Spatial Thinking for Educational Innovation: The Rwandan Iwacu Project

Brian M. Tomaszewski[1*], Jules Maurice K. M.[1], Anthony Vodacek[2], Kayla Vodacek[2], Nick Holt[2]
[1]Department of Information Science & Technology
[2]Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology
Rochester, NY 14623, USA
(1+) 585-259-9678
[*]Corresponding author: bmtski@rit.edu

ABSTRACT
In this note, we describe our research in progress efforts in Rwanda focused on developing spatial thinking skills for educational innovation and development. In this regard, we present "Iwacu" which is a Kinyarwanda word meaning "Our Home". Iwacu is an open source, modular, mobile geographic ICT (geoICT) developed using a user-centered design approach with Rwandan stakeholders. Iwacu is theoretically motivated by the ideas of spatial thinking. We discuss how Iwacu's technical implementation is closely matched with spatial thinking components we are testing via a Spatial Thinking Ability Test or STAT to measure our educational innovation. We are finding that our use of mobile geoICTs to build spatial thinking skills are having positive, unintended consequences of building strong general ICT interest among young Rwandans and providing critical education pathways for young women and girls.

Categories and Subject Descriptors
H.2.8 Database Applications: Spatial databases and GIS

General Terms
Performance, Design, Human Factors.

Keywords
Spatial Thinking, Tablet Computing, Geographic Interfaces, Secondary School Educational Development, Rwanda

1. INTRODUCTION
In the article "*Youth and ICT*", the UN states that almost half the world's population is under the age of 25 and of those, nearly a quarter are aged 12 to 24 and are becoming a major force in pioneering mobile ICT use and driving industry growth and trends [1]. The desire of more and more young people around the world to own "smart" mobile devices is creating interesting research and development challenges to inspire them to use mobile ICT for positive change and societal development.

In this regard, our research is broadly directed at how we can take advantage of growing mobile technology interest among the world's youth to develop education-based technology for addressing pressing *spatially*-oriented development issues such as climate change and poverty reduction. In particular, our research is focused on developing mobile geoICTs for building *spatial thinking* skills in secondary students. Spatial thinking is the idea of using the properties of space such as distance and scale and various spatial representation forms such as maps to structure, solve and reason about problems that are spatial in nature [2]. Specifically, we are using geoICTs such as interactive 2D cartographic maps and 3D virtual globe environments combined with field-based citizen science environmental learning experiences and educational curriculum grounded in relevant spatial thinking theory [3, 4]. Spatial thinking and geoICTs have long been recognized as for their value in development – particularly for spatial problem solving and reasoning (c.f. [5, 6]). However, little research has been conducted on building spatial thinking skills as opposed to geoICT software training in developing country contexts such as Rwanda [7]. Thus, we foresee a key opportunity to understand the educational innovation process by which geoICTs and spatial thing skills can be taught and learned via mobile devices. In the following section, we outline our project's broader research context in Rwanda as a prelude for discussing our research in progress efforts building a mobile geoICT to support spatial thinking called "Iwacu".

2. RESEARCH CONTEXT
Our efforts to build mobile geoICTs for spatial thinking are in the context of a two year project in Rwanda called "Promoting spatial thinking in natural resource management through community mapping: the case of urban and rural secondary schools" supported via the Innovation for Education program funded by the UK Department for International Development (DFID) and implemented in partnership with the Rwanda Ministry of Education (MINEDUC) [8]. DFID and MINEDUC are particularly interested in monitoring and evaluating how new, educational ideas and innovations can be incorporated into Rwandan educational practice to meet several national educational and policy goals such as increased ICT literacy and providing educational pathways for girls [9].

ICT capacities such as computing hardware in Rwandan schools are very limited compared to developed country standards. Furthermore, use of geoICTs such as Geographic Information Systems (GIS) technology is extremely limited and when utilized, is predominantly in the form of "traditional" desktop PC laboratory computing environments. Thus, our project is very novel in the sense that we are (1) emphasizing the use of open source (Android) mobile devices (tablet computers specifically) as opposed to PC/desktop environments to capitalize on growing youth mobile device usage trends and (2) a making a specific

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focus on using tablet devices as opposed to PC environments for use of geoICTs to support spatial thinking skill development.

Despite growing mobile ICT use trends, our efforts to build mobile geoICTs to support spatial thinking educational innovation to date have had to account for several practical issues: 1– lack of an existing Rwandan secondary student spatial thinking skills and 2 – general low tablet computer technical literacy and very low geoICT technical literacy of Rwandan students and teachers. The following sections briefly outline our research on addressing these issues as they provide a specific research context for discussion on the development of the Iwacu application in subsequent sections.

2.1 Rwandan Student Spatial Thinking Skills

To date, we have tested approximately 225 Rwandan secondary students from three partner schools to establish a spatial thinking skill level baseline using the Spatial Thinking Ability Test or STAT [4]. Our results have shown that spatial thinking skills levels are very low among all of our students (average of 31.4% on a 100% scale), and students did particularly poor on STAT questions involving reasoning about 3D phenomena based on 2D representation [10]. Our baseline STAT findings have thus made it quite clear that any attempts to build geoICTs to support spatial thinking must account for spatial thinking skill gaps in potential end-users.

