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ASSESSING THE USE OF GEOSPATIAL TECHNOLOGIES IN HIGHER EDUCATION TEACHING

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Abstract

Educators continually seek new technologies to complement and enhance the student learning experience. The use of technologies in the classroom promotes spatial awareness, important across a number of disciplines. To better enable students to gain spatial awareness, higher education educators creatively utilise geospatial technologies in the classroom to enhance engagement and help visualise theoretical subject content. Teaching innovations and integrating technologies into the classroom over the past decade adhere to changing technological paradigms aimed at better engaging students in lectures and seminars to increase their practical and applied understanding and make classes more interactive. This study is an analysis of insight on approaches observed in academic literature. Three these themes emerged and are articulated in this paper: classroom engagement, interactive spatial knowledge, and practical skills acquisition. The first two are concerned with learning impacts in the classroom whilst the third theme focuses on career impacts.

Keywords: *geography education, geospatial technology, higher education*

1. INTRODUCTION

Educators continually seek new technologies to complement and enhance the student learning experience (see Cope and Elwood 2009; Metoyer and Bednarz 2017; Sui 2004; Wise 2017). The use of technologies in the classroom promotes spatial awareness, important across a number of disciplines. To better enable students to gain spatial awareness, higher education (HE) educators creatively utilise geospatial technologies in the classroom to enhance engagement and help visualise theoretical subject content (see Rickles and Ellul 2017; Rose 2014; Sui 2004; Wise 2015a, 2015b). Teaching innovations and integrating technologies into the classroom over the past decade adhere to changing technological paradigms aimed at better engaging students in lectures and seminars to increase their practical and applied understanding and make classes more interactive (see Bodzin and Cirucci 2009; Heflin et al. 2017; Hogrebe et al. 2008; Hudson-Smith et al. 2009; Wise 2017).

Focusing on a specific area of pedagogic research concerning the use of technology in HE teaching is to look at geospatial technologies. Geospatial technologies are regularly used in geography, and the vast majority of papers reviewed in this study come from geographic education journals. These understandings and approaches are transferrable and important when it comes to increasing students' spatial awareness when assessing classroom content, utilising in fieldwork and gaining skills useful in future careers, as this literature review will discuss.

2. UK TEACHING FRAMEWORK: RECOGNISING HEA AND SEDA VALUES

Based on the Higher Education Academy (HEA) UK professional standards framework, the use of geospatial technologies in HE best links with HEA2 and HEA5 (Higher Education Academy 2011). Moreover, the use of geospatial technologies "fosters dynamic approaches to teaching and learning through creativity, innovation and continuous development" (HEA2) and "facilitates individuals and institutions in gaining formal recognition for quality enhanced approaches to teaching and supporting learning." Geospatial technologies are helping students apply knowledge by conducting their own research alongside learning the practical application of computer programs and software.

This review is concerned with the use of geospatial technologies, and HEA4 (professional standard) is based enhancing the quality of learning practices to underpin learning—pertinent to HEA5. Staff and Educational Development Association (SEDA) values complement HEA professional standards. Also useful to acknowledge here is SEDA1 and SEDA2 (SEDA n.d.). SEDA1 is concerned with how people learn, and geospatial technologies aid this focus by utilising varying teaching approaches, engaging students through different contexts, and making use of how innovations are enabling us to apply understandings. Related to SEDA2 is scholarly, professional and ethical practice. The use of geospatial technologies is allowing scholars and students to recognise and evaluate practices elsewhere in a readily assessable manner which helps reinforce critical, conceptual and practical knowledge and skills.

3. REVIEW APPROACH

When narrowing the selection of articles to include in this literature review, journals listed on the Thompson Reuters Social Science Citation Index (SSCI). The journals considered come from the field of geographic education and general HE journals. Academic and pedagogy experts who write about geospatial technologies will publish high quality articles in SSCI journals, and these journals are recognised as benchmarks for academic quality based on peer-review and rigour. There are 235 SSCI listed education journals, categorised as: Education & Educational Research (see Clarivate Analytics 2017). Of these, 22 journals were selected because they were specific to geographic education or general HE. Journals not searched were deemed too specific to other disciplines of had a specific regional focus.

