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A GIS Integrational Framework for Poorly Resourced Schools

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Abstract

This paper proposes an integration framework for an interactive GIS tutor (IGIST) application in poorly resourced schools. A content analysis of 35 countries, a national online survey (n=222) as well as teacher interviews (n=10) informed this study. Models such as the Technology Integration Planning model (TIP), Rogers's diffusion model and the Technological, Pedagogical and Content Knowledge model (TPACK) provided the theoretical background. After the said framework was theoretically evaluated, a quasi-experiment was performed in nine classes. Focus group interviews (n=6), teacher interviews (n=6) and evaluation forms (n=149) evaluated the viability of the IGIST integration framework.

Keywords framework, geography education, GIS, multimedia, tutor

Introduction

GIS has been welcomed by Geography teachers as a prized geospatial tool able to enhance a learner's understanding of geospatial concepts whilst enhancing geographical metacognitive thinking, problem solving and decision making (Kerski, Demirci, and Milson 2013, Chen and Wang 2015). The capacity of GIS to enable swift manipulation of large varieties of geospatial data has gained prominence within various employment fields such as sustainable development, human migration patterns, settlement geography, climate change and disaster management, to name but a few (MaKinster, Trautmann, and Barnett 2014, Chen and Wang 2015). However, for more than a half century, Geography teachers have been grappling to find suitable ways to introduce GIS practice into their teaching (Tan and Chen 2015). Despite the promising benefits of GIS, analogous implementation barriers experienced globally overshadow the teachers' optimism. This paradox is evident in the findings that a mere 10% of Singaporean Geography teachers have adopted GIS practice into their teaching (Liu and Zhu 2008). Eighty two percent (82%) of Turkish Geography teachers did not use GIS in class while approximately 33% of them did not even know what GIS was (Demirci 2012, Demirci 2009). In Germany, less than 33% of Geography teachers have integrated GIS in their classroom (Höhnle, Schubert, and Uphues 2013). India also indicates just a 2% GIS technology usage in high schools (Oza and Raval 2014). The current low adoption rates of these technologies suggest that many teachers do not know where or how to start with GIS practice integration (Hong 2014). Whereas private and well equipped schools have the opportunity to adopt state of the art educational GIS technologies in their teaching, Geography teachers in poorly resourced schools struggle to find suitable avenues within a technology-arid environment. Bridging this digital divide, between the "haves" and the "have nots", proves problematic to educational departments worldwide. To add to the list of GIS integration barriers, many schools classified as being equipped with computer labs are found to contain outdated computers infested with computer viruses (as confirmed by this study). A further hindrance to GIS practice integration is that poorly resourced schools frequently have large classes (due to a lack of funds to appoint more teachers) and experience internet connection difficulties (as confirmed by this study). For these reasons, the benefits of GIS education remain out of the reach of many Geography teachers.

In order to provide Geography teachers of poorly resourced schools with a GIS teaching solution, this paper introduces an Interactive-GIS-Tutor within a framework that includes various flexible GIS integration options. The framework has been developed to circumvent key GIS integration challenges experienced worldwide, whilst also providing flexible multi-modal avenues in utilising the IGIST, either through computers, a digital projector/whiteboard, or at home. It is established that poorly resourced schools have seldom been the focus of educational GIS developers, leaving the Geography teachers desperate in their attempts to attain curriculum outcomes. Because such teachers act as gate keepers of educational GIS innovations (Bryant and Favier 2015, 130) we invite teachers, researchers, developers and policy makers to further collaboration to support these burdened Geography teachers.

Methodology

This study aimed to develop i) an IGIST application within a framework and to ii) evaluate the IGIST within the proposed framework by means of mixed methods with a multiple case study. Multimedia design principles and the TIP model (Roblyer and Doering 2013) were used during the design of the IGIST and integration framework,. The TIP model includes aspects of Rogers's Diffusion of Innovation model (Rogers 2003) and TPACK (Koehler et al. 2014). In addition,

Rogers's model provided a framework within which to analyse GIS implementation within education (Oza and Raval 2014, Baker and Kerski 2014). A literature content analysis on GIS educational use and integration barriers on 35 countries, a national online Geography teacher survey (n=222) and teacher interviews (n=10) were utilised to identify key GIS integration barriers. Insight into these barriers was used to inform the development of a preliminary IGIST integration framework. Thereafter, an empirical evaluation was conducted on the preliminary IGIST framework in six schools, measured against a control school which conducted GIS teaching without the IGIST application. Learner focus group interviews (n=6), teacher interviews (n=6), learner evaluation forms (n=149) and observations provided qualitative and quantitative data. Atlas.ti7 was employed to analyse qualitative data, whereas AMOS software supported SEM analyses on the Technology Acceptance Model (TAM) of Davis (1993).

Development, Description and Integration of IGIST

Analysing the problem: the need for suitable GIS teaching materials Kinniburg (2012) recommends the design of effective instructional frameworks, highlighting the importance of careful consideration together with planning in order to circumvent emerging contextual GIS practice barriers. After triangulation of data gathered from the literature review preliminary national survey results (n=222) and teacher interviews (n=10), three main layers of GIS educational barriers were classified: (1) lack of support from Educational Departments in the form of workshops; (2) low levels of teacher GIS and TPACK knowledge, (3) large classes and (4) a lack of resources, including hardware and curriculum aligned easy-to-use GIS software (see Figures 3 and 5). Table 1 presents the results that emerged through the teacher survey with regard to the most frequently cited reasons as to why they struggle to implement GIS practice. As noted in Table 1, the teachers were assembled in two groups, GIS adopter (users) and GIS non-adopters (non-users). For the purpose of this study, we grouped the teachers who use or implement GIS software in schools together and named them "GIS adopters".

Table 1. GIS adopter and non-adopter comparison table regarding GIS integration barriers

Reason Cited	Adopter group Frequency (n=64)	Non-adopter group Frequency (n=133)	Total
Support: workshop/training	19	49	68
Resources: software (non- expensive/curriculum aligned/user friendly)	12	31	43
Resources: hardware/computers	11	24	35
From theory to practice	6	9	15
Resources: Teacher guides / learner booklets	1	8	9
Support/assistance	3	6	9
Resources: internet connection	1	4	5

As noted in the table, the foremost need of both Adopters and Non-adopters for enhancing GIS practice integration comprises practical workshops/training in GIS practice. Secondly, teachers expressed their need for relevant educational software and hardware. Eight teachers from the non-adopter group also requested teacher and learner guides, while six expressed their need for assistance. Further findings from the national online survey indicated that 67.5% of South African teachers never make use of geospatial technology (including Google Earth), whereas 86.7% stated that they have a definite need for curriculum orientated GIS teaching materials. These results confirm findings gleaned from ten in-depth teacher interviews which reported, overall, very little GIS software usage and an urgent need for suitable GIS software and GIS learner teacher support material (LTSM). Moreover, 45% of the grade 11 (k-11) Geography classes had more than 40 learners per class. These analogous barriers serve as backdrop in the IGIST integration framework (see Figure 4).

