Sustainable Development as Successful Technology Transfer: Empowerment Through Teaching, Learning, and Using Digital Participatory Mapping Techniques in Mazvihwa, Zimbabwe

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Appendix B – Teaching Guide for Digital Mapping

1 Equipment, Software, and Imagery

In our digital mapping, we used Garmin eTrex 10 GPS units with the University of Minnesota's DNRGPS program version 6.1.0.6 (Minnesota Department of Natural Resources 2012) for downloading data in .shp format. In some cases, we also directly downloaded .gpx files from the GPS unit to the computer. We used QGIS version 2.6 (QGIS Development Team 2014) to visualize data and imagery and make exportable and printable maps. We ran the software on an Acer Aspire E 15 laptop. The computer was charged using individual home solar systems which were largely reliable, and the GPS units required AA batteries every few days of continuous use. We were able to obtain 0.5 meter spatial resolution pan-sharpened natural color imagery from 2013 for all of Mazvihwa Communal Area, courtesy of DigitalGlobe Foundation's partnership with the University of Minnesota. The imagery is copyright DigitalGlobe, Inc, all rights reserved. In this project, we use it primarily as a basemap and teaching tool. Cellphone network reception in Mazvihwa is limited and inconsistent, so a trip to Zvishavane is required in order to send or receive files and emails, and tools which require a live internet connection such as Google Earth are not viable. Distance learning was enabled mainly by extensive text-messaging using WhatsApp.

We started with four GPS units in 2015 and were able to expand to eight in 2016. All equipment was transported by the visiting international mentors, as shipping to rural Zimbabwe is unreliable.

We chose Garmin eTrex 10 units because they are interchangeable, reasonably simple and easy to use, could be handed to anyone rather than depending on who has a smart phone (not everyone on the GPS team had smart phones), and there was no need to have an internet connection in order to archive data. QGIS was chosen because it is open source and free (and therefore does not need an internet connection to validate a software license), avoiding the problem of locking the community into technology they would not be able to maintain without funding. We made the how to sheets because many of the tasks were sufficiently technical that it would help to have sheets to follow.

2 *Teaching Strategy*

2.1 *"How-To" sheets*

The initial mapping mentor created "How-To" sheets with screenshots of the software and pictures of the GPS unit's screen, with brief descriptions of how to do a variety of common mapping tasks. (See Table B1 for a list of how-to sheet topics and the supplemental files for the sheets themselves.) In March 2015, the mentor brought digital copies on the Acer computer as well as printing out a copy of each and bringing laminating supplies to Mazvihwa, where after the learners evaluated the sheets, they laminated them. The initial learners relied heavily on these sheets when they themselves became mentors to new learners and the initial mentor was back in the US. Before leaving, the mapping mentor made a list of desired topics requested by the learners and when she went back to the US, in April 2015 she created new How-To sheets and sent them via email. Learners then went to Zvishavane to download and print them. Later in 2015 (June and beyond), the Muonde mapping team requested additional sheets on emerging skills they needed to do their mapping projects. When the initial mapping mentor returned in 2016, she printed and laminated more copies of all the sheets, as requested by the initial learners. Many of the sheets produced since the 2015 visit were the topics of advanced mapping workshops conducted during the 2016 visit (e.g. making exportable maps, projecting mapped data, and calculating areas and uncertainties).

2.2 *Hands-on, iterative, small-group instruction*

The initial mapping mentor began by teaching 10-11 people (selected by the executive director of Muonde, Abraham Mawere Ndlovu), instructing them on computer use, GPS unit use, and downloading and displaying map data on the computer. She demonstrated these activities one at a time and then had learners take turns doing each activity for themselves. She wrote unfamiliar words on a small, portable dry-erase markerboard. She chose these hands-on techniques based on her more than seven years of experience with hands-on teaching of undergraduate and graduate students on a variety of topics. She explained in English, and several learners translated into Shona so that others for whom English was more challenging could still understand. This had the effect of encouraging peer learning as well as cementing knowledge for the learners doing the translating, and eased their way into becoming mentors themselves. Examples and metaphors were made locally relevant and abstract instruction was always followed by hands-on application as mentors and learners alike went and walked around crop fields, visited distant sites like Great Zimbabwe, and addressed specific projects like calculating the area of a garden for which irrigation was proposed. Mentors assessed learning by observing whether learners could do the tasks without assistance and making suggestions and corrections when misunderstandings arose. We often paired learners who had already picked up the techniques with other learners to make sure everyone was understanding the techniques, encouraging a casual, playful attitude in which no one took themselves too seriously, mentor and learner alike. We also modified more familiar traditional teaching methods, including written and oral assignments.