The keyword search: 'geospatial technology' was conducted in each journal webpage search area. Appropriate papers that discussed and presented the use of geospatial technologies published between 2012 and 2017 were then considered. Only articles since 2012 were assessed in this literature review to ensure most up-to-date content was reviewed given technology is rapidly changing. Identifying specific keywords is common when narrowing and selecting articles from journals (see Evans 2013). Based on the search criteria, 28 academic articles were initially considered. Seven papers were later withdrawn from the analysis during the review stage because, despite keywords present, geospatial technologies were briefly alluded to and were not the focus of the articles contribution to learning and teaching in HE.

Three of the 22 journals searched yielded results relevant to the search criteria. 21 articles from the following journals are included in this literature review: *Journal of Geography* (5), *Journal of Geography in Higher Education* (15) and *Review of Research in Education* (1). Appendix A lists 19 journals that yielding no results.

Three themes emerged from this review (see Table 1). Evidence and arguments from papers reinforce each theme, discussed and referenced in the subsequent subsections accordingly. The focus of this review is not on the technologies themselves, but how they are applied in teaching to enhance engagement, make learning more interactive, innovate learning experiences and preparing students for their futures by enhancing practical skills and knowledge of necessary applications. The analysis of article content was done qualitatively, to relate ideas, points argued and any models developed in papers to understand the use of geospatial technologies in HE teaching conceptually of practically.

Table 1. 21 articles included in the analysis from 2012-2017, number of papers published in each journal based on emerged theme.

Theme	Focus and Review of Content Emerged	JoG	JGHE	RRE
Classroom Engagement	*In a classroom setting, more with connecting theory, concerned more with delivery methods and techniques, teaching practice*	3	7	1
Interactive Spatial Knowledge	*Working in the field and outside the classroom, more hands on, putting theory to practice, focus on the overall learning experience*	-	5	-
Practical Skills Acquisition	*Training and vocation to increase employability, assessing the skills students need to thrive in future employment given new demands of technology*	2	3	-

JoG=*Journal of Geography*; JGHE=*Journal of Geography in Higher Education*; RRE=*Review of Research in Education*

4. ANALYSIS OF LITERATURE ON THE USE OF GEOSPATIAL TECHNOLOGIES IN HE

Table 2 displays each reference and shows the wide range of geospatial technologies discussed. Looking at the themes outlined in Table 1, the capacity concerning how technologies are applied to teaching is quite diverse showing the wide-transferability of these technologies. The first two themes focus on learning impacts whilst the third theme focuses on career impacts. Results and discussions outlining the use of geospatial technologies were overwhelmingly positive. Approaches, highlights, and discussions of findings focusing on the use of geospatial technologies in HE based on each identified theme from the literature assessed is where this review now turns.

Table 2. Focus and type of each article analysed.

Reference	Theory Article	Teaching Delivery	Primary Research	Secondary Analysis	Model Developed	Technologies Discussed
Classroom Engagement						
Hogrebe & Tate (2012)	x	x				GIS; GIS Online
Hwang (2013)	x			x	x	GIS
Manson et al. (2014)		x	x			GIS Online
Rickles & Ellul (2014)		x	x			GIS
Robinson et al. (2015)		x				GIS Online; Use of MOOCs
Bearman et al. (2016)	x	x			x	GIS
Carrera & Asensio (2016)			x			3D Augmented Reality; Smartphones
Jo et al. (2016)			x			GIS Online
Carrera et al. (2017)		x	x			3D Augmented Reality
Hsu et al. (2017)		x	x			Google Earth
Ricker & Thatcher (2017)		x			x	GIS; Mobile Devices
Interactive Spatial Knowledge						
Glass (2015)		x	x			GPS; Mobile Devices; iSurvey app
Philips et al. (2015)			x			3D Geovisualisation; GEOsimulator
Williams et al. (2016)		x	x			Remote Sensing; GPS; Drones
Battista & Manaugh (2017)	x	x				GIS
Kim (2017)		x	x			GIS; Google Earth; GPS; Digital Globe
Practical Skills Acquisition						
Schultz et al. (2013)	x				x	GIS
Martí et al. (2014)		x				GIS
Baker et al. (2015)	x					GIS; Remote Sensing; GPS; Digital Globe
Etherington (2015)		x				GIS
Sack & Roth (2016)		x	x			Open-Web