Intervention: Development, description and trailblazing of the IGIST

Aiming to produce a suitable GIS application able to circumvent the key barriers, the researcher developed an interactive-GIS-tutor and mounted it on a flash drive. IGIST consists of an assortment of multimedia tutorials, interactive exercises and multiple choice assessments. The general structure of the IGIST tutorials corresponds to that of Alessi and Trollip (2001). The use of Adobe® 5.5 Captivate was incorporated in both the tutorials and the exercises of the IGIST. This Adobe

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software permits developers to create software simulations that are able to serve as tutorials as well as assessment tools. The learner will just be able to use the simulation of the demonstrating procedure, not the real QGIS software. The idea of the development of the IGIST is to simplify Quantum GIS procedures in order to provide suitable LTSM while simultaneously providing a gateway for learners towards Quantum GIS, which is currently under the General Public License (NGU) and freely downloadable from the QGIS website.

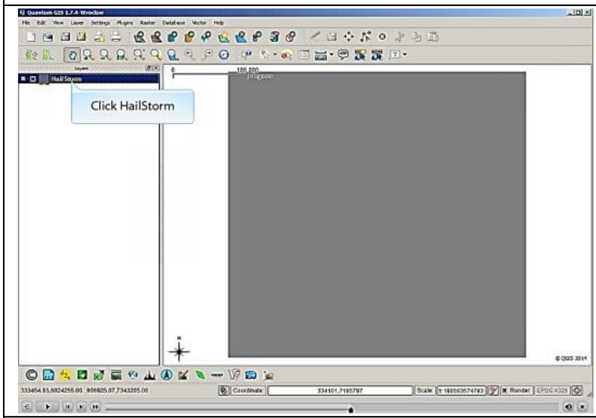
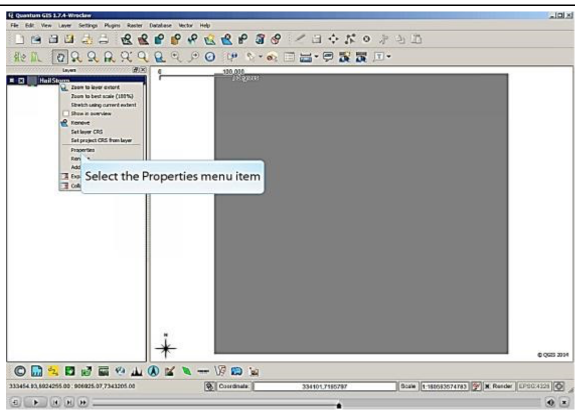
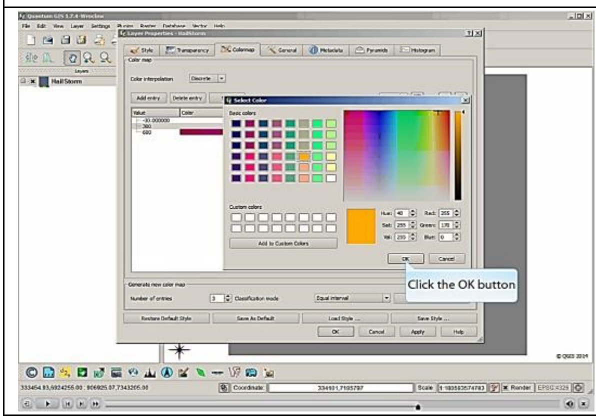
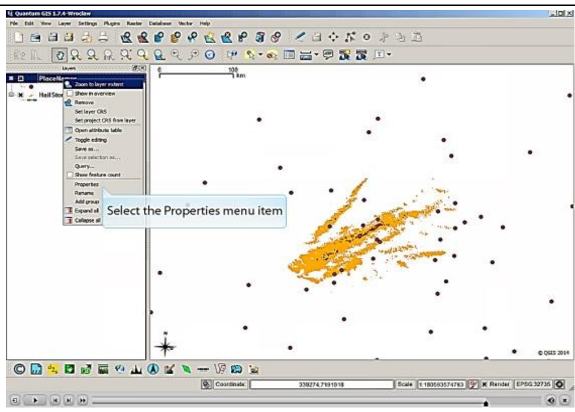
The relative advantages (borrowed from Rogers's diffusion model) of the IGIST were evident in the following aspects. Firstly, the IGIST is aligned to curriculum outcomes. Secondly, the interactive nature of the IGIST multimedia application requires only minimal facilitation, enabling the teacher to facilitate large classes. As the IGIST consists of reviewable tutorials, minimal GIS knowledge or technology skills (GIS-TPACK) and teacher time are required as a prerequisite. Lastly, because of the less complex design of the IGIST, the application is more compatible with low (entry) level computers, whilst providing a further option to interact with learners of large classes by means of a digital projector.

A pilot run found the IGIST based on ArcGIS to be a viable tool for integrating GIS practice within one FET phase (k10-12) Geography class (Fleischmann, van der Westhuizen and Cilliers 2015). This study, however, made use of QGIS, which does not require licence fees. After recommendations from this pilot study had been included, two academic staff members evaluated the IGIST and offered certain recommendations which were incorporated. Thereafter, six teachers re-evaluated the IGIST and found IGIST suitable for their own FET phase classes whilst also supporting their GIS pedagogical needs. This third IGIST edition consists of: an introduction, three tutorials, four exercises and two multiple-choice assessments. The IGIST application is self-paced, and takes on average 90 minutes to complete under normal circumstances with ordinary, average learners, with no stoppages and no explanation. The flexibility of the IGIST unlocks various possibilities, including completing the IGIST in sections, over three to five 45 minute periods aligned to time allocation as set down in the curriculum document. The IGIST accommodates both slow and fast learners, enhancing overall self-paced and in-depth learning. Learners complete an introduction, which is alternatively followed by four exercises and three tutorials. Upon their clicking on any of the IGIST activities displayed in the IGIST menu, the activity will open or can be reviewed and, in so doing, enables self-regulated learning (SRL) as well as self-directed learning (SDL).

