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Bridging the gap between technical and social competencies of urban and regional planning through mobile technology: The case of Cape Peninsula University of Technology

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Higher education institutions are entrusted with the responsibility of training future workforces that are well equipped to function in the age of the 4th industrial revolution (4IR). This role is pertinent in light of growing concerns that with the advent of 4IR, mobile technology and robotics would take over certain roles that are currently performed by humans. Using the case of Goedverwacht community service-learning project in the Western Cape province of South Africa, this paper demonstrates ways in which mobile technology is embraced and applied in urban and regional planning education at Cape Peninsula University of Technology (CPUT). The purpose of the service-learning collaboration between the Goedverwacht community and CPUT was to produce a spatial map depicting property boundaries so that the community could, amongst others, be ready for the imminent land tenure reform processes. With the input and guidance of community members, the map was compiled through the use of mobile and allied technology, including global positioning system-enabled smartphones, drones and mobile geographic information system.

Keywords: Community mapping; Mobile technology; Community service-learning; Fourth Industrial Revolution; Cape Peninsula University of Technology.

Introduction

There are concerns around the world that with the advent of the much-vaunted Fourth Industrial Revolution (4IR), certain roles that are performed by humans would diminish and ultimately cease to exist in the economic system (Schwab 2017). The basis of the fear is that, on the horizon, some duties would be fulfilled efficiently with the application of mobile technology, artificial intelligence, robotics and/or associated technologies. In light of the high unemployment rate in South Africa,[1] this concern brings to the fore the role of higher education institutions, which are entrusted with the responsibility of equipping the future workforce with skills that are relevant in the era of 4IR. Despite the unquestionable importance of education in instilling the requisite knowledge, there is a lack of literature that discusses ways in which South African higher education institutions embrace and incorporate mobile technology in teaching and learning activities.

Towards at least in part filling this gap, the aim of this article is to present elementary ways in which mobile technology is embraced in urban- and regional planning education at Cape Peninsula University of Technology (CPUT). Reflecting the importance of urban and regional planning amidst high level of unemployment in South Africa, town planning technicians represent one of the scarce skills of highest demand in the country (Republic of South Africa 2018). This implies that in the age of rapid technological changes, planners have to be innovative, adaptive and agile towards meeting the developmental needs of the country. In relation to 4IR, urban and regional planning represent a particularly relevant discussion platform given that it is an interdisciplinary profession that incorporates technical and soft or social competencies. It is widely argued that one of the key steps towards improved planning processes is the generation and the use of accurate data (Bracken 2014; Duminy, Odendaal & Watson 2014; Hao, Zhu & Zhong 2015), which the paper argues can be enhanced through the application of mobile technology. The social competencies revolve around the ability of planners to communicate and collaborate with various stakeholders involved in development processes, especially the

1. In 2019, South African employment rate stood at 29% approximately (Statistics South Africa 2019a); while the unemployment rate of the youth aged 15–24 was about 55% (Statistics South Africa 2019b).

Note: Special Collection: Mobile Technology within the 4IR era - Africa answering the call.

communities (see Duminy et al. 2014) for whom planning is carried out. It is in this context that this article argues that a fusion of technical and social facets of urban and regional planning is essential.

The nexus between technical and social competencies of urban and regional planning presented in this article is at least in part influenced by communicative theory of planning, which is also known as collaborative planning. This theory is based on an understanding that urban and regional planning is not merely a technical exercise but a process that should be cognisant of particular context and circumstances (social, political, economic, environmental, etc.) of the communities. In this way, planning is understood to be driven by processes of communication and collaboration wherein planners are mediators and not the so-called experts in development processes (for instance, see Healey 1997; Innes & Booher 2010).

In order to realise the aim of the paper stated above, the discussion explores interconnections between community service-learning and community mapping – specifically revolving around the application of geographic information system (GIS), global positioning system (GPS), remote sensing, drone technology and smartphone data-capturing techniques. As a form of community–university partnership, community service-learning grants students an opportunity to work closely with communities on projects that would benefit the communities, whilst students simultaneously learn in the process. It is widely acknowledged that community service-learning contextualises knowledge acquisition by giving students an opportunity to become well versed in society's problems (Conner & Erikson 2017; Hall 2010; Petersen & Osman 2017; Thomson et al. 2011). Service-learning exposes students to community issues first hand, instead of only being informed about them within the confines of a classroom. This article argues that this form of teaching and learning is crucial for developing the social competencies that are central in urban and regional planning.