4.1 Classroom engagement

Disciplines such as geography are seeking new ways to attract students. Ricker and Thatcher (2017) are concerned with how to attract students and argue that integrating and showing students how geospatial technologies are used in classroom early into each semester so students recognise that future classes will be engaging. They also explain how readily accessible technologies are transforming lectures and make recommendations on how to better integrate spatial technologies into teaching. Articles relating to this first theme emphasise the importance of embedding geospatial technologies into teaching delivery (e.g. Hwang 2013) to improve spatial awareness in assessment (e.g. Jo et al., 2016) and overall spatial orientation (e.g. Carrera and Asensio 2016). There was however an overall lack of methods used across the papers in this theme, as most papers were either conceptual or proposed improvements to teaching practice by reviewing theory or secondary results. The unanimous underlying goal observed across the papers was to motivate students to think spatially, attract interest in geospatial techniques to improve the learning experience, and outline theory behind why the type of geospatial technology discussed is useful towards enhancing teaching and learning. Based on the geospatial technologies considered, the main emphasis was on GIS. This is the most widespread geospatial technology on the education market and most universities hold a licenses to use this software in computer labs (or have access to the online version). The most readily accessible (and free) geospatial technology discussed is Google Earth, but this was only discussed in one article (Hsu et al. 2017).

Manson et al. (2014, 110) highlighted teaching with geospatial technologies can be challenging because "instructors have very little time to learn new software and that desktop mapping software often requires a good deal of training time." Hsu et al. (2017) echoes Manson et al. (2014) about learning with technologies, and discusses the use of Google Earth in teaching non-lab based classes to enhance spatial thinking and comprehension. Google Earth is visually interactive, but while it is easy for lecturers to download and use, they suggest finding an ideal pace when utilising Google Earth because students may struggle to keep up with content being discussed when continually navigating to and in different places. Robinson et al. (2015) also found similar findings, but surveyed students to get a sense of attainment. They discuss online teaching, using GIS-online in online teaching. In this case the lecturer does not have to be concerned with students keeping up with content because students work independently at their own pace. A sample of the maps produced were marked along with assessments and found that using GIS-online helped increase spatial thinking competency (Robinson et al. 2015).

Theoretical models were contributed in several papers (see Table 2). To Hwang (2013), geospatial technologies are not just about recognising spatial relationships, but about getting students to critically visualise issues in both social and physical environment. Hwang (2013) presents a model for learning in the classroom that relate to approaches outlined further in the next section by Philips et al. (2015) and Battista and Manaugh (2017). Hwang's (2013) model presents 'what/where' (spatially identifying) concerning spatial distribution-interactions/relationships-comparisons and 'how' (critical thinking and change) to get students to consider temporal relationships when engaging with GIS in the classroom. The focus is to get students to visualise content, and while this approach is useful when teaching GIS, the papers discussed in the next section add the element of fieldwork (which adds further direct interaction through fieldwork and data collection, discussed in the next section). Likewise, Bearman et al. (2016) have devised a cycle model aimed at critical spatial thinking. The model is based on a critique of how GIS is taught because they believe GIS classes are training students how to use the programme but want to enhance students' spatial thinking through asking-acquiring-visualising-processing-answering-presenting (then repeated accordingly) to think back to and challenge initial perspectives.