Description of some IGIST interactive activities

The Tutorials on the IGIST start with an outcomes screen followed by an introduction of GIS concepts. Table 2 summarises tutor textual and audio guidance during Tutorial 2. During this tutorial the learner is guided through procedures within GIS at their own pace as seen in Table 2. After each tutorial, the learner needs to complete an interactive exercise on concepts learned in the previous tutorial. For example, the opening scene of Tutorial 3 displays the module outcomes in text accompanied by a narrative voice. Remote sensing is reviewed within this tutorial. Thereafter, spectral and spatial resolution are explained through examples, employing dualcoding, by utilising both narration and pictures. Subsequently, the city of Pretoria is used as a real-life example, where the learner is interactively guided to create polygons in order to measure the city's development over a number of years. This tutorial consists of 84 reviewable screenshots. During the closing scene of this tutorial, the learner is invited to revisit the IGIST together with a brief description of each screenshot event. Multimedia design principles, as gathered from multimedia learning theories devised by Mayer, Schnotz, Van Merriënboer and Gagné (Mayer 2014, Van Merriënboer and Kester 2014, Gagné 1981), were employed to evaluate the IGIST application theoretically by means of a summative checklist. According to this checklist 43 of the 56 design principles were followed. use of human resources, time and finances.

Table 2: Some sequential screenshots taken from Tutorial 2

	
a) Narrated voice describing the use of vector data	**b) Narrated voice describing the use of raster data**
	
c) Narrated voice and visual clues guide learners to click on the word 'hailstorm'	**d) Narrated voice and visual clues guide learners to select the Properties menu item**
	
e) Narrated voice and visual clues guide learners to click on the OK button	**f) Narrated voice and visual clues guide learner to select Properties menu item**

the module outcomes, to revise this tutorial or continue to Exercise 3 as signposted on a menu. Table 1 displays sequential screenshots (a-f) taken from Tutorial 2 of

Development of IGIST Additional Support Material

In order to support the IGIST application, an introductory PowerPoint, learner workbook and teacher's guide were developed. The said PowerPoint (with presenter notes) consists of screenshots from the IGIST application, clarification of GIS concepts, the outlay of QGIS used by the IGIST application and a quiz. Answers to the quiz are also included in the presenter notes.

The IGIST learner workbook aims to guide the learner through the IGIST activities. This booklet consists of descriptions of GIS concepts and some questions regarding the IGIST activities (see Table 2) followed by quizzes. The workbook can be used for continuous assessment purposes. The exercises in it may either be peer assessed, self-assessed or teacher assessed. A memo to the answers is included in the teacher's guide. In schools that experience difficulties regarding a lack of resources, the workbook can provide revision notes for exam purposes. The IGIST teacher's guide consists of a checklist of steps needed to set up the IGIST application. Presenter's notes on PowerPoint are provided as well as instructions towards the implementation of the IGIST framework with various options available. Memos to questions in the learner workbook are also provided.

Development of the IGIST Integration Framework

After the IGIST application and IGIST teaching and learning support material developments, such as the learner workbook and teacher's guide, the Technology Integration Planning (TIP) model was used to develop an integration framework. This model is recommended by scholars to guide the teacher in planning their strategy towards an integrated new technology (Roblyer and Doering 2013). TIP is based on a problem-solving model which allows the teacher to select the best strategies for technology integration. Three main phases of the planning process: analysis of learning and teacher needs, planning for integration and post-instruction analysis and revisions are included in TIP (see Figure 3). During step 1, the relative advantage of the IGIST has been determined while step 2 included a TPACK assessment of teacher's knowledge and skills regarding technology, pedagogy and GIS. Step three included objectives and assessments aligned with the curriculum; step 4 involved integration strategies/options depending on resources available as well as learners' computer literacy. Step 5 has been captured in a computer checklist to ensure that the IGIST application would be workable. In addition, analyses of test results and workbook answers, together with feedback from teachers and learners, have been taken up in reflection and reports, which comprise step 7. The authors found that the TIP model was useful during the development of an IGIST. As noted in Figure 6, GIS learning starts with an introductory PowerPoint and accompanying notes within the learner workbook and teacher guide. Thereafter, five options (A, B, C, D and E) in Figure 6 are suggested for the use of the IGIST application within its framework. Both class and school contexts influence the choice of option.

Components of IGIST Integration Framework

During the use of TIP as guidance during the development of the IGIST integration framework, the following components of the latter were created as displayed in Figure 6. **IGIST learner workbook and teacher's guide**

The IGIST learner workbook and teacher's guide concurrently scaffold both learner and teacher through the various IGIST sections and activities, thereby supporting teachers who lack GISTPACK. The IGIST *learner workbook* provides questions in tandem with IGIST tutorials and exercises. As some schools lack Geography textbooks, the workbook also supplies GIS notes from which the learner can study for the exam. The IGIST *teacher's guide* contains notes on GIS, a technology checklist with requirements needed to run the IGIST application, memos for the learner workbook questions, a rubric for the workbook as well as the answers to the learner's multiple choice question test and some games. The workbook and guide provide support to both learner and teacher throughout the activities and are also curriculum aligned. The IGIST learner workbook and teacher guide are downloadable cost free from the Geography Department website and are also included in the "seed teacher" IGIST USB resource package handed out during the IGIST short courses offered by the university.

Lesson 1: IGIST PowerPoint introduction

Of the introductory lesson, approximately 30 minutes consists of a PowerPoint lesson with screenshots from the IGIST (see Figure 5) explaining the IGIST dashboard and main GIS concepts, and includes a quiz. Each slide contains lecturing notes and is supported with descriptive notes within the teacher's guide.

Lesson 2 & 3: IGIST options

The flexible use of the IGIST application, with its five options, allows IGIST use in a variety of schools with diverse contexts. As intimated, school resources may vary concerning the availability of a data projector, an interactive whiteboard, the number of workable and virus free computers and internet connections. The teacher is able to match the IGIST teaching option according to resources available as well as to the computer literacy level of the learners. For example, the buddying method of seating two learners per computer may lessen computer anxiety and also the possible split attention deficit, where learners take turns in doing the IGIST activity and completing the workbook questions. In times of teacher strikes, the learner can make use of the IGIST application at home. It is important to note that these options can also be mixed, and tailored according to the class context.

The following options are therefore possible:

- Option A

The use of the IGIST application, via digital projector and laptop, is suitable for large classes, and schools lacking a computer lab with working computers. Within this option the teacher can make use of learners to demonstrate the application in front of the others, whereas the rest of the class can advise these learners where to click. Computer speakers are a necessity, to ensure that multimedia works at optimum capacity.

- Option B

Using option B enables buddying, where a high achiever can work together with a low achiever, or one lacking computer skills. One learner does the activity, whilst the other completes the section in the learner workbook. After each activity, the learners switch roles. Earphone "splitters" allow two headphones in one jack. Learners are able to repeat the activities and also pause if they want to discuss some of these. Together they complete the multiple choice questions that form part of the application

- Option C

Option C can be chosen for schools that possess a workable computer laboratory with one computer per learner. This option allows the learners to work on their own through all the IGIST activities whilst completing questions in the learner workbook and permits the learners to redo IGIST activities at their own pace and inclination. During these activities the teacher acts as facilitator.

