MEETING THE NEED FOR GIS SKILLS IN DEVELOPING COUNTRIES: THE CASE OF INFORMAL SETTLEMENTS

Ian D. Bishop
Department of Geomatics
University of Melbourne

Mike Barry
Department of Geomatics
University of Cape Town

Elsworth McPherson
Department of Geography
University of the Western Cape

Joiana Nascarella
Department of Geomatics
University of Melbourne

Karen Urquhart
Department of Geomatics
University of Melbourne

Francisco Escobar
Department of Geomatics
University of Melbourne

Running Head: Multimedia teaching and informal settlements

Corresponding Author: Ian Bishop, Dept of Geomatics, University of Melbourne 3010, Australia
E-mail: idbishop@unimelb.edu.au

ABSTRACT

Informal settlements are a chronic issue in developing countries. Management and formalisation processes require good spatial data and analytical tools. While software such as geographic information systems (GIS) are widely available, access to good data and skilled users may be limited. In this paper we suggest that digital multimedia learning tools, accessible via the World Wide Web (WWW) may be part of the solution. We present the rationale for, and structure of, a suite of prototype learning modules for neighbourhood operations. We illustrate the use of these operations by converting shack locations into population density maps for the Imizamo Yethu settlement near Cape Town, South Africa. This prototype forms a part of a larger web site that also includes background information, data sources and software.

1. INTRODUCTION

Solutions to problems in the developing world are often inhibited by lack of access to pertinent data, by a shortage of people skilled in problem solving and even by restricted access to materials for educating people in appropriate technologies. There are often, of course, further impediments to implementation of preferred solutions, but this paper is concerned primarily with the education process and hence limited to the provision of the knowledge necessary for dealing with complex problems. More specifically, the paper deals with the potential of spatial information technologies, beginning with geographic information systems (GIS). Such multidisciplinary and integrative tools are of special importance when problems are multifaceted. This is clearly true in the management of informal settlements.

Informal settlements (also known as "squatter settlements" and "shanty towns") are largely unstructured and unplanned. They are a common feature of developing countries and are typically the product of an urgent need for shelter by the urban poor. As such, they are characterized by a dense proliferation of small, make-shift shelters built from diverse materials (e.g. plastic, tin and asbestos sheeting, wooden planks), degradation of the local ecosystem, e.g. erosion, poor water quality and sanitation, and severe social problems. Durand-Lasserve and Clerc (1996) suggest that as many as 70% of the urban residents in developing countries live in irregular or informal settlements.

The improvement of living conditions in informal settlements is one of the most complex and pressing challenges facing developing countries today. Intervention to ameliorate such situations may be applied on a continuum of cost and sophistication. Intervention begins with the supply of basic services and utilities to alleviate unsanitary and harsh living conditions and the formalisation of land rights to the extent that legitimate landholders feel secure against eviction and the improvement of shelter. At the other end of the spectrum, fully serviced housing with tarred roads and freehold ownership can be supplied. The level of intervention depends on the social, political and economic environment pertaining to each situation.

In the authors' experience in Cape Town, South Africa, intervention by land administrators in informal settlements requires spatial and socioeconomic data collection and analysis far more frequently than for the administration of a stable urban environment. The first stage of data collection and analysis involves assessing the situation prior to intervention. This may involve an aerial survey along with some form of socioeconomic census. If social conditions in a particular settlement are particularly volatile, then it may be necessary to conduct time series analyses to evaluate the changing nature of land occupation patterns and the changing social dynamic of an informal settlement in order to make informed decisions about planned intervention. The second stage involves using the available information to negotiate the sort of intervention that is feasible with community representatives. The third stage involves measuring if the agreed interventions take place in the manner 'agreed upon' with the community by monitoring if the actual pattern of land occupations matches the planned pattern.

Monitoring is required to see that agreements between land administrators and community representation are followed. This is problematic because the community representatives may not have a mandate to negotiate a particular agreement on a community's behalf. Secondly, the community as a whole may have objectives that conflict substantially with those of the land administration authorities, and consequently the rules relating to a particular agreement may be manipulated. A number of author's have commented on the complex and continually changing social dynamic in informal settlements (e.g Cross 1999, 1994; Davies and Fourie 1998). Cross (1999) observes that in South Africa the situation is turbulent, sometimes violent and the tenure generally insecure. The work of Fourie (1993), Davies and Fourie (1998) and Barry (1999) point to a typical informal settlement comprising a plurality of individuals, groups and sub-groups who have conflicting interests and goals. They assume that conflict is inherent and natural in the relationships between different individuals, groups and sub-groups within a settlement and between these entities and external forces such as the local authority or an external hostile interest group. As different entities strive to maximise their own goals and interests in competing for power, land and resources, so the nature of the tenure rules and practices change.