Synonymous with community-based planning, community mapping encourages synergism between communities, government and other stakeholders towards understanding the status quo (e.g. social, spatial and environmental) and aspirations of communities. The process lends itself towards the concept of subsidiarity wherein community members are directly responsible for managing their needs (Carra 2018). Community mapping offers activism platform where citizens are mobilised to lobby for better services (Kalandides 2018) and give their view on developmental issues. An important aspect of community mapping is risk analysis, which in the context of this article requires up-to-date socio-spatial data to aid the land tenure reform processes. It is well known that formal land administration system in South Africa does not accommodate non-formal land rights arrangements employed in communal areas and informal settlements (Hornby et al. 2017). This gap results in a lack of reliable, land-related information, which adversely affects planning in such areas. Accordingly, residents in communal areas of South Africa do not know the legal and institutional arrangements that inform land tenure reform in their communities and have no platform to enquire or voice their concerns. Often, locals are adversely affected when development decisions are taken on their behalf, causing uncertainty and tension amongst community members (Cousins & Pollard 2017; Hornby et al. 2017). Communication that is part of grassroots community mapping is thus meant to ensure that people are informed about policies and various processes that may have an impact on their livelihoods.

Against this backdrop, this article uses the case study of Goedverwacht Mission Station (community-based mapping and service-learning) initiative to demonstrate how mobile technology was used as a foundation for equipping students with the elementary skills needed in the 4IR era. Following this introductory note, the next section provides a brief overview of the fundamentals of the technology that this article is based upon, followed by the declaration of ethics-related matters. The penultimate section presents the Goedverwacht Mission Station community-based mapping project, followed by concluding remarks.

Mobile and allied technology

As a preamble to the initiative that is the subject of this article, this section overviews the underlying technology, namely, GIS, GPS and remote sensing.

Geographic information system technology

Geographic information system software consists of a broad range of applications but essentially entails a combination of two environments, namely, geo-referenced data and digital maps. Geographic information system data sets can be compiled in accordance with the user's desired outcome through analysing, managing, visualising and creating data. In this way, GIS serves as the collective point for data manipulation according to the user's desired outcome (Gimond 2019). The power of GIS lies in its ability to perform spatial analysis, which is a process that deals with the quantification of patterns observed in a GIS environment. The main purpose of spatial analysis is to understand the relationship, trends and patterns between geographic features (Erica, Nelson & Greenough 2016). Knowing the location and bearing of things, the proximity of objects or things, and the relationships between these allows for better-informed planning and decision-making. This allows for quicker responses to network changes, better prediction of events that can change the interconnected network parts, the ability to identify problems along the network, the identification of the location and number of 'things' (e.g. houses) impacted by an event, and, in essence, allows power to be re-instituted back into a community (Hecht 2014).

Mobile GIS is a tool specifically meant for spatial mapping and analysis using Global Navigation Satellite System (GNSS) (location and attributes). Handheld GIS computers

(Trimble Nomad) are used to build geo-referenced GIS databases of features in the field. This instrument has a differential GNSS receiver with an accuracy of 1 m – 3 m in the horizontal (YX coordinates) and generally half or one-third of the YX accuracy in elevation (Z), which is sufficient for mapping and spatial analysis but not for detailed design. Mobile GIS are designed for work in informal settlements and many other aspects where infrastructure planning needs geographic referencing with the use of GNSS. Such data are convertible to computer-aided design (CAD) and GIS formats for enabling spatial analysis and the compilation of CAD or GIS drawings or maps.