 Option D

Option D makes it possible for absent learners to complete the activities and workbook at home since the IGIST application, the learner workbook and introductory PowerPoint with presenter's notes, are mounted on a USB flash stick.

 Option E

For learners with an internet connection at home, option E can be used during times of teacher strikes or during teacher or learner absences. The learner can download the IGIST application together with the workbook and introductory PowerPoint, making anytime, anywhere learning possible.

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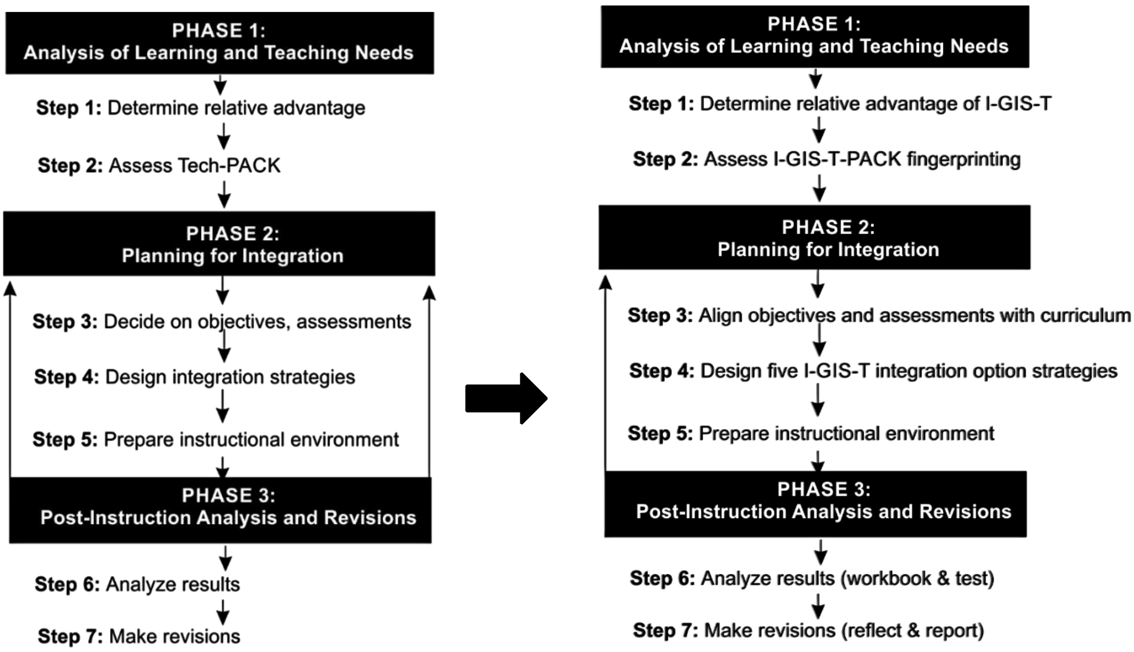
Figure 1: Screenshot taken from Tutorial 3.



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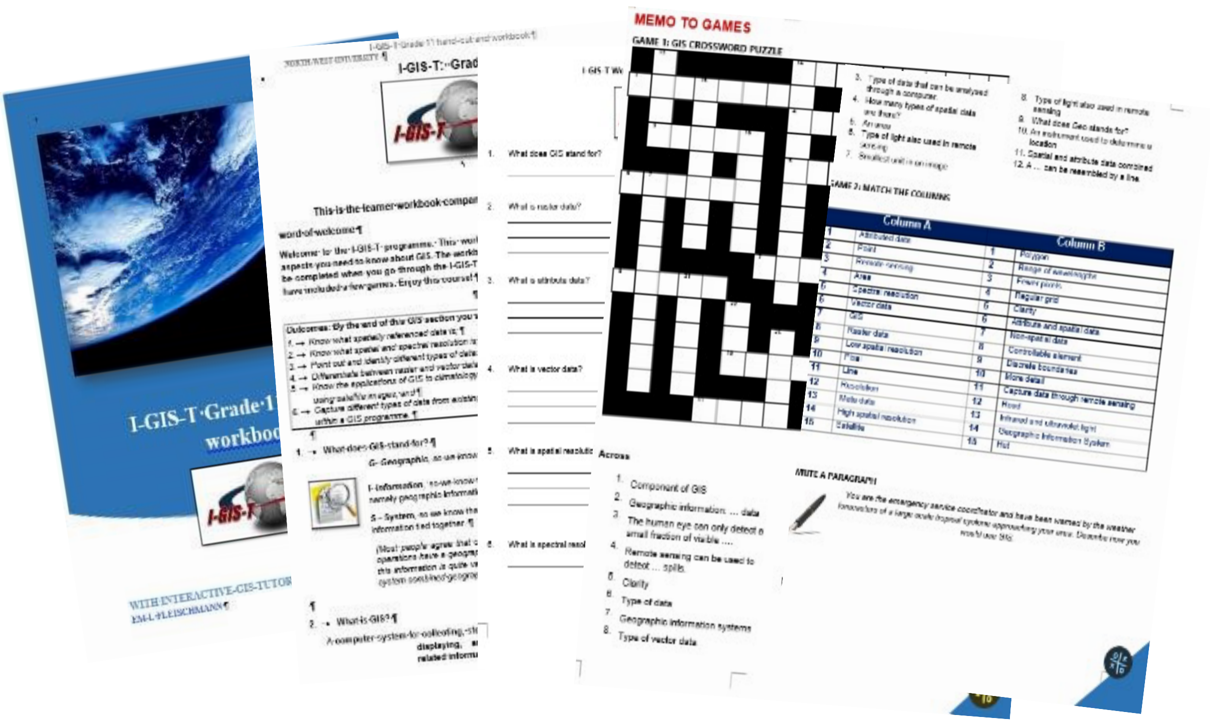

I-GIS-T Grade 1
workbo
WITH INTERACTIVE-GIS-TUTOR
MEMO TO GAMES
GAME 1: GIS CROSSWORD PUZZLE
Column A
Column B
WRITE A PARAGRAPH