Ongoing education for participants from the community and land administration institutions in the role of spatial information in the intervention process is an integral part of that process. A prerequisite for intervention is a framework of up-to-date spatial information and a user community with both the skills to use specific software products and an underlying knowledge of spatial information science. As Hall *et al* (2001) point out:

> Many governments in developing countries….have mandated identification and diagnosis of urban poverty as a first means of establishing investment strategies to ameliorate the continuance and spread of structural urban poverty in their societies. (p240)

Software, appropriate digital data, relevant educational materials and an existing skill base among educators may all be in short supply in developing countries making rapid assimilation and application of the technology difficult.

This paper briefly reviews the options in GIS education, including the learning theories which support the concept of interactivity as a key process in effective learning. We then compare a range of available software products, which can be used to support multimedia development. We then describe the structure and development of one component module within a larger GIS learning environment (http://www.geom.unimelb.edu.au/gisweb). Neighbourhood operations are conceptually difficult to some students. Their application here is illustrated through mapping of changes in population density in an informal settlement. Finally we describe the other components of the web site – including links to data and software sources - developed during this project – and discuss the viability of the World Wide Web (WWW) as a delivery mechanism in developing countries.

2. GIS EDUCATION

Since the emergence of GIS in the late 1980s, there has been a shortage of skills in its use, at all levels. This shortage has been identified in both developed (Tomlinson, 1993) and developing (Bishop et al, 2000) countries. Raper and Green (1992) were of the view that the "technical complexity of GIS principles and their sophisticated implementation in a computing environment" make GIS implementation and operations quite difficult to understand. They suggested that the addition of graphical art, images and animation to traditional textual media and sound, "offer an effective way of putting across the graphical concepts which are vital to GIS".

Geographic information science and geographic information systems entered University curricula in the early 1980s and, because of these graphical concepts, were soon the subject of experiments with multimedia as a teaching aid: Perhaps the first example of a GIS tutorial package was ARCDEMO (Green, 1987). This was followed by GISTutor (Raper and Green, 1989). This was about the same time as some of the early – and lasting – GIS textbooks began appearing (e.g. Burrough, 1986). As the decade went on a substantial body of texts covering the theory and application of GIS developed. These formed the backbone of GIS education over this period. Teaching of GIS through the 1990s continued to follow a largely conventional course with lectures on theory and practical sessions using either the latest technology from the major vendors (ESRI, Intergraph) or more commonly much simplified products from university based developers (MAP, IDRISI, macGIS).

In 1988 the NCGIA began to develop a core curriculum for GIS education (Goodchild and Kemp, 1990). Although not prescriptive with regard to appropriate delivery mechanisms, the NCGIA made little attempt to develop the curriculum beyond a textual listing. That this was soon made available on the WWW did not make it a multimedia initiative. It is only in the last few years – with the increasing use of the WWW and increasing student pressure for distance learning – that new computer based instructional products have appeared.

A further prominent player in the field is UNIGIS, a network of Universities cooperating in the design and delivery of distance learning in GIS. The program was established in 1992 and now includes sites in 14 countries. Students use printed as well as digital study materials. The digital materials are accessible only to UNIGIS students (Hardwick et al , 1999). The University of Texas Virtual Geography Department, on the other hand, treats the Web as a common resource and provides an access point for other curriculum development projects around the world (www.Colorado.EDU/geography/virtdept/contents.html).

In our view, the addition of interactivity to multimedia teaching tools allows students to better comprehend how GIS processes work, through interaction with the maps, images and other information presented. The use of interactive multimedia presentations also makes GIS data 'real' by allowing students to understand where it fits in the 'real world' (Cartwright 1998). Above all, multimedia is a convenient method of teaching GIS concepts as it has the potential to effectively portray and communicate specific information with which students have encountered difficulties (Cartwright 1998). Importantly, interactive multimedia allows students to learn in their own time, at their own pace and to the level of detail that they require. In addition to this, using multimedia to illustrate complex operations prevents students from taking a 'black box' approach to GIS.