2.2 Teacher geoICT Technology Training

To date, we have conducted ten, four hour (half day) geoICT and mobile technology training sessions with Rwandan secondary teachers from our partner schools. The intent of these sessions has been to provide teachers with desktop geoICT and mobile technology professional skill development for instructing their students. Many of the teachers had never used Android tablet computers or any form of geoICT before the trainings. Informal evidence from these teacher training sessions has revealed that teachers have been capable of quickly learning basic tablet computer use but have been more challenged with learning desktop geoICT tools such as ArcMap[1] given its interface and conceptual complexity. Our baseline STAT results combined with teacher training observations have thusly informed development of a mobile geoICT application to support spatial thinking called Iwacu designed to address these issues.

3. The Iwacu Application

"Iwacu" is a Kinyarwanda word meaning "Our Home". It is an appropriate word to name the application given the application's focus on teaching spatial thinking skill development with geoICTs that represent the local Rwandan environment.

3.1 Iwacu Use-Case Scenario

The following use-case scenario, as motivated by our overall research context (as discussed in section 2), was developed to guide Iwacu's initial design, conceptual development, and establish an overall vision for Iwacu:

Elyse is a 16 year old secondary school student attending Groupe Scolaire de Officiel de Butare in the Butare province of Rwanda. Elyse is interested in and alarmed by environmental issues which affect her area, such as deforestation. And yet, she is not aware of any methods for actually confronting local deforestation. Isn't there anything she can do? One day, her Geography teacher issues her an Android tablet with a mapping application on it. The teacher gives Elyse the assignment of documenting the deforestation occurring in the area of Butare where Elyse's family lives. Walking home, Elyse notices a rather distinct line where the forest begins and a field of destroyed trees begins. She pulls out the tablet, maps the line with the mapping application, and uploads the data she collected to a central server for storage and sharing with her classmates and community members. The next day at school, Elyse learns from her Geography teacher that the location Elyse recorded actually differs drastically from the last official recording taken two years ago. Elyse's discovery helps her to think spatially about and better understand the nature of Rwanda's deforestation problem. Through her experience with using the mapping application, she is curious to learn more about the spatial dimensions of her local environment with geographic ICTs and eventually, share her knowledge with her fellow students, scientists and community members.

3.2 Iwacu User-Centered Design

To address the items outlined in sections 2.1 and 2.2, a user-centered design approach has been used to develop Iwacu based on established geoICT tool design practice [11]. Semi-structured interviews were conducted in January 2014 to solicit feedback from Rwandan teachers on development of Iwacu using the visual prototypes and other teacher experiences at that point in the project (Figure 1).

Figure 1. Interviewing Rwandan school teachers about Iwacu.

At this point, Iwacu was only a paper-based, visual design concept, and the teachers had been working with ArcMap on PC environments and Open Data Kit (ODK) Collect[2] on Android tablet devices. This combination of experiences proved quite valuable however as it provided good insights into usability issues teachers were having with ArcMap and ODK Collect that could mitigate any potential Iwacu usability issues. Key design insights derived from the semi-structured interviews included:

- the needed for simple, non-scientific language in interface components;
- better visual cues for prompting interaction such as when the user should swipe a screen as well as graphical icons to indicate action;

[1] www.esri.com/software/arcgis

[2] http://opendatakit.org/use/collect/

- the importance of a clear workflow of interaction in terms of order of screens like that used by ODK Collect.

Based on the semi-structured interviews, we have developed a beta version of Iwacu discussed in the following section.

3.3 Iwacu Technical Description

Iwacu is an open source, native Android application. Figure 2 is an Iwacu system overview.

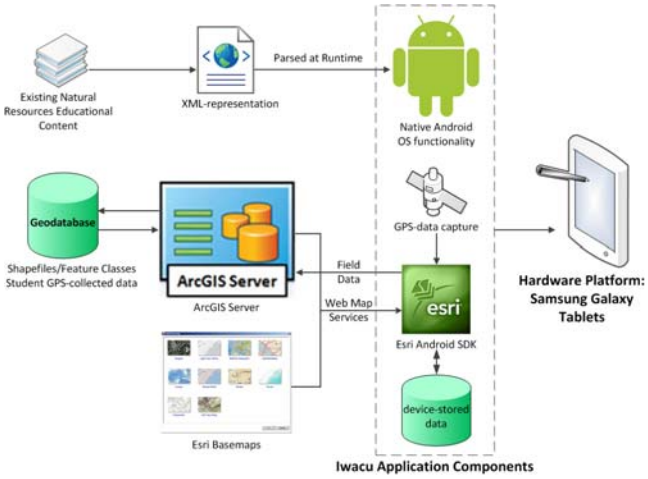

Figure 2. Iwacu system overview.