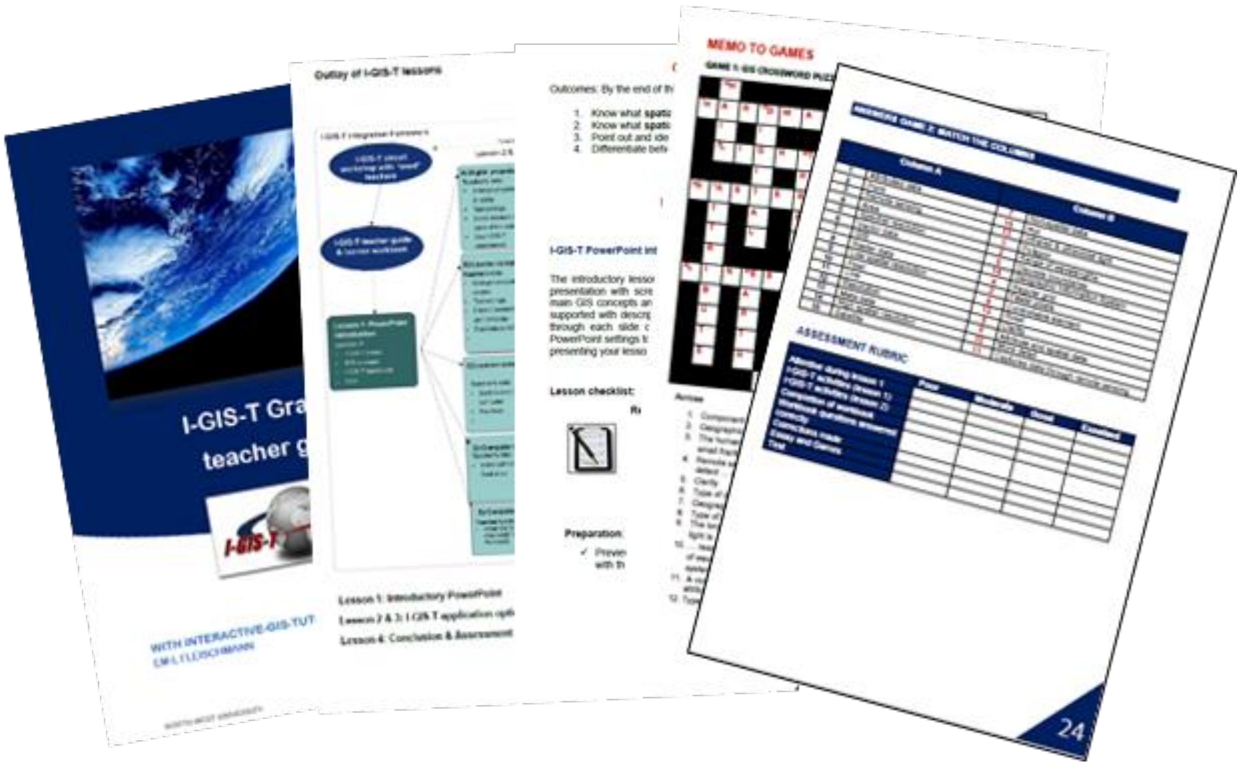
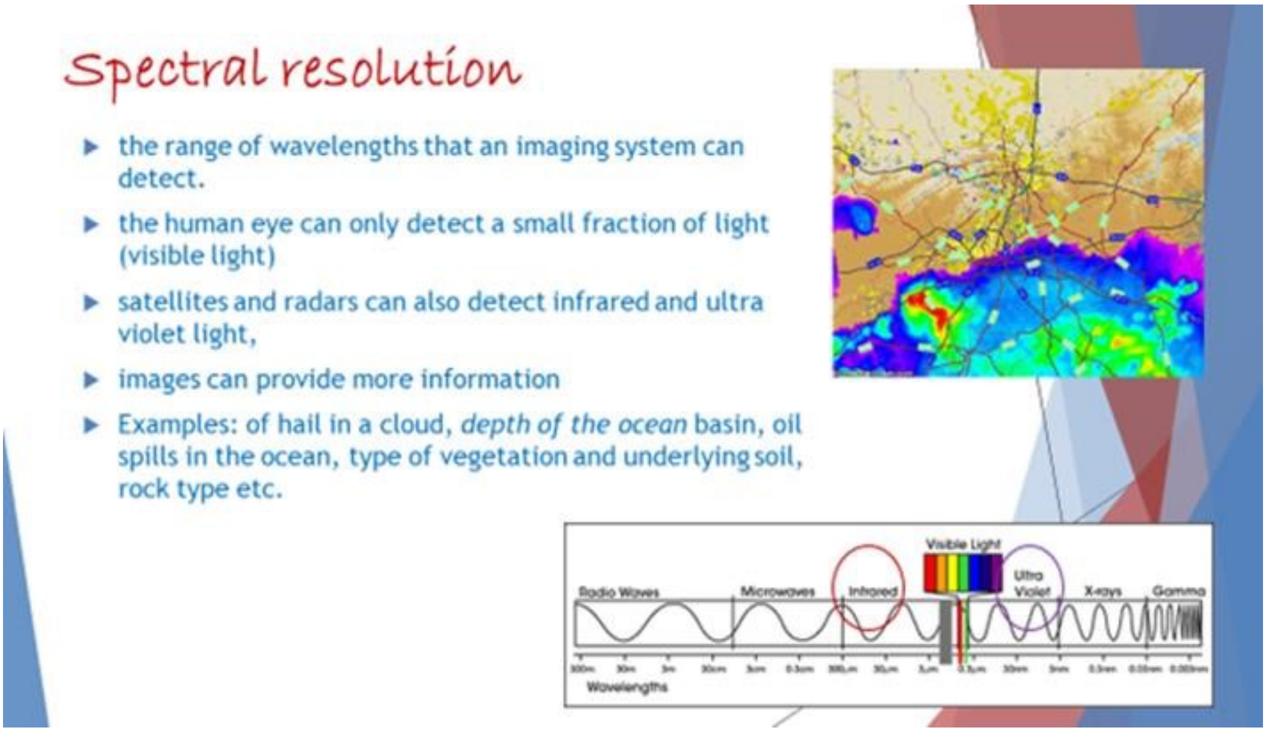

I-GIS-T Gra
teacher g
Outline of I-GIS-T lessons
MEMO TO GAMES
ASSESSMENT RUBRIC
Lesson checklist
Preparation
24