3. INTERACTIVITY AND LEARNING

Cognitive theories (Eklund and Woo 1998) suggest that there are four stages in human learning:

- Orientation - relating prior knowledge;
- Coaching - apprenticeship learning;
- Tuning - practice;
- Routinisation - gradual increased student autonomy.

These stages form a cognitive model, which assumes that knowledge consists of units and links. The four stages can be described in cognitive terms through the following processes:

- Connection - weak links are created between old knowledge and new knowledge;
- Accretion - knowledge is expanded with many new weak links created;

- Articulation - links are strengthened while some are deleted;
- Solidification - units and links are strengthened.

Cognitive theories need to be considered when creating Multimedia learning tools, and are particularly relevant to the production of interactive instruction. Several cognitive theories considered in the production of our interactive GIS learning modules were: Cognitive flexibility, Activity theory, Discourse theory, and Conversation theory (Eklund and Woo 1998).

Cognitive flexibility theory is the belief that examining a concept from more than one perspective will increase comprehension of the concept. Therefore presenting material in a variety of forms, such as examples, case studies, interactive exercises, is likely to lead to positive and effective learning.

Activity theory emphasises interactivity between learners and material. It is a view of learning based on the idea that human learning is mediated through practical activity.

Discourse theory also emphasises transaction between learners and material. Discourse theory considers the users' reasons for making 'connections' between 'links', and how these 'connections' have some individual meaning to the user. This is relevant for learning based on navigation through an interactive lesson. A users choice of navigation may be influenced by the task and the document structure, as well as the prior knowledge and intent of the learner. It is for this reason that perhaps a simple interactive structure of windows linked with 'next' navigation buttons may not be suitable, and more complex path structures may need to be considered when developing an interactive lesson.

In the case of computer aided learning, **conversation theory** characterises learning as interaction between a computer and a human, where exchanges of information are termed a 'learning conversation'.

Constructivist theories have, in turn, been developed from these cognitive psychology principles (Thompson et al, 1996). Constructivist learning theories place less emphasis on the sequence of instruction and more emphasis on the design of the learning environment (Lefoe 1998). Constructivist theories share the beliefs that:

1. Learning is an active process of constructing rather than acquiring knowledge, and
2. Instruction is a process of supporting that construction rather than communicating knowledge (Duffy and Cunningham 1996; Lefoe 1998).

This is a challenging issue for multimedia learning environments, and has been an important consideration in the design of the interactive GIS learning modules.

4. CHOICE OF DEVELOPMENT PLATFORM

Dalgarno (1998) reviewed a number of tools for development of multimedia education tools. These were evaluated for their ability to incorporate: (1) various media elements (e.g. sound, animation), (2) interactivity (e.g. hot keys, searching), (3) feedback (e.g. analysis of text responses, scoring), and (4) simulation and development of microworlds. The results of this assessment are presented in Table 1.

This analysis suggests that the best capabilities for the use of media elements are provided by Toolbook, Director, Authorware, and Hypercard. Director was found to provide the most animation options, including straight and curved paths and automatic 'inbetweening' of size and position. Director was also found to accommodate duplication across pages and the use of photos and bitmaps extremely well. Authorware, Toolbook and FrontPage have the better support for providing navigation options. Both Director and Hypercard were also found to provide most navigation options, but would require the addition of scripting. Toolbook and Authorware are the only tools to provide questions with feedback without the need for scripting. Therefore when using other tools (e.g. Director) for the provision of questions and feedback in the creation of interactive GIS lessons, it is expected that additional scripting will be required. Generally, simulations and microworlds are the most difficult to provide from an authoring perspective, as is reflected in the review of all six authoring tools. Toolbook and Authorware provide the best support for dragging objects and specifying responses corresponding to where objects are dragged, whereas the other tools require complex scripting (Dalgarno 1998).

