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The Viability of a Bimodal Application of an Interactive-GIS-Tutor within Low-Resourced South African Schools

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Abstract
Adhering to the United Nations' call to implement Geographical Information Systems (GIS) education, GIS was phased into the South African Further Education and Training (FET) Geography curriculum over the period 2006-2008. Yet, following the global trend, the slow adoption rate of GIS education points to the presence of GIS implementation barriers, due to a lack of educational GIS research. This implies that GIS curriculum development has outpaced GIS educational research. To support Geography teachers, an Interactive-GIS-Tutor (IGIST) application has been developed. This multiple case study evaluates the bimodal use of the Interactive-GISTutor (IGIST) on i) computers and ii) a projector/whiteboard within large classes, in low resourced schools. Both quantitative and qualitative methods were used. Preliminary learner (n=149) and teacher (n=6) evaluations of the IGIST are being analysed and discussed, followed by learner focus group (n=6 x 8) and teacher interview (n=6) discussions. In this article, we advocate the IGIST and its bimodal use option as desirable and a viable and flexible GIS teaching option.
Keywords evaluation, Geography, GIS, multimedia, tutor

Introduction

The development and usefulness of Geographic Information Systems (GIS) applications have earned global recognition (United Nations 2012). However, in order to maintain the momentum of GIS development, urgent and ongoing educational research is needed to investigate the teaching practices most suitable for both teachers and learners (Sui 2014). Although educational GIS has gained influence within the United States of America, Canada, and England, followed by Denmark, Germany, France, Finland, and Sweden (Ateş 2013), the majority of teachers worldwide still struggle to find suitable ways to introduce GIS practice in their classrooms (Baker, Palmer, & Kerski 2009). In this manner, perplexing educational problems, along with uncertainty regarding the integration of GIS practice, have come to the fore worldwide. Indeed, as GIS technologies, platforms and capacities rapidly proliferate, it is undeniable that educational GIS research within developing countries is lagging.

GIS education globally measured

With the aim of investigating GIS implementation within education, scholars make use of Roger's Diffusion of Innovation model (White 2005; Baker & Kerski 2014; Oza & Raval 2014).

Within this model, diffusion is defined as: "…the process by which an innovation is communicated through certain channels over time, among members of a social system" (Rogers 2003). Rogers categorises innovation adopters, a model which classifies Geography teachers into five categories, namely the innovators, early adopters, early majority, late majority and the laggards. A content analysis of GIS educational literature in 35 countries reveals that a majority of 27 of these countries experience difficulties in integrating GIS software into their lessons. The adoption of GIS practice was found to be still lagging within the innovative phase (I). Surprisingly this phase (I) includes both developed and developing countries such as Austria, Canada and Japan, Ghana, India and Rwanda. According to this analysis, countries such as Finland, France, the Netherlands and Norway are frontrunners as regards the inclusion of GIS practice within their classes. These four countries, therefore, qualify to be categorised within the late majority group, *i.e.* showing the highest adoption rate of GIS practice in education.

GIS education in South Africa and a possible solution

Following the global trend, South African teachers have struggled to implement GIS practice since the phasing-in of GIS into the Further Education and Training (FET)-phase school curriculum between 2008 and 2010 by the South African Department of Basic Education (DBE). Extending this line of thought, Scheepers (2009) suggested that the slow diffusion of GIS practice through South African schools is due to the lack of supportive academic research into GIS within the South African context. Nevertheless, GIS has been re-introduced into the South African Curriculum and Assessment Policy Statement (CAPS) (South Africa 2011). The digital divide within SA presents major barriers to educational developments (South Africa 2004). However, these barriers can be transformed into opportunities for academia and teacher partnerships with GIS software developers and GIS professionals. To meet these challenges, the creation of GIS learning teaching support materials (LTSM) such as Paper GIS (Eksteen & Pretorius *et al* 2012), USB-GIS, I-GIS (Milson & Earle 2007) multimedia applications (Balram & Dragićevic 2008), WebGIS and GIS tutorials (Hong 2014) has the potential to ease GIS integration. Although GIS tutorials have been criticized for allowing a Skinnerian approach, not accommodating learner-centred learning, Hong (2014) has argued that a teacher-friendly GIS application design, would catalyse GIS adoption within schools. We agree with this notion in that teachers are keyholders towards GIS adoption within the classroom. Therefore, within this learner-centred and teacher-centred learning tension, an interactive-GIS-tutorial might overcome the initial GIS implementation barriers and ease GIS adoption within developing countries (Fleischmann, van der Westhuizen, Cilliers 2015). In addition, the use of a hybrid of instructional methods, such as video clips and tutorials with interactive exercises was found to significantly increase student performance within Higher Education (Kamruzzman 2014).

Theoretical frameworks

Rogers' Diffusion Model and the Technology Acceptance Model (TAM) of Davis were employed in this study. The former innovation model provided a theoretical framework to evaluate global GIS practice adoption within educational literature. An advantage of the use of Rogers' model is that social influence is taken into account, a factor which is lacking in Davis' Technology Acceptance Model (TAM). The use of Rogers' model may be beneficial within South Africa, as social influence plays an important role within South African cultures. Furthermore, Rogers' model provided a framework for the evaluation of the IGIST application, which in this study mainly focused on the perceived relative advantage of the application. Rogers (2003:22) categorises innovation adopters, which places the FET phase Geography teachers into one of five categories, according to their innovativeness (see Figure 1).In addition, this study employed the use of TAM during the empirical evaluation of the IGIST. When developing a new application, developers wish to know the extent of acceptance of their application within a certain population. TAM serves to predict the behavioural intent (BI) of the teacher, which in turn helps to envisage the actual adoption of the technology in question. Fred Davis, the innovator of TAM, classified user acceptance as being essential for the acceptance of an innovation.