2.3 *Workshops in larger groups, including group discussion and role-play activities*

The initial learners presented their work to the larger Muonde research team, and later led workshops training the rest of the team in digital mapping techniques. We also used large, whole-Muonde workshops to analyze and discuss the effectiveness of the teaching and learning of digital mapping. In larger workshops we used techniques like role-playing, group discussions, prompts in which we asked each person to respond in turn (allowing shy people to be heard as well as more assertive people).

3 What made teaching so successful in our case

Several important strategies for teaching and learning emerged from the group's assessment of the digital mapping projects. It was key to make learning relevant to the learners, to pay attention to the social aspects of learning, to work from familiar teaching methods, and to use multiple learning modalities.

Mentors worked to make learning relevant on several levels. Examples, exercises, and analogies were based in the local culture, for example referring to the computer as a household and the operating system of the computer as the head of household (Muonde had computers with four different operating systems at the time) and the programs on the computer as members of the household. When doing practical exercises, we found relevant topics motivated by real needs, for example measuring how far school children have to walk to school or showing how many Muonde innovation projects have been implemented in Mazvihwa. Most importantly, though, was instruction in Shona. This meant that the learning was accessible to more people as well as building confidence in the learners to become mentors themselves, both with each other and for new learners in the future.

Paying attention to the social aspects of learning and mentoring was also key. Fostering an informal and encouraging atmosphere made mentors accessible to learners – learners felt comfortable going straight to mentors when they had questions, and peers were able to encourage each other as well. Individual attention was important in making sure that everyone was following the lessons and participating as well as in building a strong relationship between mentors and learners. Working in small groups helped provide both accountability and support, particularly for learners who were taking longer to grasp the material, and setting collaborative goals (both in the sense that they were collectively decided on and in the sense that they were achieved as a group) kept everyone involved in the process. All that said, there was also friendly competition between learners. We also used fun incentives to motivate participation, including field trips (for example, to Great Zimbabwe), and during our workshop on map projections, the special treat of eating oranges (after peeling off their skins to see how flattening a sphere introduces distortions in the map). Finally, jokes and humor were an important part of making the learning fun, engaging, and low-stress. These included describing the motion of satellites as being similar to stirring tea and inventing funny mnemonics to remember acronyms (see below and in the main paper for multiple examples).

To complement the unusual teaching style and environment, we also modified more traditional teaching methods that the learners would be more familiar with. Intensive education outside a classroom setting was a new experience for most of the learners. The Zimbabwean primary and secondary education systems, as well as university education for the learners who had had the experience, provided a model of education which was very different from their mapping education in several important ways. Some of the techniques used in our mapping classes, such as group assignments and presentations, occur at the university level even though they are not used in grade school. Even at the university level the group work may not be as participatory as ours, and everyone may not contribute and benefit. On the other hand, other techniques in our mapping classes, such as the use of markerboards, pictures, and "how-to"-style specific instructions, are used only in preschool or early childhood development settings; we used this to cater for different learning capabilities. So to complement these techniques, we also had written assignments, verbal tests in which we asked learners to explain what they understood or to present their work to the larger Muonde team, and practical exams to see whether learners had acquired the mapping skills. Learners asked questions on difficult points and took notes in notebooks like schoolchildren do, and reviewed them frequently (especially when the initial mapping mentor had left). Learners also developed mnemonics to remember certain points. To remember the order of the letters in "GPS," the Muonde team invented a phrase: *gondo rapamura shomwe*, which means "an eagle managed to peel the amarula seed" which is nonsensically funny and memorable.