Based on Dalgarno's review, Director (Elley et al, 1997) was chosen for the initial development. This reflects both existing software availability and the intention to concentrate on explanatory materials rather than assessment materials. Both self-assessment tests and formal assessment procedures will be added in a second development stage. Director fares extremely well in providing capabilities for the incorporation of media elements. For interactive elements and questions with feedback, additional scripting using Director's Lingo scripting language was required. For simulations and microworlds, Director would require complex scripting – such development was not however included in this project. Finally, and of considerable importance, is the ability of a Director project to be saved in a format which is directly accessible from the WWW with the free Shockwave plug-in.

5. NEIGHBOURHOOD OPERATIONS

The are many complex operations in GIS based data analysis which could benefit from a multimedia approach. Based on our own experience of conceptual and operational difficulties experienced by students we have chosen the generation of maps based on neighbourhood statistics as a developmental case study. This module was developed independent of the informal settlement issue but is illustrated here with examples taken from the Imizumo Yethu (‘through collective action’ - Xhosa) settlement in Hout Bay near Cape Town, South Africa.

Cell neighbourhood operations in GIS are important when a situation requires the analysis of relationships between locations, rather than the interpretation of characteristics at individual locations. Neighbourhood operations are often referred to as ‘Focal Functions’ as their action generates a value for the ‘focus’ of a neighbourhood. A neighbourhood, as defined by Tomlin (1990), is “any set of one or more locations that bear a specified distance and/or directional relationship to a particular location, the *neighbourhood focus*”. The neighbourhood can be any size and may be circular, square (or rectangular), donut-shaped or wedge-shaped.

Different statistics can be used to characterise scanning neighbourhoods. The nine statistical operations that form the basis of the Neighbourhood Operations module are Sum, Average, Maximum, Minimum, Median, Majority, Minority, Diversity and Range. Students have difficulty knowing which to use and especially in knowing which are appropriate for nominal, ordinal and interval scaled data.

The purpose of the Neighbourhood Operations module is to aid students in developing the skills necessary to assess a given scenario and apply the appropriate statistical operation. On completion of the Neighbourhood Operations Module, students should have a strong grasp of the concepts involved in Neighbourhood Operations. In establishing a multimedia learning module the options should be analysed in terms of content, control and flow.

Content

It was determined that the Module should therefore include:

- **Specific Theory:** Introductory theory and concepts
- **Simple Interactive Examples:** Examples demonstrating the computational methods covered in the Specific theory.
- **Worked Examples:** Realistic, more complex examples illustrating the procedure involved in applying the computational methods covered in both the Specific Theory and Simple Interactive Examples sections (see Figure 1)
- **Questions With Feedback:** Questions which require the student to apply the knowledge learnt in the previous sections. The questions mu st be presented in a similar fashion to the interactive examples, so as not to confuse the student, and useful feedback must be provided.

Control

As this learning module is designed to enhance the learning of theory and concepts related to the use of Neighbourhood Operations in GIS applications, it is essential to identify that different people learn in different ways. Thus, the design of this module needs to accommodate the varying levels of understanding users may have of the material presented in the lesson.

It is therefore essential to provide the user with an appropriate degree of control. The following general control guidelines were established, and adhered to in the design of each of the components of the module, and to the module as a whole:

- **The user should be able to leave the lesson at any point they feel is appropriate:**
  Students may wish to complete a lesson for various reasons, they may feel they are already confident in their understanding of the material, or they may simply wish to complete the lesson at a later time.
- **The user should be able to begin any section of the module without having to have completed any of the previous sections:**
  Students may wish to skip components of the module, or review components of the module that they have already completed.
- **Guidance as to the suggested direction of the lesson should be available:** Regardless of whether a student wants to skip or review sections of the module, it is required that the module have a suggested flow. This will guide students along the path, which gives complete coverage of the material.

Flow

Based on the control guidelines and the required content of the module established above, the flow of the module can be defined. Flow charts are an integral part of the storyboarding, planning, and design process involved in module development. They were useful in identifying content and control related issues and have also been used as a foundation for the creation of the module and each of its components. Figure 2 shows the flow chart for the interactive examples section of the module.

6. NEIGHBOURHOOD OPERATIONS ON INFORMAL SETTLEMENT DATA

Monitoring the population density of informal settlements is one of the most common analyses performed in land administration. Experience in local administrative authorities in Cape Town is that this is most often done by counting shacks on a series of analogue photographs taken at different epochs. We use the example of Imizamo Yethu to show how neighbourhood analysis can assist in understanding population growth and distribution.