Of the studies assessed based on this first theme, only three papers were based on data collection. Jo et al. (2016) assessed if students increased their overall spatial thinking when using GIS-online in World Geography (module) lectures. Jo et al. (2016) tested students across five classes and found that only two class groups saw increased scores over the duration of one semester. Carrera and Asensio (2016) did conduct a test with students to look at before and after results (based on a treatment group and a control group). To understand if AR and 3D technologies enhance spatial orientation skills, those in the treatment group engaged with conventional cartography using paper based maps before utilising AR 3D geospatial technologies. Carrera and Asensio (2016) collected data to see if differences occurred in pre-test and post-test results. They found that the treatment group showed improvement from the pre-test to the post-test because they gained additional skills and knowledge from the paper maps opposed to using only the technology. Both Carrera and Asensio (2016) and Jo et al. (2016) found that the use of geospatial technologies can enhance overall spatial thinking abilities—but traditional cartographic understandings are still necessary to learn.

Most papers considered in this section highlighted that benefits of using geospatial technologies to enhance delivery (generally or theoretically), but was not evidence based. This suggests that while teaching enhancement approaches put forward conceptual arguments, more research is needed to test these models in classroom settings to see if the use of geospatial technologies do impact on spatial thinking abilities, and more importantly on knowledge attainment. Manson et al. (2014) surveyed students across two years to understand what they gained from open-web mapping. Concerning the pedagogical value, students who participated in the study found it easy to engage with and liked the accessibility of being able to make maps online, but many did also note that using the programme was occasionally confusing to use. HEA2 is concerned with creativity, innovation and continuous development and HEA4 concerns quality of learning, and while these papers in this section adhere to these principle overall, evidence presented by Jo et al. (2016) suggests no statistical significance was found to increase students spatial awareness when using geospatial technologies in the classroom. Similarly, referring back to Carrera and Asensio's (2016) study, getting students to engage with conventional cartography alongside the use of AR 3D technologies (treatment group) improved their spatial orientation skills opposed to those who only engaged with the technology (the control group).

Articles that fit this first theme primarily assessed teaching methods. While the use of geospatial technologies is more common in geography, Rickles and Ellul (2014) critiqued the use of GIS in different disciplines. As the next section will show, teaching with GIS can be interactive and engaging outside the classroom. At the centre of Rickles and Ellul's (2014) critique is the classroom based approach when teaching GIS in other disciplines (primarily Architecture, Anthropology and History). Hogrebe and Tate (2012) also present an interdisciplinary approach to teaching GIS using GIS-online to help students identify real-world problems. However, their approach was standard and only discussed how to use maps and GIS-online to describe data when teaching, proposing how GIS visually enhances delivery, stating "data previously inaccessible to most users are transformed into visual patterns of meaningful relationships based on location and spatial content" using GIS-online (Hogrebe and Tate 2012, 82). To segue into the next section, these authors argue that there is a need to move away from a 'one-size fits all' approach when teaching GIS towards making use of the technology in ways that are more interactive and based on the disciplinary needs of the students engaging with such geospatial technologies. Carrera et al. (2017) found that while geospatial technologies are important to utilise, there is a need to focus on in-class training to increase skill competencies, but the focus addressed is challenged by and differs to the articles in the next section.

4.2 Interactive spatial knowledge

Articles analysed in the previous section were primarily critique papers that focused on enhancing delivery techniques. Several did argue that spatial thinking needs to go beyond classroom settings by integrating methods of data collection through hands on application to build skills and competencies to simultaneously extend knowledge production. Moreover, papers assessed in this section go beyond traditional teaching methods to explore how geospatial technologies enhance the learning experience by moving beyond more traditional classroom settings. Interactive uses of geospatial technologies build on engagement, and the articles in this section focus more on putting theory into practice. There is still a focus on quality and maintaining teaching standards, but the approaches explored in these papers emphasise innovative interactions (often through fieldwork). Studies relating to this theme were more engaging with students with four of the five papers based on primary data collection. Each paper also focused primarily on fieldwork techniques and involving students in data collection outside to the classroom using GPS (e.g. Glass 2015; Williams et al. 2016) to bring back and enter into GIS (e.g. Battista and Manaugh 2017; Kim 2017) or a GEOsimulator to create 3D geovisualisations (e.g. Philips et al. 2015). A common point stressed in each of the papers was students could or did improve their critical spatial thinking skills. Furthermore, interactive engagement in the field enhanced their learning experience. Papers noted above on *classroom engagement* seemed set on more traditional learning techniques, but with students seeking more interactive and immersive training, also reflected on concerning *practical skills acquisition* below, the focus is placed on the overall learning experience. Students in Kim's (2017) article were exposed to several geospatial technologies, including GIS, Google Earth, GPS and Digital Globe, and transferred data to other accessible outlets including Google Maps and Google SketchUp.