Finally, our teaching strategies made use of many different learning modalities, which made the material more accessible to different people and easier to learn and retain via different kinds of repetition. After the initial mapping mentor left, the Muonde learners referred to and simplified the how-to sheets to explain them to others and had hands-on tasks to practice their skills with, as well as distance learning through WhatsApp and emailed how-to sheets. Muonde mentors used analogies to teach others, including likening the GPS unit to a more familiar older model Motorola phone.

3.1 A few notes on methods that did not work

The teaching team found that flexibility was essential: trying to hold the group to a specific schedule of lessons was impossible due to weather and unexpected social obligations. In a similar sense, when the team got tired, there was no point in continuing and we simply resumed the next day with whatever lesson we had finished with the previous day (reviewing the material so that we could pick up where we had left off).

Simpler concepts needed to be understood before more complex concepts were explained. For example, explaining how GPS works with different satellites communicating their distances to the GPS unit was too complex for an initial instruction in 2015, but in the second round of workshops in 2016 we were able to explain this. The international mapping mentor could only explain a little bit before the Muonde team needed to stop and translate; trying to say too much at once had poor results as the translators would not be able to remember everything she had said, and the other team members couldn't catch enough of the explanation in English.

Understanding how to record tracks on the GPS was a particularly difficult lesson, both conceptually and practically. In the initial workshops, we needed to return to the concept multiple times before the team could grasp how to start and stop recording the track and where to walk. In the intervening year between the first and second workshops, one team member mapped a feature that would have been better represented by a line rather than by points, but either did not remember how to do so or did not realize that a line would be a better representation. These thoughts were corrected after the second round of workshops after further group discussion and instruction.

Several years after the workshops, many members of the team still feel confident in recording points and tracks, however making maps has become difficult without ongoing instruction and practice. This is likely due to the lack of familiarity with the computer, and the fact that there is only one computer. The single computer means that only some people have regular access to it to practice, and that logistically speaking it will be those individuals who will use it to make maps. When those individuals are busy with other projects, it is difficult for others to come to that location to use the computer, especially because the knowledgeable individuals who drive the peer learning are not available to help with instruction in that case. This amounts to a bottleneck: more computers and more training for more members of the mapping team would enable mapping to become more widely available and used by Muonde.

4 Project Costs

In order to help evaluate scalability, we report the associated costs of the project: Including airfare for two mentors from the US to visit twice, the total was approximately $28,000 USD.

Broken down, the approximate costs for our mapping project are as follows (in 2015 dollars)

each Garmin GPS unit cost $100 plus tax (and there were eight units);
the Acer Aspire laptop cost $300 plus tax;
plane tickets for the visiting mentors cost $2000 each ($3000 each in 2016).
DNRGPS and QGIS are both open source and free of charge.
Fuel and drivers for vehicles to bring participants and facilitation costs $270 per workshop, and food and compensation $55 per workshop day per person.

For eight GPS units, two visiting mentors who visited twice, and 5 full workshops with 275 workshop-person-days between larger and smaller workshops, the total cost of this project is approximately $28,000. (Assuming paying participants $10/hour, the minimum wage in California in 2017.)

Additional costs included batteries for the GPS units and the maintenance of a home solar power system for charging the computer, and data charges for sending files (amount depending on the amount of data sent).

We funded this project partly through financial contributions to the Muonde Trust and partly through a US National Science Foundation grant (see Acknowledgements section in the main paper).

5 How-To Sheets

Table B1. List of How-To sheet topics and when they were created. “March 2015” sheets were created in advance of the first visit’s workshops; “April 2015” sheets were created in response to the questions raised during the 2015 workshops; the “June 2015” sheets and “October 2015” sheet were created at the request of the GPS team as their applications for mapping expanded. The How-To sheets themselves are available in a separate file.