The Imizamo Yethu informal settlement has grown rapidly through the 1990s. Agreements to provide formal, freehold land rights were initiated at the beginning of the decade, but owing to the volatility of the situation registration only commenced in the latter part of 1999 (Barry 1999). Aerial photographs (both conventional and digital) were collected for each year from 1992 to 1997. From these the outlines of shacks and other building were either digitised manually or with the assistance of computer aided techniques (Mason et al, 1997). Visual inspection of the shack distributions supports the impression of rapid growth but does not immediately provide any quantitative data on changes in shack distribution and density. Neighbourhood operations can assist in confirming the growth, quantifying the trend and analysing the spatial distribution.

Figure 3 shows the distribution of shacks in 1997. The original shack polygons have been converted to a 2.5 metre grid. The lower map is the result of application of the sum statistic within a square 50 by 50 metre neighbourhood. The result was divided by 4 and the map then shows the percentage ground cover by buildings. The shading shows increasing proportions of ground surface covered by shacks.

Making some assumptions about the typical numbers of people living in a hut of certain dimensions (e.g. 5 people per 5m by 5m hut), the hut density can be readily converted to a population density map. Figure 4 shows the change in population density between 1994 and 1997. In this case a 1 ha (100m x 100m) square neighbourhood was used. This produces maps with less rapid variations in value across the density surface than in the 0.25 ha neighbourhoods of Figure 3.

7. DELIVERY OPTIONS AND PRODUCTS

The World Wide Web (WWW) has the potential for widespread delivery of educational materials. Interactive web-based materials can meet the ideals of constructivist theory and become a substitute for traditional printed media such as the textbook (Marion and Hacking 1997). In South Africa, where good communications infrastructure exists, IT-based learning may also be cheaper than textbooks. With the current exchange rates, textbooks are not affordable for many students, since most come from Europe and the USA. This may be another example of technology leapfrog such as is occurring in telecommunication with the rapid adoption of the mobile telephone in developing countries. Institutions may become wide ranging users of IT-based learning without ever having developed substantial libraries or a textbook culture.

In some other parts of Africa there would be difficulty with web-based delivery. The Africa Virtual University, for example, prefers to distribute videotapes and uses satellite video links because the low and slow web access levels. At the University of Jos in Nigeria they use a web simulator with 4 gigabytes of data which is downloaded and made available on the University's internal network. The Director of the Centre for Lifelong Learning at the Technikon of Southern Africa, on the other hand, suggests basing delivery on the e-mail system. He says:

> People living in Africa often have great difficulty receiving and sending even faxes due to problems relating to electricity supply, equipment maintenance, etc. Those people who have access to electronic mail do however receive and send messages without much difficulty. (Paul West, http://pgw.org/pw/)

Another option for sites without web access is for the same material to be compiled and distributed on CD-ROM or DVD.

Assuming that, in almost any location, a suitable delivery mechanism exists, then we can bring the teaching tools to the potential users. Of great importance to effective use, however, is the concurrent availability of pertinent local data. Theory development needs to occur in an applications context. With this in mind, we have also developed an informal settlement web site (http://www.geom.unimelb.edu.au/informal) to support the teaching module. This includes:

- Historical background on the development of informal settlements in South Africa and Imizamo Yethu in particular
- Digital data and rectified aerial photographs of the site including a digital terrain model on a 5 m grid and shack outlines for the years 1993, 1994, 1996 and 1997.
- Links to other sources of digital data (e.g. the Cape Metropolitan Council in the Cape Town area, and the digital chart of the world [DCW])
- Links to GIS software sources – including free products such as ARC Explorer
- Other published papers on this topic
- Some images from the site and the region

Regular update of all materials is essential as the currency of data, software products and web-links rapidly declines. Resource currency is a further advantage of web-based delivery.

8. CONCLUSIONS

The work described here had several components. Our intention has been to show that:

- GIS can be used to develop an understanding of the structure and structural changes in informal settlements. Such knowledge is integral to effective management
- Web-based learning materials can be developed which facilitate understanding of the GIS-based analytical procedures.

It is assumed, but not shown, that wide-spread access to the learning materials will eventually lead to greater familiarity with GIS and its analytical procedures. This in turn should provide for greater awareness of informal settlement issues and eventually better decision making by land administrators from negotiation phases through to designing and monitoring intervention processes.