Students today are regularly using mobile devices, and companies that create geospatial technology software have developed mobile applications that instructors and students can readily download. Glass (2015) made use of an iSurvey app joined with GPS. Students reported in the survey that the use of the mobile devices enabled them to critically analyse data captured in real time. Glass (2015) strongly promotes fieldwork to enhance classroom discussions and lab work to go beyond using data that comes with software packages or can be accessed online. Comparing these results to Kim (2017, 12), who assesses the pedagogical benefits of using geospatial technologies in community based participation research, students noted how they gained transferrable skills and findings showed "participants increased their understanding of their local community." Kim (2017) conducted a Likert-scale survey with students to assess the learning experience; in assessing pedagogical benefits, all results were positive with mean scores showing students agree or strongly agree on skills acquisition, applying skills and information technology (for instance), based on the learning experience linking learning-research-practice. Philips et al. (2015) went further to try and understand the student experience by defining six phases (1. problem definition; 2. study design; 3. fieldwork; 4. analysis and modelling; 5. synthesis; and 6. visualisation and communication). Battista and Manaugh's (2017) article was approached differently because they did not collect data directly from students, but put forward a conceptual approach to engaging students with fieldwork to use in the classroom, which did relate to a more applied approach discussed by Williams et al. (2016). Similarly, Battista and Manaugh (2017) put forward a five point framework (1. examination; 2. measurement; 3. recording object attributes in the field; 4. grounding field data and visualising in GIS; and 5. recommendations for mitigating risk). This framework is in line with Philips et al. (2015), but arguably does not engage students as much. There were more concerned with using GIS to assess and critically examine different spatial relationships. Battista and Manaugh (2017) also stress the importance that "qualitative data collection in the field underscores that space is alive" and that subjective interpretation is needed in GIS related fieldwork and classroom interpretation, whereas Philips et al. (2015) put forward a more objective framework for data collection, entering data and then interpreting it.

The student survey conducted by Philips et al. (2015), similar to other studies in this section, aimed to capture student reflections on their experiences of fieldwork and using the technology (in this case the GEOsimulator for 3D geovisualisation) based on the learning phases. Their findings showed students increased learning motivation and became more immersed in the work (compared to when they were learning about 2D cartography). The main critique concerns technology limitations and some confusion at the start about how to use the

GEOsimulator—but students did mention that this was overcome through regular use of the programme (and this technology is arguably more challenging to learn and use compared to GIS or GPS). Williams et al. (2016) reflected on an international field study where students from Wales visited New Zealand to learn and apply remote sensing techniques using GPS devices and drones to capture, map and analyse environmental management. This was arguably the most enabling approach discussed across all the papers, and similar to other studies, a survey was conducted with the field study students to gain their reflections of the experience. The field study was not linked to a particular class, but to the course. This learning experience added to classroom discussions the following semester. Williams et al. (2016) discussed how the field course was enhanced based on feedback from previous years because students wanted to apply more theory in the field through practical applications. The work was based on two case study locations, and the only critique was students would have preferred working in different landscapes opposed to two related areas. Students also remarked that using drones to produce their own geospatial data for interpretation enhanced the learning experience.

One of the main take away findings from this section, leading into the next section, was the amount of transferrable skills students gained. Feedback reported on in these papers offers useful insight for teaching scholars when attempting to further build on knowledge and skills gained outside the classroom (Kim, 2017) through more enhanced learning practices, which will benefit students when they enter future employment.