TAM evaluates the intention to use an application (BI), employing the measurement of perceived ease of use (E) and usefulness of innovations/applications (U), as both E and U predict the attitude towards using the application (A). Since the intention to use the application is largely influenced by attitude, U and E are vital within computer-acceptance behaviours. The attitude towards the use of the application (A) and perceived usefulness (U) serves as an indicator of the intentional use of the application. Consequently, as depicted in Figure 2, TAM assumes that technology usage is determined by BI, whereas BI = A + U (Davis *et al.*, 1989:985). Globally, scholars describe the perceived positive usefulness of GIS, which could be indicative of (U). However, because the perceived ease of use of GIS applications within education (E) might hinder GIS practice integration, TAM could be instrumental in predicting the actual use of GIS applications. In addition, TAM might be a suitable model to specify the causal relationships between system *design features*, perceived usefulness (U), perceived ease of use (E), and attitudes towards using (A) with behavioural intent to use (BI) and actual use of the application (Davis, 1993:475). TAM was first employed within a GIS adoption study amongst geography teachers in Taiwan. This tested the willingness of teachers to attend GIS workshops. It also tested the intention to use the application within the

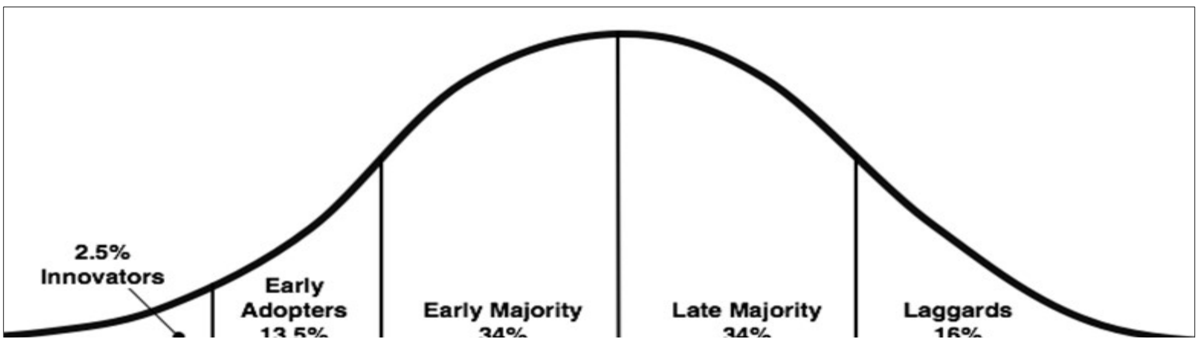

Figure 1: Categories of innovativeness (Rogers, 2003:281)

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class (BI) (Lay *et al.*, 2013a:120). During this study, age, gender, level of education and school type were controlled (Lay *et al.*, 2013a:122). TAM was employed to evaluate the effectiveness of GIS workshops utilizing structural equation analysis (Lay *et al.*, 2013b:191). On the whole, TAM is "a cost-effective tool in screening potential candidate systems or programs" (Gao, 2005:239) and could be useful in this study as well.

The purpose of the study and article

Because teachers act as the gatekeepers of educational GIS innovations (Bryant & Favier 2015), this study took into account the various factors postulated by Rogers (2003) that would influence the teacher in adopting an innovation, or not: i) relative advantage (see table 1), ii) the needs of the teacher (table 3) and iii) complexity (ease of use) (Table 3).
In addition, the authors propose a GIS educational dialogue and collaboration between academia, teachers, GIS developers, GIS specialists and the Educational Departments of developing countries. We look forward to a dialogue with all interested parties.

IGIST development

In response to GIS teaching and learning challenges, an Interactive-GIS-Tutor (IGIST) has been developed (Fleischmann & van der Westhuizen, 2017), aiming to circumvent main GIS integration barriers. The IGIST is a self-paced, USB user-friendly multimedia, GIS tutor application. As the IGIST application is mounted on a flash drive, the learners can repeat the activities at home, making anywhere, anytime learning possible. The IGIST application contains Quantum based GIS tutorials, exercises and assessments. The IGIST is only a simulation of the real QGIS software. Adobe 5.5 Captivate software was used to create software simulations used for both GIS tutorials and assessment tools. The IGIST can be utilised employing a projector/whiteboard, especially for large classes, or where computer labs are lacking. It can also be used by one or two learners per computer. The flexible use of the IGIST provides teachers with various integration options according to their class sizes and the resources available.
The concept behind the development of the IGIST is to abridge QGIS procedures in order to provide anytime, anywhere, suitable, curriculum-aligned, GIS learning teaching support material (LTSM). The relative advantage of IGIST is the self-paced nature of the IGIST. This application has the potential to open up opportunities for low achievers to engage interactively with GIS, being guided by visual and audio clues within the IGIST application (Fleischmann, 2013). It also provides a possible gateway for high achievers to become acquainted with QGIS, as the tutorial is based on QGIS and familiarise the learner with the QGIS dashboard. This is freely downloadable on the

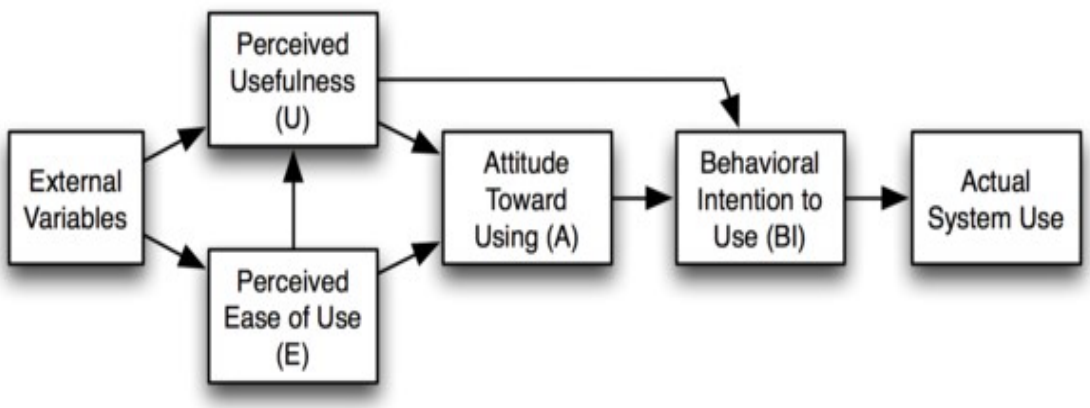

Figure 2: Technology acceptance model (TAM) (Davis, 1993:479; Davis *et al.,* 1989:985)

QGIS website and is already in use in Western Cape schools. Figure 3 depicts the screen layout of the IGIST: **A** represents the menu, whereas **B** frames the activity control panel. This allows for reviewing/redoing tutorials and exercises. Frame displays the challenge that the learner is required to complete within this exercise. D simulates the sequential changes in the screen when the correct procedure is followed. The IGIST application consists of an introduction (section A), three tutorials (sections B, D and F) as well as four exercises (C, E, G and H) which may be selected from the menu (see Figure 4). The introduction (section A) consists of 13 screenshots and opens with a description of the tutorials and exercises within the IGIST application.