Key features include: 1 – local device caching of educational for offline use, 2 – GPS-based field data collection, and 3 – web map services incorporation (when an internet connection is available. In terms of geoICT, Iwacu is being built using the open source ArcGIS Runtime SDK for Android[3] provided by ESRI. We have specifically chosen open source geoICT technology to allow Iwacu to be scalable and cost effective. To match spatial thinking components we are measuring via the STAT (as discussed in 2.1), Iwacu currently includes the following spatial analysis tools and geometry relationship operators: Within, Touches, Equals, Crosses and Contains, projection, map distance measure, union & difference, and buffer (Figure 3).

Figure 3. The Iwacu buffer tool. Buffers are a core spatial thinking skill. Understanding buffers teach students how to think about spatial relationships between human and environmental features such as distance from a stream that can potentially flood.

[3] https://developers.arcgis.com/android/

These tools and operators, which are common tools found in commercial GIS packages, also closely correspond with spatial thinking reasoning and problems solving tasks [12].

Iwacu also uses a flexible, modular approach for presenting spatial thinking and educational content to end users and to account for for practical issues such as lack of internet connectivity. In particular, specific educational content is stored on the Android device in an external, XML file that is parsed at run-time and presented in the interface. Extracted, external XML content are then rendered as Activity Tabs that allow XML-based content to be rendered in easy-to-use, swipe based interface interactions as per feedback we received from our end users as described in section 3.2 and aspects of ODK Collect they found intuitive and usable. Figure 4 demonstrates how Iwacu is completely flexible in terms of the learning content it delivers to students and teachers.

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<document>
   A <heading>Map Projections</heading>
   B <about>The earth is an oblique sphere…</about>
   C <activity name="Projection" map_coordinates="-
2.604080, 29.811076">Click here for an interactive map
projection…<activity>
   D <image>map_projection.png</image>
   E <video id="v5fSBQRbPR0">Watch a video…</video>
     <quiz></quiz>
</document>
```

Figure 4. Iwacu geoICT learning content delivery – the top image shows XML tags that define learning content. Boxed letters in the figure's top section correspond to graphical elements in the figure's bottom section. This approach is allowing us to design completely flexible spatial thinking educational content that can match a variety of spatially-oriented topics.

4. FUTURE WORK

We released an Iwacu beta in fall 2014[4]. Based on our previously discussed user-centered design approach and Iwacu's technical implementation, we believe Iwacu has the ability to increase student spatial thinking skills. To test and validate this assertion, we plan to conduct mid-term and final baseline STAT examinations for comparison with our baseline examinations to see if our educational interventions with Iwacu and other geoICTs have in fact improved the spatial thinking abilities of young Rwandans participating in our project.

[4] The Iwacu beta can be accessed via Google Play: https://play.google.com/store/apps/details?id=gis.iwacu_new.rit.edu.main

More importantly, the ideas behind Iwacu and other mobile geoICTs such as ODK Collect on our project are already revealing a desire of some of our participating students to seek future geoICT career and educational pathways. This desire is clearly reflected in these representative quotes from a student motivation survey we conducted where we asked our participating students: *What do you plan to do once you finish school?* Although many students indicated interest in becoming entrepreneurs or doctors, replies such as:

My future plans after finishing my secondary school is to continue in university in order to increase knowledge about geographical information communication technology and protecting environments

indicate longer-term student geoICT interest.

Furthermore, beyond geoICT and spatial thinking, the project is revealing many interesting research areas of how tablet computers in general can develop technical literacy and serve educational needs and development priorities developing country contexts. For example, teachers at our schools report that when the students use the tablets for ICT lessons, it is very difficult to get the students to stop using the tablets when the lessons are finished. Furthermore, this excitement the students are showing about using tablet computers also provides a key opportunity to empower young women (Figure 5).

Figure 5. Young Rwandan women developing spatial thinking, geoICT and general computing literacy skills.

Girls and young women are groups that has received particular close attention from the Government of Rwanda as an educational priority due to long standing Rwandan cultural and social issues that have disadvantaged educational access for girls and young women [13, 14]. Thus, our research efforts at build spatial thinking skills through tablet-based geoICTs such as Iwacu provide a key opportunity for accessing these segments of Rwandan society.

5. SUMMARY AND CONCLUSIONS

In this paper, we have described our research in progress efforts in Rwanda focused on developing spatial thinking for educational innovation. Building spatial thinking skills is important for addressing spatially-oriented development issues such as climate change and poverty. In this regard, we outlined our efforts at developing Iwacu – a modular, mobile geoICT developed using a user-centered design approach with Rwandan stakeholders and theoretically motivated by the ideas of spatial thinking. We also discussed how the technical implementation of Iwacu is closely matched with spatial thinking components we are testing via the STAT (discussed in section 2.1). We also outlined future assessment work to see if Iwacu can increase spatial thinking levels. Ultimately, we are finding that our use of mobile geoICTs to build spatial thinking skills are having positive, unintended consequences of building strong general ICT interest among young Rwandans and providing critical education pathways for young women and girls.

6. ACKNOWLEDGMENTS

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