Due to the volatility of informal settlements, data collection and analysis is required frequently to ensure that the de facto situation on the ground is in harmony with the record in the GIS. In a drawn out formalisation process such as Imizamo Yethu, a number of different actors and institutions may collect data. Education is essential for spatial information technology to be applied correctly and for all those involved in the process to be aware of the role and importance of quality information.

Using GIS education in this context not only informs people about GIS but by working through these examples, a manager can also obtain a clear understanding of trends in the pattern of land occupation and the likelihood of any intervention process achieving the objectives that the authorities intended. There are significantly more interactive educational examples that can be created based on socioeconomic movements, employment opportunities, social networks and adjudication and recording of land rights.

As more people (at all levels), acquire GIS skills the technology will become more accessible and useful to society. Following on, a better understanding of the principles will popularise GIS, leading to its implementation on a much broader scale.

ACKNOWLEDGEMENTS

This work was funded by AUSAID under the Australia South Africa Links Program. Our thanks to the Cape Metropolitan Council for provision of aerial images and digital data. Students, particularly Bonita Kleyn and Cathryn Spence, in Cape Town and Melbourne worked on aspects of the project.

REFERENCES

Barry, M. B. 1999, *Evaluating Cadastral Systems during periods of Uncertainty: An analysis of Cape Town's Xhosa speaking communities*, PhD *in litt*, Department of Civil Engineering, University of Natal.

Bishop, I. D., Escobar, F., Karuppannan, S., Williamson, I. P., Yates, P. M., Yaqub, H. W., & Suwarnarat, K. (2000). Spatial data infrastructures for cities in developing countries: lessons from the Bangkok experience. *Cities, 17*(2), 85-96.

Burrough, P. A. (1986). *Principles of Geographical Information Systems for Land Resources Assessment*. Oxford, Clarendon Press.

Cartwright, W. (1999). Extending the map metaphor using web delivered multimedia. *International Journal of Geographical Information Science*, 13, 335-354.

Cross, C. 1994. *Shack Tenure in Durban*, in Hindson H and McCarthy J (eds), *Here to Stay: Informal Settlements in KwaZulu Natal*, Indicator Press, Durban

Cross, C. 1999. *Land and Security for the Urban Poor: South African Tenure Policy under Pressure*, Workshop on Tenure Security policies in South African, Brazilian, Indian and Sub-Saharan African Cities: A Comparative Analysis, Centre for Applied Legal Studies, University of the Witwatersrand, Johannesburg 27-28 July 1999.

Dalgarno, B. 1999, *Tools For Authoring Constructivist Computer Assisted Learning Resources: A Review.* WWW Document http://cedir.uow.edu.au/ASCLITE98/ascpapers98.html

Davies, C. J., and Fourie, C. F. (1998). A Land Management Approach for Informal Settlement in South Africa. *South African Journal of Surveying and Mapping*, 24, 239-246.

Duffy, T.M. and Cunningham, D.J. (1996), Constructivism: Implications for the design and delivery of instruction, In Leofe, G. *Creating Constructivist Learning Environments on the Web: The Challenge in Higher Education.* WWW Document http://cedir.uow.edu.au/ASCLITE98/ascpapers98.html

Durand-Lasserre, A. and Clerc, V. (1996) Regularisation and inetgration of irregular settlements: lessons from experience. Urban Management Program (Working Paper 6), UNDP/UNCHS/World-Bank, Nairobi.

Ecklund, J. and Woo, R. 1999, *A Cognitive Perspective for Designing Multimedia Learning Environments.* WWW Document http://cedir.uow.edu.au/ASCLITE98/ascpapers98.html

Elley, F. et al 1997, *Macromedia® Director 6 and Lingo Authorized*, Macromedia® Press, Berkeley, Ca.

Fourie C D 1993. *A New Approach to the Zulu land Tenure System: An Historical Anthropological Explanation of the Development of an Informal Settlement.* Unpublished PhD thesis, Rhodes University, Grahamstown.

Goodchild, M.F. and Kemp, K.K. (1990) NCGIA Core Curriculum in GIS, National Center for Geographic Information and Analysis, University of California, Santa Barbara.