Tutorial 1 (section B) consists of 136 screenshots displaying the outcomes for the tutorial as aligned with the curriculum (B1). GIS is then introduced to the learner (B2) with the various uses of GIS, answering the what, how, who and why questions, as well as including problem-solving solutions. The addition of spatial data and exploring of key buttons in QGIS are being discussed such as the zoom & pan button, the use of attribute data within rainfall, various symbols on a map, GIS modelling and interpretation as well as how to save a picture file of the map within QGIS. *Exercise 1* (Section C) was compiled to create an interactive environment in which the learner makes use of knowledge and skills obtained through Tutorial 1. This tutorial ends with a multiple-choice exercise on concepts learned from Tutorial 1.

Tutorial 2 (Section D) consists of 76 screenshots which begin with an outcomes screen (D1). Hereafter, the use of GIS in spatial problems is discussed (D2). The use of GIS pertaining to a hailstorm is illustrated (D3). The use of remote sensing using a radar, an explanation on vectors, points, lines and polygons as well as raster data follows. This section closes with some interactive exercises, a review of the outcomes, and an invitation to Exercise 2 (Section E). *Exercise 2* consists of 22 consecutive screenshots. It opens with an outcomes screen to highlight various outcomes that need to be reached. The interactive exercise follows the use of remote sensing, topography and raster data. After this exercise a short multiple-choice quiz follows, ending with an invitation to proceed to Tutorial 3 or to re-do exercise 2.

Tutorial 3 (Section F) consists of 84 screenshots. It begins with an outcomes screen displaying the outcomes that need to be reached at the end of the lesson. Within this tutorial the concept of remote sensing is

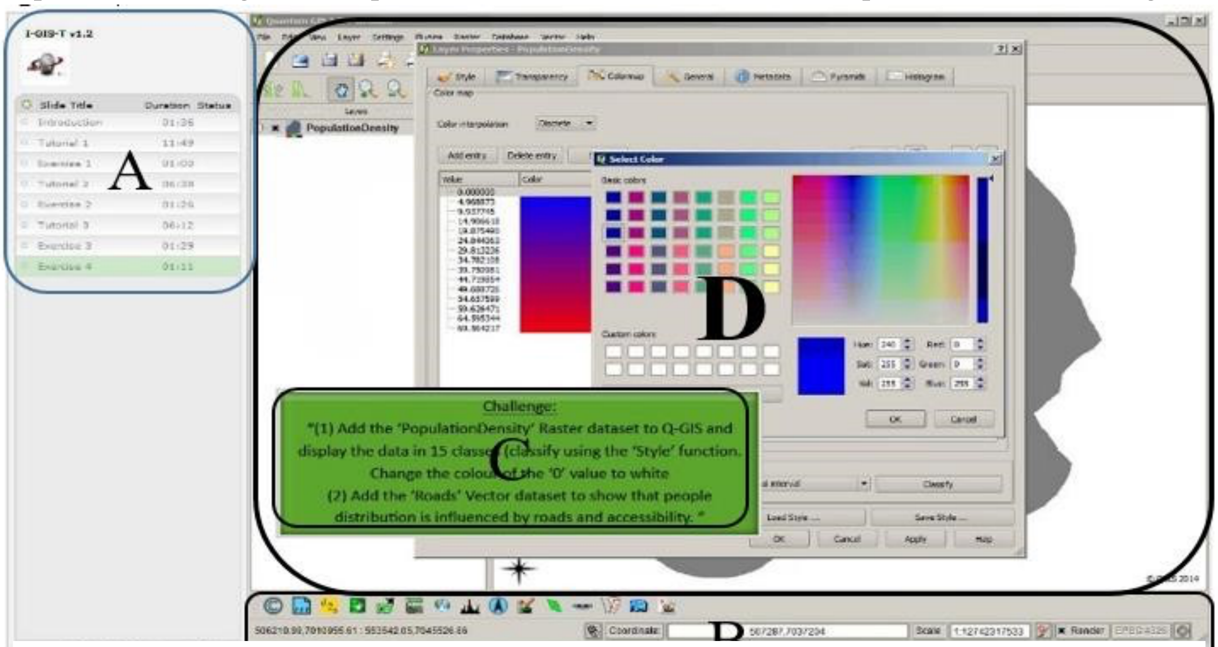

Figure 3: IGIST Screen Display

discussed whilst focussing on spatial and spectral resolution, editing on the data layer, polygons and the use of remote sensing in GIS. This tutorial also includes an interactive exercise. Finally, this tutorial ends with a review of the outcomes and an invitation to continue to Exercise 3.

Exercise 3 (Section G) contains 28 screenshots, beginning with a short interactive exercise (G1), followed by more exercises on the editing of data layers (G2); a multiple-choice quiz (G3); and an invitation to redo the

Methodology

As significant GIS knowledge development, has been found especially within the IP group (forthcoming article in South African Geographical Journal) the further aim of this mixed-method multiple-case study was to determine the bi-modal workability and viability of an IGIST application within i) a computer lab (IC), and also ii) using a digital projector/ interactive whiteboard (IP) connected to a computer, according to resources available.