Global positioning system technology

Global positioning system technology is a satellite-based navigation system made up of 24 satellites situated 20 000 km above the earth's surface. This GPS technology is freely available to anyone who has a GPS or GNSS receiver. The GPS receiver uses a radio signal broadcast from GPS satellites to determine its position. Global positioning system is the most widely used mobile technology for determining locations (Zandbergen & Barbeau 2011). Generally, there are three types of GPS receivers: recreational, mapping and surveying. Recreational GPS receivers use course acquisition (CA) to determine its position with a horizontal accuracy of 5 m – 10 m. Mapping receivers use CA code and differential pseudo-range correction to achieve a horizontal positional accuracy of 0.5 m – 1 m. Surveying receivers are able to achieve a sub-centimetre horizontal positional accuracy because they use carrier phases of multiple frequencies to model atmospheric error (Parker 2015). Both mapping and surveying GPS receivers rely on differential correction to achieve the suggested horizontal positional accuracies. Differential correction utilises two or more GPS receivers. One receiver is stationary at a known position (referred to as the base), and the other mobile (referred to as the rover). The base receiver calculates the difference between the calculated location and its actual location to define the error at that specific time (DiBiase 2014).

The correction is applied to the roving receiver's position on the instant, either in real time or by post-processing. The South African government has invested a great deal in the establishment of permanent GNSS base stations in the country known as TrigNet. TrigNet post-processed data are freely available for downloading on the Internet (Combrinck, Merry & Wonnacott 2003). A limitation in using GPS is that GPS signal cannot penetrate where a solid object obstructs the view of the sky and therefore can only provide limited location information inside a building. Mobile phones and tablets are now able to use GPS for location-based services (LBS). Assisted GPS (A-GPS) utilises information provided by the cellular network to aid the GPS receiver to calculate an accurate position more quickly (Zandbergen & Barbeau 2011). Global positioning system using a mapping receiver is needed for establishing ground control points (GCPs) when using remote sensing unmanned aerial vehicle (UAV) imagery for data collection.

Remote sensing unmanned aerial vehicle imagery

A UAV mounted with a professional-level camera and gimbal mounting is becoming a popular option for low-cost remote sensing. UAV provides a way to map features that are inaccessible by conventional mapping methods. The concern lies in producing a true digital orthophoto map using UAV images, especially when mapping undulating terrain. It is important that sufficient ground control points (GCPs) be established throughout the mapping area to correct geometric distortions that occur as a result of tilt in the camera angles. Ground control points are beacons or targets on the surface of the earth that are coordinated using instrumentation such as GPS. Coordinates are required at the centre of each GCP to improve the global accuracy of the map.

Ethical matters

The initiative that this article is based upon was not designed as a research project but was purely conceived as a community service-learning effort. As per the requirements of CPUT, the initiative was registered by the university as a service-learning project, although research ethics clearance was not applied for. The reason for not applying for ethics clearance was that, as noted above, the initiative was not conceived as a research project that would be reported on. Therefore, to overcome potential ethical concerns, certain information pertaining to the project is not disclosed herein, such as the names and the photographs of community members and students, and images of the project's output. This article merely reports on the utilisation of mobile technology as part of teaching and learning methods intended to at least in part acquaint and prepare students for the era of 4IR.

Goedverwacht Mission Station project

As alluded to in the Introduction, this article is based on the Goedverwacht Moravian Mission Station community service-learning project, which was spearheaded by CPUT's Department of Town and Regional Planning and the community of Goedverwacht. Consisting of approximately 500 families, Goedverwacht is a communal settlement located in the Western Cape province of South Africa, about 150 km north of Cape Town. The area is under the trusteeship of the Minister of Land Affairs in terms of the *Rural Areas Act* of 1987. This arrangement implies that the community does not fall under the jurisdiction of Bergrivier local municipality, and the municipality is therefore not responsible for planning, development and provision of services in Goedverwacht.

Although the residents of Goedverwacht do not have secure legal tenure (i.e. individual title deeds) for the properties they occupy, they have long-term guarantee of rights, administered by the Moravian Church. To date, the South African legal system does not provide for the registration of individual rights to land that is predominantly based on shared use. Records of land rights in communal areas are usually kept by the community leadership and they are not necessarily recorded in a formal manner or in black and white. Thus, close consultation with community members is essential for establishing the nature and extent of the rights of individuals in communal areas. In some instances, one person does not have sole rights to a piece of land but shares it with other people who claim different rights at different times. Only once the nuances of multiple land rights are uncovered can an accurate assessment be made and a way forward on sustainable land tenure reform be established. Goedverwacht project thus attempted a form of community-led land rights enquiry (through a mapping process) before the imminent formal processes. As discussed hereunder, the enormity of mapping community assets was greatly reduced with the use of mobile technology.