4.3 Practical skills acquisition

The literature that fits this last theme, from a teaching standpoint, builds on delivery techniques and theory outlined in the *classroom engagement* section above, but differed because these papers put emphasis on employability. With an emphasis on how to use geospatial technologies, these papers relate to changing student demands and desires to gain practical skills that they will use in their future careers. Etherington (2015) stressed the need to focus on computer programming in addition to solely engaging students with GIS. They argue GIS users know how to use the application, but they do not always know technicalities behind the programmes and designing software. One of the challenges of interpreting and relating articles in this section was there was little cross-linking across perspectives brought forward, as compared to discussions in the above sections. Sack and Roth (2016) outlined the use of getting students to use open-web mapping sources to ensure they are up-to-date on contemporary mapping techniques. Schultz et al. (2013) broke down skills acquisition further to assess what students need to succeed. Building on Sack and Roth's (2016) work, they outline professional (ability to apply knowledge; practical use of methods) and personal (group working; independent learning) competencies.

The three papers discussed above focused on skills enhancement. Martí et al. (2014) and Baker et al. (2015) further evaluate employment opportunities and how to design a teaching framework that meets opportunity needs whilst utilising the range of geospatial technologies. Both papers emphasise GIS, but Baker et al. (2015) also outline the use of remote sensing, GPS and Digital Globe. Martí et al. (2014) present only an overview of techniques to build into a Master's programme on how to evaluate competencies during modules to prepare students for employment, whereas Baker et al. (2015) were concerned with identifying inconsistencies across a range of geospatial technologies and how to develop a research platform that could enhance learning agendas. They suggest the need to regularly test basic spatial ability attainment across the different technologies and adapt assessments to technology changes so that students are equipped to enter the workforce with up-to-date skillsets. Arguably these papers did not offer as much depth from primary research, with each article assessing the latest technology trends, but they do offer insight on how lecturers need to adapt to the interests and demand of the twenty-first century student, which means building in valuable practical exercises related to acquiring the skills necessary for employment.

5. CONCLUSIONS

Some main takeaway points relate to Carrera and Asensio's (2016, 129) argument that "a strategy aiming for the development of spatial orientation skill in formal teaching is still missing." This point not only resonates with the AR 3D technology discussed by these authors, but with each of the technologies besides (arguably) GIS which is well-established in learning and teaching across a number of disciplines. The main critique of GIS was going beyond the 'one-size fits all' approach to teaching (see again, Rickles and Ellul 2014). Technologies are rapidly changing, and Manson et al. (2014, 110) highlight another pressing issue (in addition to the point noted above about the time needed to learn new software) that "there are few guarantees of the longevity of online mapping systems, particularly third-party applications since they were controlled from outside the university." This represents a challenge, and while free access programmes are ideal for both lecturers and students, programmes such as GIS require a license, but this will guarantee the application and support from the companies who supply the software. This might explain why more papers focus on geospatial technologies such as GIS because the usefulness of the research or conceptual understanding put forward in the article has substance, whereas work on free programmes may be deemed invalid over time (or by the time the work is published) because technologies can quickly become dated or replaced. The benefit of assessing the recent literature on the use of geospatial technologies in HE considers different approaches and allows for lecturers to consider new ideas (and technologies) to incorporate into teach.

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Appendix A.

List of SSCI listed journals that did not yield results for 'geospatial technology'

Cambridge Journal of Education; *Comparative Education*; *Comparative Education Review*; *Computers & Education*; *Critical Studies in Education*; *Education and Urban Society*; *Education Research*; *Educational Review*; *Educational Studies*; *Educational Technology and Society*; *Environmental Education Research*; *Higher Education*; *Journal of Education Research*; *Journal of Higher Education*; *Oxford Review of Education*; *Research in Higher Education*; *Review of Higher Education*; *Studies in Higher Education*; *Teaching in Higher Education*