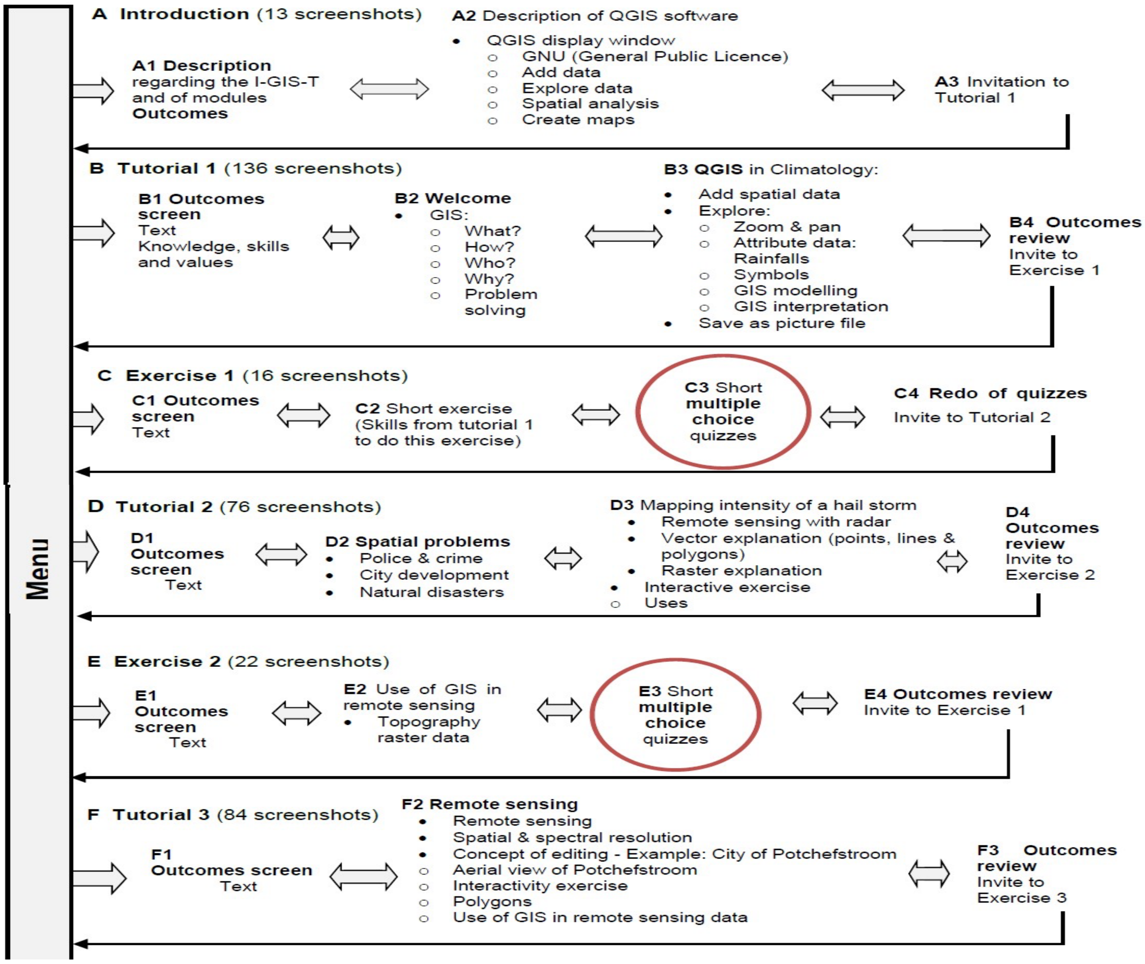

Figure 4: Compilation of IGIST Activities

quizzes followed by an invitation to Exercise 4. *Exercise 4* (Section H) contains 26 screenshots and comprises short interactive exercises (H2), based on concepts learned throughout the activities, which include the use of vector and raster data sets (H3).

Respondents

Six grade 11 Geography classes were selected, according to availability, from rural and urban poor schools in the UMgungundlovu, UMzinyathi and ILembe districts, areas within the KwaZulu-Natal province. These six classes were divided into two groups according to resources: the intervention computer (IC) group and the intervention utilizing the digital projector or interactive whiteboard group (IP). Teachers from the IP group made use of a computer/laptop connected to a digital projector. Both the IC and IP groups made use of the IGIST application (QGIS modules). The IC group (n= 62) consisted of classes from Duncan High, Valken Hoërskool and Standard Secondary High (pseudonyms), while the IP group (n= 78) consisted of classes from Vumeze High, Glenville High and Houston High (pseudonyms).

Instrumentation, data collection and analysis

The IGIST has been theoretically evaluated according to the multimedia design principles, as gathered from multimedia learning theories, devised by Mayer, Schnotz, Van Merriënboer and Gagné (Clark & Mayer 2011; Mayer 2003; Mayer, 2014; Schnotz 2014). The theoretical IGIST application evaluation was performed to evaluate the design according to learning theories and design principles, before moving towards the empirical IGIST application evaluation. The reason for including the empirical evaluation was to ensure that human resources, time and finances would be well invested.

Both *quantitative* and *qualitative* methods were used, to best determine the functionality of the IGIST within its framework. Data were collected utilising:

- a 20 question, five-point Likert scale of the IGIST evaluation questionnaire A. This was completed by only the IC group (n= 62), focussing on the technical aspects of each IGIST activity
- a 37 question, five-point Likert scale IGIST evaluation questionnaire B, focussing on the overall workability of the IGIST application, completed by both IC and IP groups (n= 149)
- six learner focus group interviews (n= 6 x 8)
- a teacher IGIST evaluation questionnaire (n= 6) with regard to ease of learning GIS, GIS pedagogy, learner-centred learning, the importance of GIS and the ease of learning GIS, and teacher in-depth interviews (n= 6).

The quantitative analysis consisted of:

- Descriptive statistics such as frequencies, means, and standard deviations for questionnaire A and B.
- Questionnaire B was analysed through Principal Component Analysis (PCA). The Oblimin rotation identified the principal components. PCA was conducted on data gained on 29[1] of the 37 questions, making use of oblique rotation (Oblimin with Kaiser Normalization). Rotation was employed to simplify the interpretation of the factor analysis. The Kaiser-Meyer-Olkin (KMO) measure verified the sample adequacy for the analysis, KMO = .919 being highly adequate for factorisation. Although five factors were extracted with eigenvalues greater than 1, the scree test revealed the first two components, with eigenvalues of 12.095 and 1.902, explaining 48.3% of the total variance, which was sufficient. (The first three factors yield a cumulative percentage of 53.44% which is only a slight increase of 5.18%.) The scree plot was ambiguous and showed inflexions that would justify retaining either 2 or 5 factors. Two factors were retained because of the convergence of the scree plot, and the distinct two groups as depicted in Table 2. Reliability and internal consistency of the instrument was measured utilizing Cronbach's Alpha, which was found to be .937 for factor 1 and .889 for factor 2, which reflected high reliability and internal consistency (see Table 2)

Qualitative analyses were performed on data gleaned from six learner focus group interviews and six teachers. Atlas.ti7 was used

[1] Questions 1 to 8 were questions pertaining to the participants' individual background, either yes or no, and were therefore excluded from the analysis of the rating of the IGIST framework.

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to analyse the transcriptions deductively and inductively. A code list compiled from the literature contained, for example, the TAM model code, whereas open coding provided in-depth insight into the dynamics of the viability of the IGIST application. A peer coder and peer auditor were employed to verify the qualitative coding and findings.

Permission to conduct this study was granted by the Ethics Committee of this University and the KwaZulu-Natal Department of Education (KZN DoBE). Principals and participants were informed and participation took place voluntarily. Confidentiality was assured and pseudonyms were allocated and also used throughout this article.