At least 166 third-year students (completing a 3-year National Diploma in Town and Regional Planning) participated in the project over a 5-year period (i.e. between 2014 and 2018). With the initiative largely related to mapping, the project activities were logically linked to a technology-related subject named 'Geographic Information Systems'. The subject deals with the fundamentals of geospatial information, including the application of spatial concepts and spatial analysis. In the subject, students are exposed to hands-on application of commercial GIS software in order to be able to operate in various environments after graduating. Practical exercises in this regard require a significant commitment of time and attention in managing geospatial projects. To encourage the spirit and culture of collaboration, students are in some instances expected to complete the projects in groups. All in all, the subject is intended to prepare students as, amongst others, the so-called planning technicians (working in government and non-governmental sectors) because it is considered as a scarce skill of highest demand in South Africa (refer to the Introduction).

As a transdisciplinary initiative, Goedverwacht service-learning project involved students and academic staff from other departments of CPUT, namely, the Department of Construction Management and Quantity Surveying and the Department of Management and Project Management. The transdisciplinary aspects of the project are discussed in detail elsewhere (Mokhele & Pinfold 2020), and, thus not covered herein given that the focus of the research is specifically on the use of mobile technology by urban and regional planning students. Nonetheless, students from different departments worked on the project in groups varying from 12 to 24 members wherein one group per week visited the community.

The project intended to bridge the gap between technical and social competencies of students using mobile technology to combine communication with cadastral mapping at an accuracy fit for purpose. As noted earlier, the process was intended to prepare the community for the imminent, government-driven land reform process, which would aid the community to transition from customary land administration to a formal one. Given that the Goedverwacht community did not have a basic map that showed, amongst others, an existing layout of the settlement, it was expected that the project would produce a status quo map that depicted land-use patterns, general property boundaries and other community assets. The main focus of the mapping was to establish a sense of place rather than the precision of cadastral boundaries. During the mapping process, reciprocal learning was encouraged between students and community members regarding information on land policy, policymaking and the availability and location of community assets. Bridging the gap between the elementary technical knowledge and social competencies enabled the students to reach members of the community without excluding anyone. Using mobile technology to gather qualitative and quantitative spatial data at an accuracy fit for purpose provided a quick response to community needs.

The mobile technology component of the Goedverwacht project had three closely inter-related objectives:

1. To implement a service-learning project that incorporates teaching methods to prepare urban and regional planning students to function in the age of 4IR. The service-learning project involved determination of property boundaries and attribute data captured in a GIS.
2. To build a GIS database that emulates a land information system incorporating both technical knowledge and social competencies.
3. To communicate with residents using mobile technology to identify community assets.

These objectives are elaborated next.

Teaching and learning (community service-learning) methods

Integrating service-learning into the GISs subject involved a three-pronged approach encompassing planning, operation and evaluation phases. The planning phase included obtaining consent from the community, followed by requisite approvals from the university. Once approvals had been obtained, the student timetable was adjusted to ensure that the proposed service-learning activities would not overburden the students. The operational phase focused on student learning and reflection. Reflection involved self-evaluation including the involvement of peers, academic staff and the community. During reflective sessions, students got extended feedback and were able to deliberate on their experiences and develop an understanding of new and challenging situations. By engaging in this questioning process, students were able to recognise and articulate their learning. The service-learning element ensured a clear and constructive alignment between the outcomes of the subject (i.e. developing and improving the application of technology) with its implementation (practising technology through teaching and collaborating in a community setting). The evaluation phase involved discussions with community partners, students and university structures to determine the extent the community, students and academic staff benefited from the project.