Figure 5 A slide from the IGIST Introductory PowerPoint



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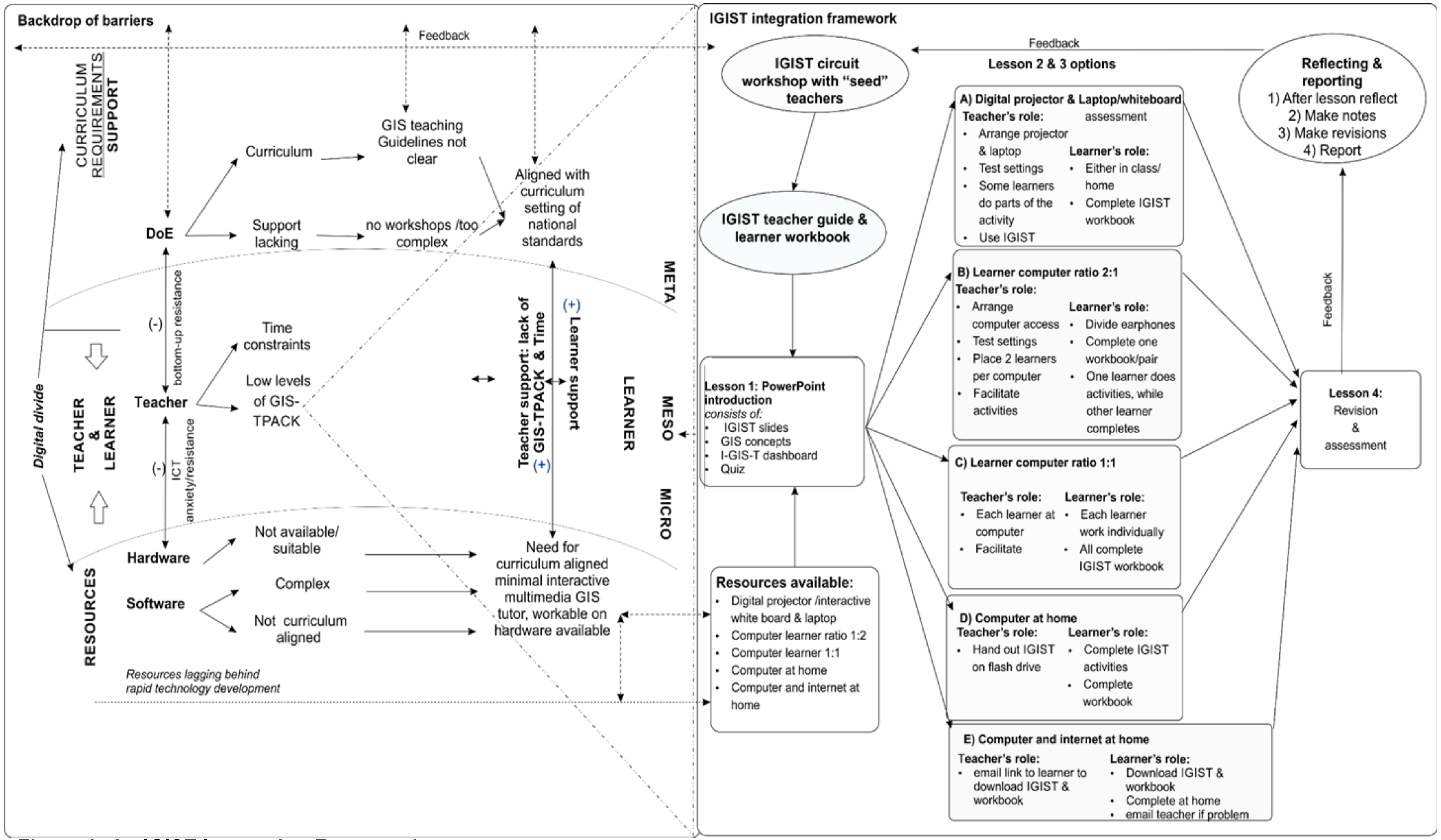

Figure 6: An IGIST Integration Framework

Lesson 4: IGIST conclusion lesson

The conclusion lesson takes approximately 45 minutes. The teacher is able to choose various options according to the needs of the learners and the resources available. Revisions can be carried out on difficult parts of the IGIST application by means of a digital projector. The learners should take turns to demonstrate the procedures. The teacher could also use the PowerPoint from Lesson 1 for reinforcement of concepts. This might be followed by a discussion of the everyday use of GIS to solve local and global problems. Learners could also be divided into groups and illustrate through drawings the most important GIS concepts they have learned. Learner assessments include: workbook assessment (continuous assessment) as well as a 20 minute multiple choice question test at the end of the GIS lessons (summative assessment).

Reflection and reporting

After the four lessons, the teachers are encouraged to reflect on the lessons and make notes in the teacher guide. These notes can be used by them for the following year and to report on during circuit workshops.

GIS teacher workshops and way forward

As previously mentioned, teachers expressed their need for more support from the DBE side and have subsequently requested more GIS workshops. This finding correlates with the findings of Tabor and Harrington (2014) who stressed the need to support GIS integration through GIS teacher workshops. The presentation of circuit teacher workshops, under the direction of the DBE, should equip the teacher with guidelines regarding GIS teaching by means of the IGIST, for the FET phase. The IGIST integration framework focusses on "seed teachers" (early adopters) to conduct workshops at their own circuits. According to Rogers's model (Rogers 2003), the use of early adopters (early users of GIS technologies) in this capacity will enhance GIS practice adoption. The IGIST teacher workshop is designed to brief the teachers on GIS curriculum requirements, taking them through the four lessons and a question time. The IGIST package given out during the workshops contains: (1) Lesson 1's PowerPoint slide show, which includes presenter's notes; (2) teacher guide with memos of workbook exercises; (3) learner workbook with notes and questions; (4) USB flash stick with the IGIST application. Teachers' suggestions from both the survey and multiple case study propose the use of "seed teachers" to attend the IGIST workshops and demonstrate the use of the IGIST within cluster workshops. The majority of the teachers in the multiple case study indicated that they would be interested in conducting IGIST workshops in their areas. These teacher cluster groups could also establish an IGIST support group, giving tips and advice to one another.

IGIST Framework Evaluation

During the post-intervention teacher interviews, the six teachers were found to be positive towards the IGIST application. The teacher from Glenville High rated the IGIST application as completely viable, with a ten out of ten. Mr Sanger rated the application as nine on the same scale from one to ten. The primary reasons for this high rating were that: (1) the IGIST was found to be useful in that teachers do not need a great deal of time to prepare as the IGIST fits are already aligned to the curriculum; (2) it was useful in surmounting the main barriers; (3) it enables learners to acquire first-hand experience and knowledge of GIS; (4) it is visual and dynamic in explaining abstract GIS concepts; (5) teachers who have low TPACK were able to navigate through the IGIST activities with ease.

Teacher IGIST evaluation

Six teachers evaluated the IGIST application according to a 23 question, four point Likert scale evaluation questionnaire C. The questionnaire, which investigated: (1) the ease of learning GIS; (2) GIS pedagogy; (3) learner centred learning; (4) the importance of GIS; (5) workability and (6) ease of overcoming GIS teaching problems, rated mostly four out of four. Only two questions rated lower, suggesting that the instructions are not always easy to follow and that learners might need help. These ratings imply that the IGIST needs to provide well defined indications of where to click, which was taken up in suggestions for further development.