Theoretical evaluation of the IGIST

According to the Adoption of Innovation Model of Rogers, the perceived attributes of an innovation (relative advantage), affect its adoption rate. During the theoretical evaluation of the IGIST, a preliminary perceived relative advantage analysis of the IGIST application was carried out. Roblyer and Doering's (2013) GIS related problems and relative advantage table has been used as a framework during this analysis. In short, the IGIST allows the Geography teacher to facilitate GIS teaching, as expected in the curriculum, allowing extra time to guide individual learners. In addition, learners are actively involved in their learning process, providing a measure of self-directed learning (SDL), following through the tutorial and its exercises at their own pace. Abstract GIS concepts are visually explained and practised within the exercises, allowing the learner to freely download QGIS from the internet, for further enrichment activities. The flexible use of a digital projector together with the IGIST, in large classes, circumvents computer accessibility problems. Finally, teachers lacking GIS training, technology support or pedagogy knowledge, might utilise the IGIST successfully after a short demonstration that could be viewed on YouTube, to reduce travelling costs. As concluded from this analysis, the concept of the IGIST application displays a considerable relative advantage that might enhance the adoption rate of this application among low-resourced schools in developing countries.

Empirical Findings and Discussion

Both quantitative and qualitative analyses were carried out.

Quantitative Findings and Discussion

IGIST learner questionnaire: Evaluation A

Results from the IGIST learner evaluation questionnaire A, that was completed by the IC group (n=62), were analysed. Each IGIST tutorial and exercise was evaluated with regard to clarity, graphics supporting learning and gaining knowledge/skill. Only the IC group completed this evaluation because each learner interacted directly with the application on a one-on-one basis. From the descriptive statistics, an average mean score higher than 4 out of a 5 point Likert scale questionnaire emerged. Although the average mean (4.11) scored well, this data indicates that future development towards further guidance within the interactive exercises is needed.

IGIST learner evaluation questionnaire B

The results found in the IGIST learner evaluation questionnaire B were analysed and represented as descriptive statistics, which are summarised in Table 1. The first eight questions accounted for demographics and were, therefore, not taken up in Table 1.

Learners found the general layout/design of the IGIST well organised, the interactive nature of the IGIST useful towards GIS learning. Multiple choice questions with feedback were found to be adequate, enhancing a better understanding of GIS and its use in daily aspects of life. Surprisingly, the highest score pertained to the recommendation of the IGIST to all grade 11 learners across South Africa (question 37). All questions with high scores are indicated using a bold font. The last tendency, established from question 37, was also strongly evident within the focus group interviews. From the learners' perspective, the IGIST was found to be a programme to be promoted to other schools. This notion was also tested during the focus group interviews, teacher evaluation questionnaire C (Table 3) as well as the teacher interviews that followed. After the descriptive statistics, a PCA was carried out on the questionnaire for factor loadings for two factors, where factor one clustered GIS *learning and attitude*, whereas the second factor represented the *technical evaluation* of the IGIST (see Table 2).

Regarding GIS learning and attitude, shown within the second column, the wish to use the IGIST at home scored the highest rating, with a motivation to learn more about GIS the second highest. As evident in the third column, the technical evaluation factor showed that detail was sufficient within the IGIST although clarity within the interactive activities is an aspect that could be enhanced. Upon further analysis of the two distinct factors, factor one, as presented in Table 2, showed an overall positive correlation with regard to *learning* (q27, q30, q23, q31, q29, q21, q36, q32), *attitude* (q27, q23, q31, q29, q20, q37, q22, q33) and *skills* (q25, q26) with respect to the IGIST application. A desire to use the IGIST at home, together with the motivation to learn more about GIS, showed the highest factor loadings. All items in Factor 2 rated positively, with the adequacy of detail and the layout of the IGIST application having the highest factor loadings. Lower factor loadings were found as regards the ease of interactive navigation, the efficacy of textual information and ease of navigation. These lower factor loadings reflected that the IGIST interactive indicators need to be refined to further enhance interactive learner navigation.

IGIST evaluation C by the teachers

The teacher is a key factor in the acceptance of a technology within the class. Teachers are the crucial decision-makers vis-à-vis technology adoption. In order to evaluate the perceived usefulness of the IGIST as perceived by the teachers, a few sub-themes were identified: ease of learning GIS, GIS pedagogy, learner-centred learning, catering to a different learner style, workability and ease of teaching GIS. Results of the IGIST teacher evaluation questionnaire C (see Table 3), indicate that the teachers mostly evaluated the IGIST as definitely easy to use while supporting GIS pedagogy and catering for different types of GIS learning styles.
Overall the pedagogical evaluation of IGIST rated high, with an indication that some teachers find the activities a challenge (Q1.4), therefore suggesting that some learners would need guidance (Q1.12). However, five of the six teachers rated the IGIST high in workability (Q2.1) and supportive of GIS teaching (Q2.2).

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Table 1. Descriptive statistics of IGIST learner evaluation questionnaire B — percentage distribution