The operational phase of the service-learning project entailed defining property boundaries from topographical features such as (wire) fences, boundary walls and hedges. These features were pointed out and clarified by community members during the students' visit to the settlement. The students would immediately mark the features on a hard copy aerial photograph. Where boundaries were not well defined and/or unmarked, and thus unobservable, residents assisted the students by verbally describing and sketching the approximate boundaries. Students walked around the settlement and enquired with community members they came across. A hard copy aerial photograph of the settlement was used to kick-start the mapping process and collaboration with the residents. The aerial photograph was obtained from the National Geo-spatial Information in electronic format and printed on an A3 size to facilitate the discussion with community members.

The initial process discussed above was followed by the application of 'mobile GIS', which consisted of a mobile device, GIS software and a GPS receiver. Before the project could commence, the mobile GIS database required structuring in accordance with the project objectives. The students were tasked with setting up a GIS data dictionary to guide data collection (see Table 1). A data dictionary categorises data sets in the GIS database. In doing so, both quantitative and qualitative data collection categories were planned so that the numerical aspects of space as well as the social significance of space could be captured. Although the GIS technology was traditionally used to collect and analyse objective data, it is increasingly being used to collect and analyse subjective data. The challenge for the students was to link geospatial data with local knowledge, which included human experiences, perceptions and emotions of space. Mobile GIS was used to document the information captured from the observation and discussions with community members, namely, boundary fences, buildings, roads, tracks, parks (and their amenities) and other types of assets. Information relating to each asset was stored and included both quantitative and qualitative data.

TABLE 1: Data dictionary for data collection.

Feature name	Feature class type	Attribute	Attribute type	Description
Land use	Point	Residential Open space Public space Recreation Retail Commercial Agriculture	Nominal/ categories	Existing use of land
Property boundary	Line	Clearly defined Uncertain Not defined	Ordinal/ranks	Delineation of the property boundary
Building type	Polygon	Dwelling Shed Toilet Backyard cottage Office Shop Factory	Nominal/ categories	Building usage
Road	Line	National Municipal Local-tar Local-dirt	Ordinal/ranks	Type and condition of roads
Home horticulture	Polygon	Summer Winter All-seasons	Interval	Residents' capacity to grow vegetables at home
Children's age (years)	Point	1–6 7–13 14–18 19–21 None	Ratio	Need for resources – kindergarten, primary school, secondary school
Direction-church	Point	North East South West	Cyclic/direction	Residents' cognitive perception of direction
Community leadership	Point	Excellent Satisfactory Unsatisfactory Unacceptable	Counts and amounts	Consensus with communal leadership

High-resolution satellite imagery was useful for settlement classification, but was not sufficiently accurate (clear) to identify general cadastral boundaries, such as fences, hedges and walls, so as to complement the community's input above. To achieve the required accuracy, large-scale aerial photography was obtained using a quad-copter drone flown 100 m above ground level. The lecturer provided a demonstration to students on how to operate a drone. In their respective weekly groups, the students subsequently took turns to fly the drone under the supervision of the lecturer. The drone was Wi-Fi enabled, which means that it could broadcast the information captured directly to a smartphone of the lecturer. The device of the lecturer was used because of the cumbersome process for installing the application on a mobile phone. Most students found the flight controller and smartphone applications easy to use. Once the area had been flown, the imagery was downloaded by the lecturer onto the university GIS workstations on campus. Students were then required to perform an affine transformation using pre-marked control points to correct the geometric distortions of the image that occurred because of non-ideal camera angles and conflicting scale. The transformation error residuals obtained indicated the accuracy of the image and the quality of students' work. The large-scale aerial photography required pre-marked GCPs co-ordinated to sub-metre accuracy. The pre-marked GCPs were used to minimise the scale distortion of the imagery when incorporated in GIS. A GPS receiver with differential correction capability was used to coordinate GCPs at a sub-metre accuracy. Mobile GIS and GPS were used for geo-referencing features and recording attribute data. The students used their smartphones to take geo-referenced terrestrial photographs, which were then added to the geo-database along with the spatial information and attributes (Pinfold 2018).