Green, N.P.A. (1987). Teach yourself geographical information systems: the design, creation and use of demonstrators and tutors. *International Journal of Geographical Information Systems*, 1, 279-290

Hall, G. B., Malcolm, N. W., & Piwowar, J. M. (2001). Integration of remote sensing and GIS to detect pockets of urban poverty: the case of Rosario, Argentina. *Transactions in GIS, 5*, 235-253.

Hardwick, S., Kemp, K., Ploszajtska, T. and Reeve, D. (1999) Delivering courses internationally. International Symposium 'Learning and Teaching Geography in Higher Education'. Hawaii, 23 March, 1999. (http://www.chelt.ac.uk/el/philg/gdn/hawaii/top.htm)

Leofe, G. 1998, *Creating Constructivist Learning Environments on the Web: The Challenge in Higher Education*. WWW Document http://cedir.uow.edu.au/ASCLITE98/ascpapers98.html

Marion, A. and Hacking, E.H. *Educational Publishing and the World Wide Web* WWW Document http://www-jime.open.ac.uk/9812/marion-98-2-paper.html

Mason, S. O., Baltsavias, E. P., and Bishop, I. D. (1997). Spatial decision support systems for the management of informal settlements. In Computers, Environment and Urban Systems, 21, 189-208.

Raper, J.F., and Green, N.P.A. (1989). Development of a hypertext based tutor for Geographic Information Systems, *British Journal of Educational Technology*, 3, 164-172.

Raper, J., and Green, N. (1992). Teaching the principles of GIS: lessons from the GISTutor project. *International Journal of Geographical Information Systems*, 6, 279-290.

Thompson, A.B., Simonsen, M.R., Hargrave, C.P. (Eds) (1996). Educational Technology A review of the Research, In Leofe, G. *Creating Constructivist Learning Environments on the Web: The Challenge in Higher Education*. WWW Document http://cedir.uow.edu.au/ASCLITE98/ascpapers98.html

Tomlin, D. 1990, *Geographic Information Systems and Cartographic Modeling*, Prentice-Hall Inc., New Jersey

Tomlinson, R. 1993, State Government of Victoria Strategic Framework for GIS Development. Prepared for Office of Geographic Data Co-ordination, Victoria, Australia. Tomlinson Associates Ltd., Ontario, Canada, 77 pages.

Table 1. Evaluation of multimedia development tools (P - poor, F - fair, G – good, E – excellent)

	Authorware	Director	Toolbook	Hypercard	Frontpage	Visual J++
MEDIA ELEMENTS						
Positioning and sizing	G - E	G	E	F	F	G
Duplication of objects, pages	G	E	E	E	G	G
Text	E	G – E	E	F – G	G	P
Photos and Bitmaps	F – G	E	G	G	G – E	G
Drawings	E	G	E	P	P	P
Animations	G	E	G	G	F-G	F
Sound	G	G – E	E	E	G	F
Video	E	E	E	G – E	G – E	P
Transition effects	E	E	G	E	P	P
Colour and Palettes	G	E	E	G - E	G	G
Window creation, sizing and positioning	F	F	G	P -F	G	F
INTERACTIVITY						
Text fields	F	F – G	E	F – G	E	F
Hot Keys	E	F	G	F	P	F
Menus	G – E	F	G	F – G	F – G	F
Buttons and Icons	E	G	E	F	G	F
Hot Spots	E	G	E	F	G – E	P
Hypertext	E	F	E	F	E	P
Media Controls	G	G – E	E	G	G	P
Ease of jumping to page	E	G	E	G	E	F
Ease of creating Back, Next and Previous functions	G	G	E	E	E	P
Searching	E	P	E	E	G	P
FEEDBACK						
Multiple Choice	F – G	F – G	E	F – G	F	F
Text answer	E	F	E	F – G	F	F
Numeric answer	G	F	G	F – G	F	F
Graphical response, such as dragging and connecting	G	F - G	E	F	F	F
Feedback for each Response	G	F	E	F	F	F
Scoring	G	F	E	F	P	F
Control over attempts	G	F	E	F	P	F
SIMULATION						
Selecting objects	F	F	F	F	F	F
Dragging objects	E	F – G	E	F	F	P – F
Drawing	P	P	G	P	P	F
Storing a “world”	F	G	G	F	P	G – E
Updating a “world” display	F	F	G	F	P	G
Generating “world” changes and Processing data	G	G	G	F - G	F	G - E
Saving and loading “world”	G	F	G	P	P	G - E