Item	Statement	1	2	3	4	5	Mean	STD
9	The instructions were clear	3.4	4.7	12.2	52.7	27.0	3.95	.943
10	The IGIST was easy to navigate	3.4	11.0	24.5	41.1	18.5	3.62	1.02
11	**General layout/design of the IGIST was well organised**	**2.0**	**2.7**	**16.2**	**51.4**	**27.7**	**4.00**	**.857**
12	The textual information effectively conveyed the concepts and applications of GIS	0	5.4	32.7	47.6	14.3	3.71	.778
13	Graphics and animations were effective in illustrating the concepts and applications	1.4	4.1	19.6	54.1	20.9	3.89	.826
14	**Interactivity (user control) was useful for learning GIS concepts**	**1.4**	**4.7**	**14.2**	**48.0**	**31.8**	**4.04**	**.880**
15	**The multiple-choice questions with feedback were adequate for testing concepts**	**.7**	**4.0**	**14.1**	**40.3**	**40.9.**	**4.17**	**.865**
16	The interactive lessons were easy to navigate	1.3	6.7	21.5	52.3	18.1	3.79	.864
17	Time needed to open the lessons was acceptable	1.4	6.8	23.6	43.9	24.3	3.83	.921
18	The level of detail in the lesson was adequate	1.3	6.7	21.5	53.0	17.4	3.79	.859
19	The narration was clear	3.4	12.2	20.3	44.6	19.6	3.65	1.04
20	The IGIST application increased my interest towards geography lessons	1.3	9.4	20.1	36.9	32.2	3.89	1.01
21	**The IGIST helped me to understand GIS better**	**1.3**	**2.7**	**12.8**	**46.3**	**36.9**	**4.15**	**.841**
22	The IGIST application increased my curiosity to learn more in the classroom	2.0	8.8	19.7	44.2	25.2	3.82	.979
23	The IGIST application increased my curiosity to learn more about GIS	1.4	5.4	20.9	44.6	27.7	3.92	.907
24	**The IGIST application helped me to understand how geography is used in daily life**	**0**	**2.0**	**16.1**	**46.3**	**35.6**	**4.15**	**.760**
25	The IGIST application improved my computer skills	6.1	14.3	27.2	32.0	20.4	3.46	1.15
26	The IGIST application helped me to improve my inquiry skills	3.4	11.6	30.6	42.2	12.2	3.48	.968
27	The IGIST application motivated me to learn more about GIS technologies	1.3	6.7	24.2	47.0	20.8	3.79	.895
28	I would like to use the IGIST application at home	4.0	7.4	20.1	38.3	30.2	3.83	1.07
29	I like to learn GIS with the IGIST at my own pace	2.0	5.4	19.6	39.2	33.8	3.97	.969
30	I feel in control of my learning with IGIST	2.7	8.2	29.3	41.5	18.4	3.65	.964
31	I would like to learn more about QGIS software, on which the IGIST is based	.7	10.1	18.8	44.3	26.2	3.85	.947
32	I could direct my own learning by using the IGIST	.7	8.1	30.2	44.3	16.8	3.68	.871
33	The IGIST made me aware of job opportunities in GIS	.7	7.4	15.4	42.3	34.2	4.02	.926
34	The IGIST increased my awareness of the use of GIS in solving geospatial problems	0	3.4	26.2	46.3	24.2	3.91	.796
35	The IGIST workbook is a sufficient companion together with the IGIST	2.0	5.4	18.8	57.7	16.1	3.81	.844
36	The PowerPoint promoted my understanding of GIS concepts	1.3	4.0	21.5	50.3	22.8	3.89	.847
37	**I think the IGIST application should be made available for all grade 11 Geography learners**	**0**	**5.4**	**14.8**	**27.5**	**52.3**	**4.27**	**.905**

Table 2. Principal component analysis (PCA) of IGIST learner evaluation questionnaire B

Pattern Matrix		Component	
		1	2
q28	The wish to use the IGIST application at home	.879	
q27	The motivation to learn more about GIS	.799	
q25	Improved computer skills	.788	
q26	Improvement of learner inquiry skills	.752	
q30	Learner control of learning	.751	
q23	The curiosity to learn more about GIS	.745	
q31	The desire to learn QGIS	.721	
q29	The enjoyment of learning GIS at own pace	.682	
q21	The support of understanding of GIS	.656	
q20	The enhancement of interest towards geography lessons	.613	
q37	The belief that the IGIST application should be available to all grade 11 learners	.594	
q22	The enhancement of class interest	.571	
q36	The increase of understanding of GIS concepts through the PowerPoint	.420	.332
q32	The use of self-directed learning	.407	
Q35	The sufficiency of the IGIST workbook companion	.340	
q18	The adequacy of detail		.812
q11	The layout of the IGIST		.768
q13	The efficacy of graphics and animations		.748
q14	The usefulness of the interactivity		.697
q17	The adequacy of application opening time		.686
q15	The adequacy of the multiple-choice questions and feedback		.650
q9	The clarity of the instructions		.624
q19	The narration clarity		.602
q16	The easiness of interactive navigation		.591
q12	The efficacy of textual information		.560
q10	The ease of navigation		.502
q24	The increasing of understanding the use of geography in daily life		.454
q33	The awareness of GIS job opportunities	.326	.399
q34	The usefulness of GIS to solve geospatial problems	.	.360
	Cronbach Alpha	.937	.889
	Mean Inter Item Correlation (MIIC)	.489	.385
	Mean (pre-Test)	3.8435	3.8830
	Standard deviation (pre-test)	.66829	.57505

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Table 3. Results from IGIST teacher evaluation questionnaire C - frequency distribution

Item	Questions		1	2	3	4
1.1	Ease of learning GIS	The IGIST is plug and play friendly. (Easy to install)	0	0	1	5
1.2		It is easy to handle IGIST software	0	0	1	5
1.3		The IGIST application features make learning easier	0	0	1	5
1.4		The instructions of the IGIST application are easy to follow	0	0	3	3
1.5		The IGIST has adequate time allocation for activities	0	0	2	4
1.6	GIS Pedagogy	The IGIST application is relevant regarding curriculum requirements	1	0	0	5
1.7		The IGIST has sufficient varieties of lesson strategies	1	0	0	5
1.8		The IGIST has an infusion of higher order thinking skills	0	0	0	5
1.9		The IGIST has suggested enrichment activities	1	0	1	4
1.10	Learner-centred learning	The learners should enjoy the IGIST application activities	0	0	1	5
1.11		The learners should be interested in the IGIST activities	0	0	2	4
1.12		The learners should be able to work on their own	0	0	3	3
1.13		The learners should be able to self-pace their learning	0	0	2	4
1.14	Catering for different types of GIS learning styles	The IGIST provides tools for experimental learning	0	0	1	5
1.15		The IGIST provides tools for constructive learning	0	0	1	5
1.16		The IGIST caters for different learning styles	0	0	2	4
1.17		The IGIST increases understanding/acquisition of skills	0	0	1	5
1.18		The IGIST encourages real life application of geographical skills	0	0	1	5
2.1	Workability	The IGIST is a workable option regarding GIS teaching and learning	0	1	0	5
2.2	Ease of teaching GIS	Is the IGIST application able to overcome your GIS teaching-learning barriers?	0	0	1	5

(Note: 1 definitely not, 2 sometimes, 3 mostly and 4 definitely)

Qualitative Findings and Discussion

In order to explore the viability of the IGIST, data were gathered from six FET phase Geography teachers and six learner focus group interviews. The summative network regarding the category for IGIST viability is depicted in Figure 5, indicating the dynamics within IGIST viability. The network in Figure 5 includes a workability/viability evaluation as well as TAM components (darker coloured labels). The use of TAM is a known method of predicting acceptance of a technology. Within the network, constructed from qualitative data (see Figure 5), TAM came to the fore with (1) PU, (2) PEoU, (3) A and (4) use BI. PU and PEoU closely align with Table 3 as well as the relative advantage of Roger’s model (evaluated during the development of the IGIST, see Table 1).