Land information system

Students were required to use GIS to build a land information system to document the cadastral data gathered. It was important that the land information system is easily accessible and up-to-date. Three thematic maps were produced using GIS: (1) a cadastral land-use map, (2) a building construction (top structure) map and (3) a 'sense of place' map. The work was completed in groups and submitted to the lecturer for formal assessment. The cadastral land-use map was colour coded to visualise settlement patterns. Buildings on each property were then graded according to their completeness, exterior state and floor area, reflecting the character of top structures in Goedverwacht. Student emotions conjured up during community engagement were also documented, coded and spatially analysed to visualise a 'sense of place' from an outsider's point of view. The purpose of this exercise was to teach students the value of technology in expressing the social sentiments of a community.

Communication with residents

Cadastral mapping involved communicating with Goedverwacht residents regardless of their gender, status or class. Students were asked to explore three mapping techniques: (1) participatory mapping, (2) cognitive mapping and (3) community mapping. Participatory mapping involved obtaining the community's information without the person (i.e. community member) being involved in the mapping process. Cognitive mapping is a perception of space rather than a spatial map. This gives an understanding of the community's views of space. Cognitive mapping allows people to express their feelings about local conditions. Finally, community mapping involved the community drawing sketches and diagrams of their settlement, which were subsequently converted (and refined) by students into a more legible format in GIS. During the mapping process, students were able to communicate, describe and explain matters regarding land policy and land reform to the residents. The mapping enabled students to reach out to a wide range of households whilst making use of technology to document community assets.

Project output

The output of the Goedverwacht project was an interim cadastral plan that depicted land-use patterns, property boundaries and community assets such as community facilities. It is expected that the map can be used by the community to negotiate with government (and other stakeholders) in a bid for a community-driven solution to land tenure reform. Notably, the accuracy of the demarcated boundaries (and the overall map) did not necessarily comply with the technical mapping guidelines, thus reducing unnecessary time and cost associated with the accuracy required for formal registration of properties. The property boundaries (and other elements of the map) were based on arrangements that have worked in the community for decades, instead of imposing what would be deemed technically logical or correct. Because the map was derived at a grassroots level, all residents were given a chance to participate in the process despite their status, class, position, etc., in the community. The mapping process was particularly simplified so that the technical aspects of mapping did not restrict the participation of community members. During the mapping exercise, students were able to learn from the residents who in turn gained knowledge about land rights and security of tenure. The students were accordingly introduced to various aspects of mobile technology as a means of collecting and assembling data in the era of 4IR.

Conclusion

Through the case of Goedverwacht community service-learning project, this article presented basic ways in which mobile technology is embraced and employed in urban and regional planning education at CPUT so as to prepare students for the age of 4IR. Linking people to land and collecting multi-layered geospatial data were done using techniques and tools such as GPS-enabled smartphones, drones, satellite imagery and mobile GIS or GPS (see also Kakembo & Van Niekerk 2014). The use of application software designed to run on a mobile device and GIS software configured for all users enabled non-technical (lay) community members to participate in the process. Notably, community mapping allowed knowledge and information to be provided by non-specialists who were better able to express their challenges, needs, goals, aspirations and priorities. A community-driven participatory GIS was used to manage data and provide residents with an opportunity to participate in development processes.

With the input of community members, the project facilitated the gathering of geospatial information into a simple database and map, which can be updated regularly and be used by the community and other stakeholders for development planning purposes. The ultimate purpose of the mapping exercise was to establish cadastral boundaries at an accuracy that was not necessarily constrained by technical and legal requirements for formal land registration. An interim general plan (compiled with the community) would become the basis for facilitating planning that is flexible, dynamic and locally desirable. The geographic data were stored in ArcGIS computer program's geo-database where it could be readily accessed and updated by the students and/or staff. The intention is to ultimately equip and empower community representatives with elementary GIS and mobile technology skills so that they could view and update the database themselves as well as pass the knowledge to the fellow community members. The authors are optimistic that the foregoing elementary efforts will be built upon and embedded in urban and regional planning curricula so as to improve the intricate nexus between the social and technical aspects of the discipline in the age of 4IR and beyond.

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The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this research article.

Authors' contributions

All authors contributed equally to this work.

Ethical considerations

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