When Created	Topic	Title
June 2015	Computer use	General notes about using the computer
April 2015	Computer use	Using the touchpad
April 2015	Computer use	Scrolling/looking through a list
April 2015	Computer use	Using the keyboard
March 2015	Computer use	Turning the Acer on and using the Start Screen in Windows 8
March 2015	Computer use	Using the Desktop and getting back to the Start Screen in Windows 8
March 2015	Computer use	Turning the computer off in Windows 8
March 2015	Computer use	Safely ejecting (removing) an external hard drive in Windows 8
April 2015	Computer use	Finding data files on the Acer

June 2015	Computer use	Spreadsheet basics in Libre Office Calc
June 2015	Computer use	Document basics in Libre Office Writer
March 2015	GPS use	Using the Garmin eTrex 10 (GPS unit)
March 2015	GPS use	Marking a waypoint with the Garmin eTrex 10 (GPS unit)
March 2015	GPS use	Waypoint averaging with the Garmin eTrex 10 (GPS unit)
March 2015	GPS use	Recording and saving a track with the Garmin eTrex 10 (GPS unit)
April 2015	Downloading Data	More tips on downloading points and tracks using DNRGPS
April 2015	Downloading Data	More tips on using the Garmin eTrex 10
April 2015	GPS use	Taking photos with cameras and locations from Garmin eTrex 10
April 2015	Downloading Data	Uploading points to GPS unit using DNRGPS
March 2015	Downloading Data	Plugging in GPS and starting up DNRGPS
March 2015	Downloading Data	Downloading Waypoints from GPS using DNRGPS
March 2015	Downloading Data	Saving Waypoints from DNRGPS
March 2015	Downloading Data	Saving Tracks from DNRGPS
March 2015	Using QGIS	Looking at data in QGIS
March 2015	Using QGIS	To add waypoints and tracks to the map in QGIS
March 2015	Using QGIS	Changing symbology/the way the waypoints and tracks look in QGIS
March 2015	Using QGIS	Zooming to look at specific data in QGIS
April 2015	Using QGIS	Saving a spreadsheet as Comma Separated Values in LibreOffice Calc
April 2015	Using QGIS	Add Comma Separated Values table to the map in QGIS
April 2015	Using QGIS	Joining the Comma Separated Values table to the waypoints in QGIS
April 2015	Using QGIS	Checking values in the attribute field of points/lines/polygons in QGIS
April 2015	Using QGIS	Labeling points in QGIS
April 2015	Making Exportable Maps	Making a quick map from the main program in QGIS
April 2015	Making Exportable Maps	Using the Print Composer to make a map in QGIS
April 2015	Making Exportable Maps	Adding a map to the Print Composer in QGIS
April 2015	Making Exportable Maps	Adding a scale bar to the Print Composer in QGIS
April 2015	Making Exportable Maps	Adding a legend to the map in the Print Composer in QGIS
April 2015	Making Exportable Maps	Adding a north arrow to the map in the Print Composer in QGIS
April 2015	Making Exportable Maps	Adding a title and map source information in the Print Composer in QGIS
April 2015	Making Exportable Maps	Exporting the map in the Print Composer in QGIS
April 2015	Using QGIS	Other tips for how to use QGIS
October 2015	Making Exportable Maps	How to make a map showing different kinds of Muonde Projects in QGIS
October 2015	Making Exportable Maps	How to change the symbology/colors for different kinds of objects in QGIS
April 2015	Projections & Calculations	What is a map projection (Coordinate Reference System)?
April 2015	Projections & Calculations	Setting the projection (Coordinate Reference System) in QGIS
April 2015	Projections & Calculations	Projecting a layer into UTM zone 36S in QGIS

April 2015	Projections & Calculations	Calculating the area of a polygon or length of a line in QGIS
April 2015	Projections & Calculations	Calculating a buffer around a vector
April 2015	Projections & Calculations	Calculating the uncertainty/error in the area of your field in QGIS
April 2015	Data Management	How to organize your files in order to make backup copies
April 2015	Data Management	How to copy files to an external drive and backup CommunityData folder
June 2015	Data Management	Tips for good data-keeping habits

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