PU and PEoU were found to emerge during the interviews. Teachers and learners favoured the use of the IGIST over the textbook, which were used in the previous grade. The main reason for the preference was that GIS concepts are abstract and difficult to understand through textbook only. Both teachers and learners indicated that the visuality of GIS concept explanations clarified their understanding of GIS concepts. Sixteen quotes suggested that the IGIST positively enhanced their attitude towards GIS, whereas two quotes suggested the opposite. Regarding the workability of the IGIST, 17 quotes confirmed the IGIST to be workable whereas 4 quotes suggested some difficulties. The negative quotes stemmed

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from low sound volume and screen resolution that needed to be adjusted during the exercise. From Figure 5, the viability of the IGIST is best manifested in the following quotes, found to be representative of most of the remarks from users. The evaluation of the IGIST application showed that IGIST was to a large extent workable, with 17 positive quotes compared to 4 negative ones (see Figure 5). Overall, the teachers evaluated the IGIST application as a viable multimedia tool. Mr Green stated: *“My personal opinion, I’ll say 10, completely viable”* (P12,13:15). Mr Sanger also rated the IGIST to be 9 out of 10, but he mentioned, *“...with the assumption that schools have the computer resources”* (P14, 20:22). Mr Green had not attended the IGIST workshop because of sports duties, but found the IGIST to be compatible with his interactive whiteboard. He experienced no problems other than low sound levels and the need to alter the screen resolution. Ms Duma also evaluated the IGIST application as completely viable, exclaiming *“…it's very easy to use. You don't need to be very computer literate…and it’s not too long... you don't need too much time, so it fits in nicely with the curriculum”*. Mr Green agreed, stating *“… my personal opinion, I’ll say, completely viable”*. Mr Sanger also rated the IGIST as 9 out of 10, but he mentioned: *“...with the assumption that schools have the computer resources”*. Mr Hinibar felt *“the IGIST is definitely workable”*. Ms Hoomla, from Houston High, however, experienced several technical issues as this school’s Computer Application Technology (CAT) teacher was on sick leave, the class did not follow the computer guidelines given and therefore experienced *“everything as a bit of a rush”*. Because of the possibility that this situation will arise again, we strongly recommend following the computer checklist guidelines beforehand (which only implies the checking of possible learner log in accounts, sound cards on computers, screen resolution and sound volume). However, both Mr Hinibar and Ms Hoomla agreed that, should the sound and screen resolution issue be sorted out, the IGIST would support their GIS teaching. All the teachers in this study indicated that they would promote the IGIST application to other teachers, which served as an indication of the workability of the IGIST, whereas four of the teachers were very

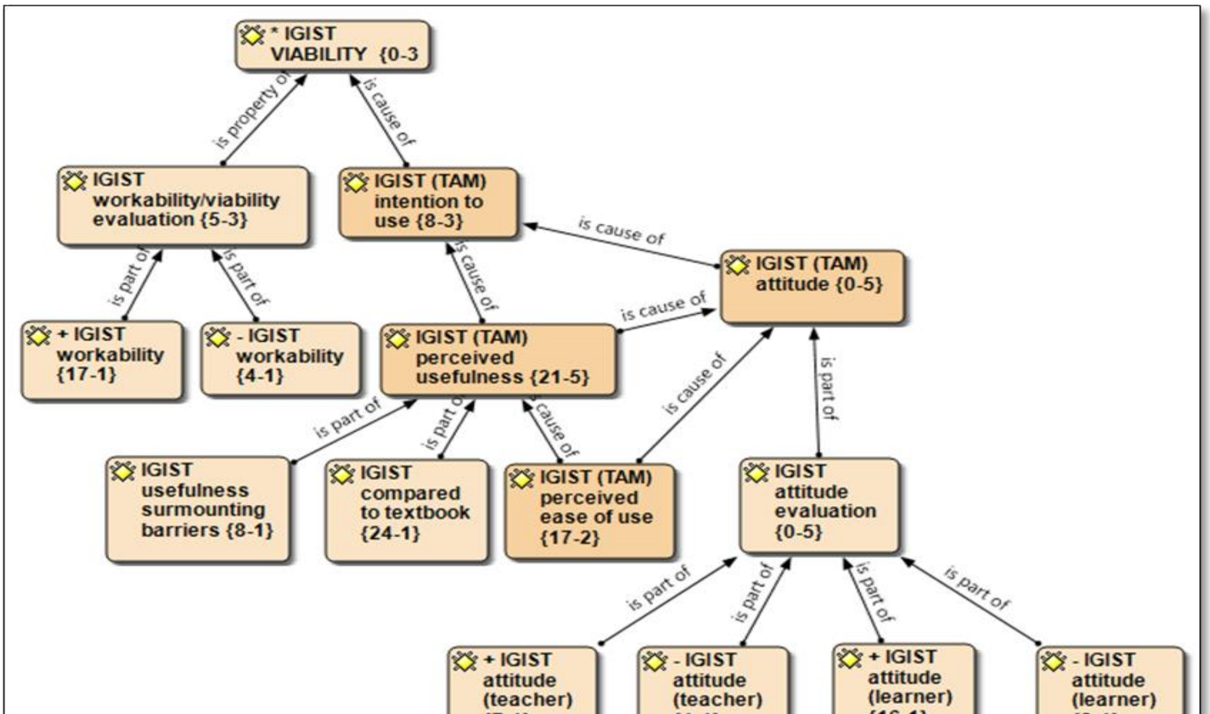

Figure 5: Summative network on I-GIS-T viability

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interested in conducting IGIST workshops in their clusters. Ms Venter declared that the IGIST application was easier to use than QGIS: *"… I could actually follow it and I felt confident that I can do this, whereas before, I didn't* and *we installed QGIS in our lab once, but our computers crashed because it could not handle the large file sizes"*. Ms Duma also referred to the complexities of Arcview 3.3, that the school had purchased some years before, and not having time available to master it, although the software is available at school, whereas with the IGIST, she *"found [it] much easier to use, not requiring thick manuals to work through"*.

Overall, the learners were positive towards the IGIST, which was reflected in remarks such as *"I think IGIST is fantastic, although I didn't like GIS, but I think listening to this and seeing how it works kind of changed my mind about GIS"* and *"an awesome programme to use when considering all aspects that affect our lives"* and also in the remark, *"overall impression is an excellent tutorial, easy and understandable"*. All the learners and teachers indicated that they found the IGIST much more interesting and prefer it to the textbook.

Upon further investigation, it turned out that the learner who struggled during the IGIST computer group was computer illiterate and therefore experienced computer anxiety. In such cases, "buddying" could work (one weak learner with a stronger learner), where two learners could be at one computer, sharing headphones (see Figure 6).