Teachers rated the IGIST application as a viable multimedia tool for GIS practice. There were, however, concomitant assumptions that the sound volume and the computer resolution can be managed within the application, the IGIST installation is manageable and that schools have computers or a digital projector available.

The IGIST and its framework was mostly perceived as user friendly, supporting GIS pedagogy, workable and able to circumvent the main GIS teaching barriers.

Learner focus groups

Six learner focus groups provided insight regarding the viability of the IGIST application from the learners' perspectives. The IGIST viability rating of 46 learners from six focus groups, averaged 8.5 on a scale of one to 10. These results enable the drawing of the following inference:

Learners rated the IGIST application as a viable multimedia tool for GIS practice with the assumption that the sound volume and the computer resolution could be managed within the application.

Learner IGIST evaluation A & B

Learner IGIST evaluation questionnaire A generated an average mean (4.1) on a five-point Likert scale, which is good, with the lowest score being 3.95 out of five with regard to further development towards clarity in the tutorials.

Learner IGIST evaluation questionnaire B generated two distinct factors. "*I think the IGIST application should be made available for all grade 11 Geography learners*", scored 4.27 on the five point Likert scale, which indicated a positive evaluation of the IGIST by the learners. The lowest score was found to be 3.48 which was generated by the question, "*the IGIST application helped me to improve my inquiry skills*". This was indicative that more exploratory activities were needed. An acceptable fit to the TAM model was indicated. Pathways of PEoU→PU→A→BI indicated a practically significant effect as did the discovery that A (attitude) seems to be important as regards the intention to use the application (BI); attitude is therefore also important in this study and is addressed in one of the secondary research questions. SEM was applied to validate the data against the TAM. As the behavioural intent (BI) construct within this model could possibly be an indicator towards the final usage of the IGIST application, data were validated against TAM. Questions were coded according to TAM constructs depicted in Figure 5, where PEoU indicates the perceived ease of use, PU the perceived usefulness, A the attitude towards the application and BI the intention to use the IGIST application. The q indicates the question number within the IGIST TAM path analysis and reliability. A TAM path analysis, indicated in Figure 5, was drawn using Analysis of Moment Structures (AMOS) software.

Various pathways, indicated in Figure 5, were measured.

The reliability of constructs was calculated, which measured the Cronbach's alpha values of each of the constructs, PEoU (.806), PU (.880), A (.884) and BI (.698), indicating high internal consistency. It is noticed that PEoU is an exogenous variable, whereas PU, A and BI are endogenous variables. Figure 7 and Table 3 illustrate the estimates of standardised regression weights.

Table 3: Analysis of pathways with standardised regression estimates and p-values

Pathway	Estimate	S.E.	C.R.	P
PEoU → PU	.945	.134	5.528	<.001
PEoU → A	-.865	.727	1.479	.139
PU → A	1.731	.999	2.758	.006
PU → BI	.021	.375	.099	.921
A → BI	.889	.259	3.903	<.001

All estimates of the measurement model (items loading on constructs) were statistically significant ($p<0.001$). The estimates of PEoU → PU, PU → A and from A → BI were found to be statistically significant, whereas those of PEoU → A and PU → BI, were not statistically significant. This indicated that PU represented a total mediator of PEoU → A and that A represented a total mediator for the effect PU → BI.

 The five point IGIST evaluation questionnaires A and B evaluated the IGIST application and its framework to a high extent (scaling 4.1) and moderately-high extent (scaling 3.48) extent as both a workable and a viable GIS learning teaching tool for the learners. TAM could serve as a prediction method within marketing development to indicate actual use.

Figure 8 depicts the IGIST teaching-learning dynamics found within each of the six intervention classes during Lessons 2 and 3. The legend in the right upper corner identifies the resource situation of the school as well as TPACK, the teacher and the learner. The coloured circles/ellipses represent barriers: language barrier (bl), time barrier (bt), large class size barrier (bCs) and TPACK barrier (bTPACK). In the bottom right hand corner, various types of direction processes are identified: the flow of the direction of knowledge as a black arrow, direction of interaction as a blue one, negative impact of barrier as a red one and the reduced impact of a barrier as a dotted red arrow. The direction of action/process is indicated by the arrow head. The figure is further divided into *macro*, *meso* and *micro* aspects. *Micro* factors refer to the classroom or learning environment, *meso* factors to the school and community, while the *macro* system denotes societal conditions that affect teaching, such as development of teachers and learners as well as the national curriculum (Rosenberg and Koehler 2015).

Within the inner circle, IC indicates the computer intervention groups, IP the digital projector intervention groups and IP (W) the interactive whiteboard group, which is a variation on the digital projector intervention group. As evident in Figure 6, the computer laboratory of Vumeze, Houston and Glenville were outdated and had a fair number of computer viruses. The option of the intervention by means of the digital projector / interactive whiteboard circumvented this resource barrier. Also note that three teachers experienced TPACK barriers (Valken, Vumeze and Houston), whereas the IGIST intervention supported low TPACK in these schools. As the flow of knowledge was from the IGIST application directly to the learner, with which the learner interacted directly, a high TPACK was not required. Also note that the barrier of large class sizes in two schools (Vumeze and Glenville) could be circumvented by the IP / interactive whiteboard option. Time as barrier (bt) for the teacher also had a reduced impact on all the teachers who referred to time as a barrier during the pre-intervention interviews.

During the IGIST intervention, we perceived that the teachers found the IGIST application as ready and easy to use (plug-and-play), with minimum installation difficulties. However, as the IGIST did not offer a multiple language option, the language barrier still had a negative impact on learning.

The IGIST application options A, B and C are workable in all six Geography classes, minimising the constraints of low levels of teacher TPACK, large classes and a non-workable computer laboratories.

Conclusion

The literature content analysis of GIS in 35 countries, a national online survey (n=222) and teacher interviews (n=10) indicated the need for a minimally interactive GIS tutor with flexible options to accommodate various technologically poorly resourced environments and needs (see Figure 5). An IGIST application was developed according to multimedia design principles. The IGIST and its preliminary integration framework were evaluated in six schools and turned out to be a viable option for Geography teachers with regard to GIS teaching. Within the setting of large classes, the IGIST application within its integration framework by means of a projector/interactive whiteboard, was demonstrated to be an effective teaching option. The findings of this research also suggested that some minor technical revisions are needed.