(source: adapted from analysis by Dalgarno, 1998)

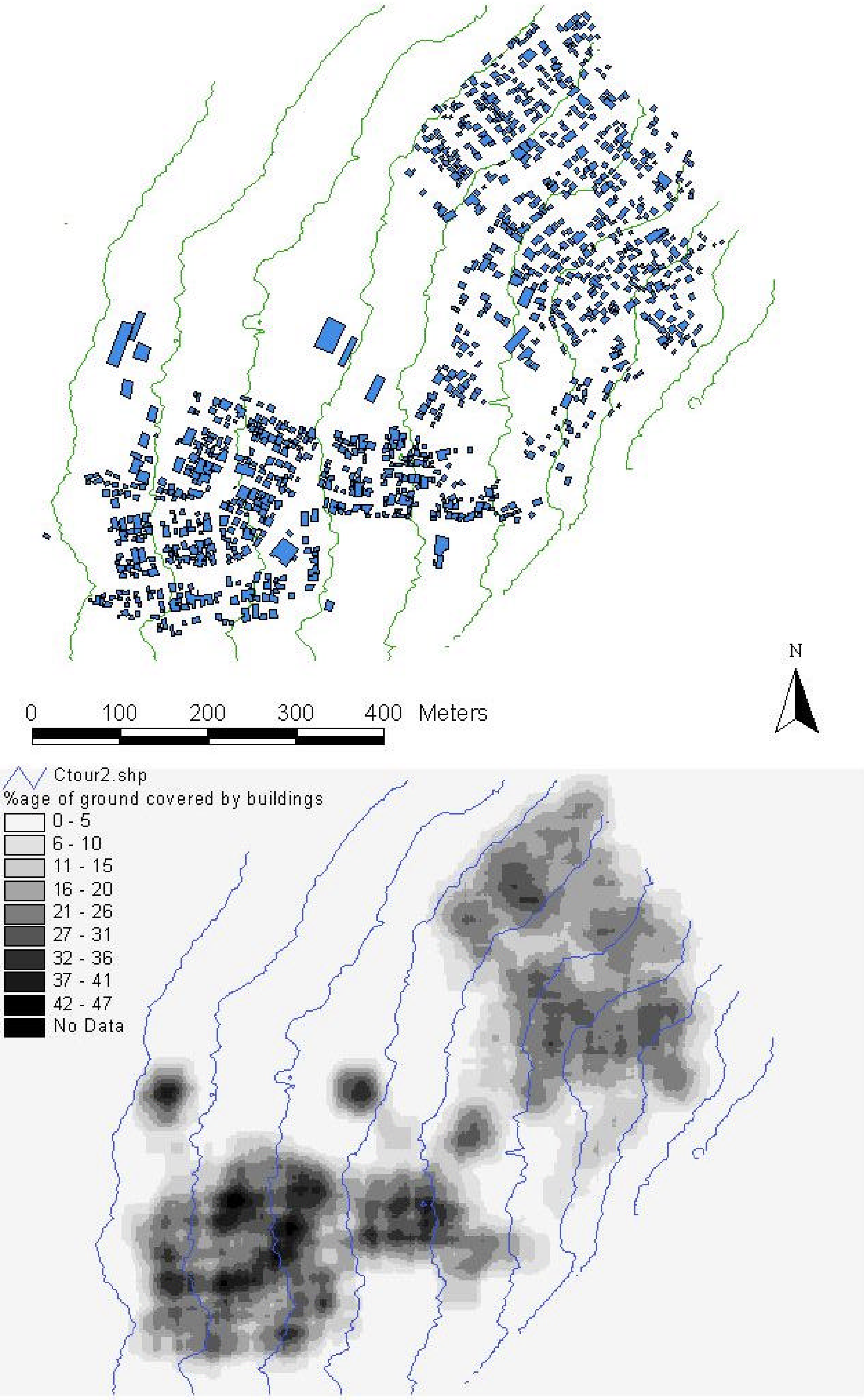

Figure 3. The 1997 distribution of shacks in the Imizumo Yethu informal settlement (above). The conversion of shack distribution to a ground cover density map (below).