The learners were to a large extent affirmative towards IGIST's workability, mostly indicating interest and gaining of knowledge. Upon asking the learners from Houston High to rate the IGIST as a viable multimedia tool they did so as follows... *9,8,8,8,8,8,8 and 8* out of a scale from 1 to 10 (average 8.1). Vumeze High's learners rated the IGIST as *9, 10, 9, 9,10,10,10 and 10* on a scale from 1 to 10 (average 9.6).

Negative quotes mostly stressed the need to enhance the sound volume and to control the sound volume from within the application.

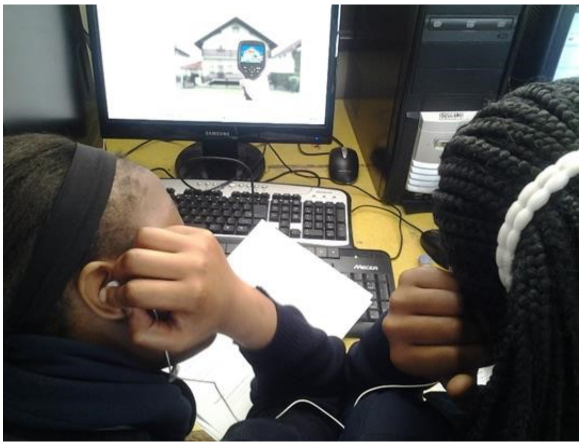

Figure 6: IGIST buddying in low resourced schools during an IGIST tutorial (two learners per computer)

Furthermore, some learners complained that the screen resolution was not set, cutting off some parts of the display and that they would like to receive further explanation regarding why certain buttons were chosen within the exercises. These complaints are taken up within further IGIST developmental suggestions. Valken Hoërskool's focus group rated the IGIST as 6, 8, 8, 7, 7, 8 and 7 (average 7.2 on a 10-point scale) and explained: *"…mainly what brought it down was you couldn't really hear what they were saying"*. These learners have mostly experienced difficulty with the sound quality and narrator's accent.

Conclusion

Data yielded by this study provides convincing evidence that the IGIST was mostly perceived as learner user-friendly and workable (as seen in the network in figure 5) in that it is able to circumvent the main GIS teaching barriers in low-resourced South African schools through the provision of using a digital projector within large classes lacking enough workable computers. Although the sample size of the teacher evaluation questionnaire was only six, this quantitative data, when combined with in-depth interviews regarding GIS teaching barriers and the workability of the IGIST, was useful in the enhancement of reliability. Slight changes to improve the technical quality as suggested by some users include improvement in sound quality, screen resolution, and clearer click indications; if these were sorted out, this would be to a large extent workable and viable within the class setting. However, the attendance of either an IGIST workshop or careful following of the computer checklist provided is crucial for the computer groups. The digital projector/whiteboard method of teaching circumvents other computer-integration difficulties such as log on passwords, missing sound cards, computer virus problems and old or non-functioning computers. Two assertions were drawn from this investigation:

- **Assertion 1:** Teachers rated the IGIST application's bimodal use to a large extent, as a viable one for GIS practice, with the assumption that the sound volume, and the computer resolution, can be managed within the application, the IGIST installation is manageable, and schools have computers available.
- **Assertion 2:** Learners rated the IGIST application, to a large extent, as a viable multimedia tool for GIS practice, with the assumption that the sound volume, and the computer resolution, can be managed within the application.

Limitations and future recommendations

Only six sites were investigated, in rural and impoverished urban areas. The main recommendation of this research envisions supporting South African schools with a user-friendly IGIST application, which was, with the assumption that the sound volume would be further enhanced, evaluated as being viable by teachers and learners of this study. Further recommendations include a multiple language option, as well as availability through the University's website. The IGIST thereby provides an additional software option to the paper GIS currently used in some poorly resourced schools. Future research includes a comparative study of the IGIST application against other GIS learning teaching support material currently available in South Africa, such as Paper GIS and ArcView. The IGIST application within this study was based on QGIS, but can also be based on ArcView providing benefits of long-distance learning.

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Appendix
I-GIS-T evaluation questionnaire A

Please complete the corresponding evaluation ***after*** *each corresponding I-GIS-T activity by* ***encircling*** *the corresponding number in the shaded area*

	Strongly disagree	**Disagree**	**Neither agree, nor disagree**	**Agree**	**Strongly Agree**
A - Introduction: (1:30)					
The introduction was clear.	1	2	3	4	5
The graphics supported my gaining of understanding of GIS.	1	2	3	4	5
Any comment/thought					
B - Tutorial 1: (12 min)					
This tutorial explained GIS in a clear way	1	2	3	4	5
The graphics supported my gaining of understanding of GIS.	1	2	3	4	5
Any comment/thought?					
C- Exercise 1: (03:00)					
I gained GIS skills from this exercise	1	2	3	4	5
The graphics supported my gaining of understanding of GIS.	1	2	3	4	5
What was your test score?					
How many attempts did you use?					
Any comment/thought?					
D- Tutorial 2: (5:30)					
This tutorial explained GIS in a clear way	1	2	3	4	5
The graphics supported my gaining of understanding of GIS.	1	2	3	4	5
I gained new insight into GIS	1	2	3	4	5
E – Exercise 2: (2:30)					
I gained GIS skills from this exercise	1	2	3	4	5

Any overall comment on the I-GIS-T?

	Strongly disagree	Disagree	Neither agree, nor disagree	Agree	Strongly Agree
The graphics supported my gaining of understanding of GIS.	1	2	3	4	5
I gained new insight into GIS.	1	2	3	4	5
What was your test score?					
How many attempts did you use?					
Any comment/thought?					
F- Tutorial 3: (6:00)					
This tutorial explained GIS in a clear way.	1	2	3	4	5
The graphics supported my gaining of understanding of GIS.	1	2	3	4	5
I have gained new GIS insight during this tutorial.	1	2	3	4	5
Any comment/thought?					
G- Exercise 3: (2:15)					
I gained GIS skills from this exercise.	1	2	3	4	5
The graphics supported my gaining of understanding of GIS.	1	2	3	4	5
What was your test score?	1	2	3	4	5
How many attempts did you use?	1	2	3	4	5
Any comment/thought?					
H- Exercise 4 (2:00)					
I gained GIS skills from this exercise.	1	2	3	4	5
The graphics supported my gaining of understanding of GIS.	1	2	3	4	5
I have gained new GIS insight during this tutorial.	1	2	3	4	5
Any comment/thought?					

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