, risking crocodile attacks. The government wants to support the small producers, because Gula Apong producers protects the mangrove forests, which are environmentally protected areas of important biodiversity. Moreover, there is a growing consumer market for Gula Apong which needs further exploitation.

Analysis of use cases and requirements: The Appong use case and project was tackled by a mixed group of students from VU and UNIMAS. The group held interviews at the Ministry of Entrepreneurial Development (MIED) in Sarawak, and visited Gula Apong farmers in the forest. They saw how the farmers collected Nipa juice and observed the production and packaging of Gula Apong at home. They visited the farmers' homes, to get to know the local livelihoods. A mobile app named Appong was proposed. It will serve three types of users: (i) potential customers to help increase sales; (ii) producers, to stimulate cooperation between producers; (iii) the local government. The government can support the farmers, in return for their production data, by providing them rights to harvest in the public mangrove forests.

Engineering, deploying, evaluating: After requirements elicitation a prototype was built. It allows Gula Apong producers to enter information about offerings and sales locations. A web interface was designed for the government, to monitor the data on overall sales activities of Gula Apong in the region. The prototype was presented by the students for evaluation at the Ministry of Industrial and Entrepreneurial Development in Sarawak.

Sustainability analysisand reflection: The economic feasibility of the Appong application in an ecosystem is assessed using the *e³value* methodology [9]. The *e³value* method maps the actors (or market segments) in a value network, the value they exchange with each other, and calculates for each actor the income this generates. This model can evaluate quantitatively the feasibility of a complete value network.

4.4 The EDUCOMX student project

During interviews with parents, school teachers and children in Kampung PJ, the ICT4D students were told that, although English is widely spoken in urban areas of Malaysia, in poor rural areas English education at primary schools lags behind the urban (private) schools. Since school subjects such as science and math are taught in English, poor knowledge of English limits education of rural children.

Fig. 3. Testing the EDUCOMX app with children in the kampong. EDUCOMX is platform independent. Here it is deployed on XO laptop from OLPC.

Elicitation of needs: Learning English is of key importance for children in the *kampung*, according to parents and school teachers who were interviewed. Since educational resources at public schools are not sufficient, alternative learning methods are sought. The students propose a mobile Smartphone app, (as most of the families here in the *kampung* own a Smartphone, despite a lack of Internet connectivity). The app, built by a mixed group of VU and UNIMAS students is dubbed EDUCOMX. The app can be run on Smartphone or in any browser. UNIMAS has deployed a number of XO laptops (see Figure 3) for user tests of this application in the *kampung*.

Use case and requirements analysis: The students decide to build EDUCOMX as a pilot mobile app to teach children English. They try to make the app engaging, while staying in the scope of the English learning methods used at school. For the use case and requirements analysis, the students meet a group of children in the *kampung*, and ask them to draw their favorite superheroes and write down their hobbies and aspirations, as inspiration for the artwork that will be used for the reading material of the app. This process has great significance in context analysis – as taught by the ICT4D 3.0 framework – user interviews and stories are often deciding factors in the success of an application deployed in the field.

Engineering, deploying and evaluating: For EDUCOMX, gamification methods are used, as a game will unconsciously help improve your English. The design looks playful and includes animations, sounds, fun colors and images. A scoring system is implemented. Users (children) can continue through chapters that look and feel like game levels, which they have to complete in order continue to the next level. Status bars show user progress and scores. User testing with children was a central activity of this project. After one week of building and lab testing, the first user tests for the

prototype were carried out in Kampung PJ with a group of 21 children in the age range of 10 –12. The children were able to freely play with the application, in the style of a living lab see Figure 3. The children liked the concept of the comic books and started to read the sentences aloud so it was good to hear their reading skills. The questions at the end were a bit difficult for them. We noticed that there were too many pages before the quiz started so after some pages they were having a hard time concentrating on reading. The children seemed to enjoy unlocking new chapters and were motivated to get all questions correct. They started to share answers with other children to help them unlock new chapters. They liked the sound effects of answering the questions. We noticed that the return button and the logout button were at a wrong place on the screen and should be moved.

Sustainability and reflection: There are two main contextual issues here, that influence design decisions: (i) connectivity and (ii) specificity. First, in rural areas there is no (consistent) internet access, making online content not a design option. Second, the now existing digital learning platforms are not tailored to the local culture or specific wishes of the end users (the children). The user tests were the central activity of this project and provided much new insights. The students learned how to make design decisions based on context and user requirements. The sustainability analysis revealed the need for further exploration of the use case. This will be followed up by UNIMAS.

4.5 Project results

The three student groups delivered the reports and software in time and presented the projects at a community ceremony at Kampung PJ and at a final ICT4D conference at UNIMAS. Personal reflection reports were submitted. All students passed the assessment. A short video clip on the making-of the student projects can be seen at https://w4ra.org/2018/06/28/a-living-lab-in-kampung-pinggan-jaya-sarawak-short-clip/.

5 Evaluation and conclusion

In line with CSL principles, evaluation of the ICT4D course is done along two axes: (i) did the course achieve its educational goals? (ii) are the student projects carried out in a community-centered way and do the results meet local needs?

To evaluate if (i) the educational goals were met, we evaluate if this course makes the next generation of information and computing scientists aware of the potential role of ICTs for the developing and emerging world, with a strong appreciation for the highly diverse and complex contexts, social-cultural factors and human needs. Based on the student assessments, the reflection reports and the group deliverables, the course ”ICT4D in the Field” has achieved its educational and societal goals. The students have collaborated sufficiently with the users, learned from the context, and

worked iteratively, testing and improving the technological solution according to users' requirements.

To evaluate if (ii) the project is community-oriented and context-sensitive, we assess the student projects and the number of interactions and design decisions, based on local requirements. Concerning effectiveness and results, it is clear, in terms of serving the community, that one month is far too short to do a full context analysis, engage with the users, build a long term relationship and deploy and test a working information system. In terms of ICT4D 3.0, this was only a first cycle deployment including a number of sub-iterations. It is important to foster long-term partnerships and work with local partners. The long relationship between UNIMAS and the local communities is key in the successful collaboration. The collaboration between VU and UNIMAS is characterized by commitment and trust.

A great challenge for long-term sustainability of the course is funding. Organization and planning of a course between two continents is an interesting experience, which takes efforts and time. For the lecturers the lecturing effort is bigger than in regular courses. In terms of community service orientation, the project is a first step towards deployment of sustainable ICT4D solutions. Continuation of the project will be needed to build up long lasting relationships with the communities and achieve long-term sustainability. The student reflection reports show that the whole experience of designing, building, deploying

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