The national survey was completed online, which mainly resulted in answers from those teachers who were technologically literate. Furthermore, as availability sampling within the survey was used rather than randomisation, generalisability was compromised. However, findings did show distinct patterns and trends that could be of assistance in future educational GIS development and research. Furthermore, thick descriptions of each school within the multiple case study provide a means to analytically generalise to schools with similar contexts and resources. Qualitative findings of the multiple-case study (Part 2) were already saturated within the first cycle, with a few minor changes as suggestions for further development. Upon mixing and merging inferences, it was found that the results and findings triangulated well. From these, the following metainferences are drawn pertaining to the viability of the IGIST application:

- *The IGIST integration framework was rated as highly viable and capable of successfully integrating the IGIST application. Learners were, overall, very positive towards the IGIST activities and rated their IGIST learning experience highly. Further development suggestions were in the direction of more clarity within the application as well as more exploratory activities within the framework.*

A further testing of GIS knowledge and GIS attitude after a period of time could also be informative regarding its long term effect on memory and attitude, which might well add value to the multimedia debate. Furthermore, additional research is needed to evaluate the use of the proposed GIS-TPACK fingerprinting to identify the teachers' needs that should be addressed during teacher GIS workshops and possible student teacher GIS training. In addition, the IGIST application development mostly made use of the cognitive and behaviouristic design principles, whereas constructivist principles could be infused into the application, through possible hypertext links.

References

Alessi, Stephen M, and Stanley R Trollip. 2001. *Multimedia for learning: methods and development*. 3rd ed. Boston: Allyn and Bacon.

Baker, Thomas, and J. J. Kerski. 2014. "Lonely trailblazers: examining the early implementation of Geospatial technologies in Science classrooms." In *Teaching Science and investigating environmental issues with geospatial technology*, edited by J MaKinster, N Trautmann and M Barnett, 251-267. New York: Springer.

Bryant, Lara M.P., and Tim Favier. 2015. "Professional development focusing on inquiry-based learning using GIS." In

ISSN: 2517- 9861

Geospatial technologies and Geography education in a changing world, geospatial practices and lessons learned, edited by O.M. Solari, Ali Demirci and Joop Van der Schee, 127-139. New York: Springer.

Chen, C., and Yao-Hui Wang. 2015. "Geospatial education in high schools: curriculums, methodologies, and practices." In *Geospatial technologies and geography education in a changing world, geospatial practices and lessons learned*, edited by O.M. Solari, A. Demirci and Joop Van der Schee, 67-76. New York: Springer.

Davis, F.D. 1993. "User acceptance of information technology: system characteristics, user perceptions and behavioral impacts." *Int. J. Man-machine studies* 38:475-487.

Demirci, A. 2012. "Turkey: GIS for teachers and the advancement of GIS in Geography education." In *Turkey: GIS for teachers and the advancement of GIS in Geography education*, edited by Andrew J. Milson, A. Demirci and J.J. Kerski, 271-281. New York: Springer.

Demirci, Ali. 2009. "How do teachers approach new technologies: geography teachers' attitudes towards Geographic Information Systems (GIS)." *European Journal of Educational Studies* 1 (1):43-53.

Fleischmann, E. M-L., Christo P. van der Westhuizen, and D.P. Cilliers. 2015. "Interactive-GISTutor (IGIST) integration: Creating a digital space gateway within a textbook-bound South African Geography class." *International Journal of Education and Development using Information and Communication Technology* 11 (2):23-37.

Gagne, Robert M. 1981. "Planning and authoring computer-assisted instruction lessons." *Educational Technology* 21 (9):17-21.

Höhnle, Steffen, Jan Christoph Schubert, and Rainer Uphues. 2013. "What are the constraints to GIS usage? Selected results of a teacher survey about constraints in the school context." *International Research in Geographical and Environmental Education* 22 (3):226-240. doi: 10.1080/10382046.2013.817662.

Hong, Jung Eun. 2014. "Promoting teacher adoption of GIS using teacher-centered and teacherfriendly design." *Journal of Geography* 00:1-12. doi: 10.1080/00221341.2013.872171.

Kerski, Joseph, A. Demirci, and Andrew J. Milson. 2013. "The global landscape of GIS in secondary education." *Journal of Geography* 112 (6):232-247.

Kinniburgh, John. 2012. "Australia: inquiry learning with GIS to stimulate coastal storm inundation." In *International perspectives on teaching and learning with GIS in secondary schools*, edited by Andrew J. Milson, A. Demirci and J.J. Kerski, 12-25. New York: Springer.

Koehler, M. J., P. Mishra, K. Kereluik, T. S. Shin, and C.R. Graham. 2014. "The technological pedagogical content knowledge framework." In *Handbook of research on educational communications and technology*, edited by J. Michael Spector, 101-111. New York: Springer.

Liu, Suxia, and Xuan Zhu. 2008. "Designing a structured and interactive learning environment based on GIS for secondary Geography education." *Journal of Geography* 107 (1):12-19. doi: 10.1080/00221340801944425.

MaKinster, J, N. Trautmann, and M. Barnett. 2014. "Introduction." In *Teaching science and investigating environmental issues with geospatial technology*, 353. New York: Springer.

Mayer, R. E. 2014. "Cognitive theory of multimedia learning." In *The Cambridge handbook of multimedia learning*, edited by R. E. Mayer, 43-71. New York: Cambridge University Press.

Oza, Mehul P., and Nikunj Raval. 2014. "The implementation and effectiveness of geographic information systems technology and methods in high school education." *International Journal for Research in Education* 3 (6):25-32.

Roblyer, M. D., and A. Doering. 2013. *Integrating educational technology into teaching*. 6th ed. Boston: Pearson.

Rogers, E.M. 2003. *Diffusion of innovations*. 5th ed. New York: Free Press.

Rosenberg, Joshua, and M. J. Koehler. 2015. "Context and technological pedagogical content knowledge (TPACK): a systematic review." *Journal of Research on Technology in Education* 47 (3):186-210.

Tabor, Lisa K., and John A. Harrington. 2014. "Lessons learned from professional development workshops on using GIS to teach Geography and History in the K-12 classroom." *The Geography Teacher* 11 (2):47-54.

Tan, Geok Chin Ivy, and Qiu Fen Jade Chen. 2015. "An assessment of the use of GIS in teaching." In *Geospatial technologies and Geography education in a changing world, geospatial practices and lessons learned*, edited by O.M. Solari, A. Demirci and Joop Van der Schee, 154-167. New York: Springer.

Van Merriënboer, Jeroen J.G., and Liesbeth Kester. 2014. "The four-component instructional design model: multimedia principles in environments for complex learning." In *The Cambridge handbook of multimedia learning*, edited by R. E. Mayer, 104-148. New York: Cambridge University Press.

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