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Smartphone GIS: exploring technological competency in active learning across geography

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ABSTRACT

Smartphones are increasingly becoming embedded in geography curriculums, meaning research is needed to gather insights from the student perspective to guide best practice for optimised implementation across diverse cohorts. This is particularly important in the context of ensuring that UN Sustainable Development Goal 4 (Quality Education) is met. In this article, we report on the role that student competency in technology (i.e. everyday user versus occasional user) and sub-discipline (i.e. human geography versus physical geography) plays in student engagement with smartphone technology to support active learning. Exercises were developed in Survey123, Field Maps, and QField for QGIS across undergraduate and postgraduate geography programmes. Focus groups identified three common themes among students in response to the use of this mobile technology in geographic research. Firstly, our research highlights the need to consider technology learning as a dynamic entity, perhaps even a continuum, with students identifying negative opinions of their technology skillsets, even when their baseline was quite advanced. Secondly, such activities should not necessarily be uniform across cohorts of students, with our results identifying substantially different responses across undergraduate and postgraduate cohorts. Finally, we highlight the need to think critically about whether such smartphone applications are necessary for all data collection tasks across different application areas, with a preference for human geography exercises identified by students.

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Introduction

Active learning in geography is increasingly being supported by technology (Fisher & Binns, 2016; Jo et al., 2016; Patterson, 2007; Priestnall et al., 2019; Roehl et al., 2013), with

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students progressively recognising the dynamic and interactive learning environment created through various technologies as beneficial to their tertiary educational experiences (Taylor, 2023). Smartphones offer greater scope and flexibility than desktop computers (Norris et al., 2011), with their usage in higher education becoming more ubiquitous, particularly to support the understanding and application of geographic information science (GIS) (Holloway et al., 2021; Pánek & Glass, 2018; Rossiter, 2022; Stoltman, 2012). Smartphone GIS has been shown to support student learning through the active nature of the exercises (Pánek & Glass, 2018); however, research has identified that many students remain unaware of the potential of their smartphones to support their learning (Woodcock et al., 2012), as well as a dichotomy of views with regard to the differing technologies (Holloway et al., 2021). With smartphones now embedded in geography curriculums, research is needed to gather insights from the student perspective in order to guide best practice for optimised implementation across diverse cohorts.

Most research exploring student use of mobile GIS applications on smartphones in the classroom has not assessed the student baseline experience with technology (Anbaroglu et al., 2020; De Donatis et al., 2016; Holloway et al., 2021; Pánek & Glass, 2018). Where it has been considered, researchers simply stated that students were either selected with no GIS experience in their academic studies (Park, 2022) or were asked about their explicit GIS experience during a qualitative data collection post study (Ruan et al., 2021). Research that has focused on training teachers in the use of GIS smartphone technology (as opposed to students) has collected baseline experience much more readily (considering the relatively small sample size). For example, Hong and Melville (2018) trained teachers in the use of Collector for ArcGIS within secondary education, surveying teachers prior to the workshops with a self-reflection ranking of their ability, while Sebastián-López and de Miguel González (2020) went further and utilized the European Commission's DigiComp framework to assess competency. Research by Zehra and Kozikoğlu (2020) has shown that technological competency, such as using the internet, virtual learning environments, and social media can support student development towards many of the 21st Century learning skills that tertiary education aims to develop, including critical thought, problem solving, and the reflection of this development on their performance in academic and social skills. While the question of how technological competencies affect the ability of students to use GIS has long been posed by educators (Baker et al., 2012), a consensus has not yet been reached.

The wide adoption of technological teaching, particularly within GIS, aligns with Fawns' (2022) consideration of technological determinism. This concept views technology as driving a social change where outcomes can be predicted by their design (Kaplan, 2009). Learning GIS necessitates the use of technology prior to the course-level decisions, meaning choices about technology, tasks, social configurations, and resources are restricted by what is possible within the established departmental program (Fawns, 2022). This suggests a need to implement a holistic view, such as practice theory or posthumanism; however, this does overlook the axes of differentiation (e.g. everyday versus occasional users) in students related to their technological learning. A challenge of integrating GIS technologies into wider geography curriculums is to consider diversity within the concept of technological determinism. This echoes Laurillard (2013) who states that the potential for technology will only be realized once we understand how students learn. Digital natives have been the focus of a lot of research in recent years

(Bullen & Morgan, 2016; Ng, 2012), where most authors try to dispel the myth (Bennet et al., 2008) arguing that the assumption of homogenous technological competencies, motivations, and skills for an entire generation is highly problematic. The question of how a diverse cohort of students learn, especially related to technology, therefore remains open.

Such considerations of heterogeneity in the learning of smartphone GIS can be further compounded by the fact that geography as a discipline bridges the human-physical divide. Smartphone GIS applications in the classroom have been used across a wide array of geographic thematic areas (see Table 1), including human geography (Sense of Place – Panek & Glass, Urban Geography – Holloway et al., 2021) and physical geography (Geology – De Donatis et al., 2016; Ruan et al., 2021, Air Pollution – Park, 2022), with several researchers using this technology to collect data for research (Dalla Pria et al., 2022; Lindsay & Kong, 2020; Montagnetti & Guarino, 2021; Quirini-Poplawski & Semczuk, 2021), primarily in physical geography and biogeography. These articles indicate that the predominant learning outcome in using smartphone GIS has been the thematic topic, with GIS learning outcomes often secondary.

Where the primary focus of the learning outcomes was GIS, predominantly supporting students to create their own mobile GIS application, instructors provided users with a choice to select their own thematic topic. Research has identified successful learning outcomes of the technology, but a lack of active learning on the thematic topic (Anbaroglu et al., 2020; Sebastián-López & de Miguel González, 2020). Therefore, the question remains open as to which thematic topics (or group of topics) are best suited to support student learning for both GIS and different thematic areas, whether certain topics are more relevant to support the pedagogy related to learning material beyond technology use, and in particular identify trends that can support instructors to identify when they should use specific pedagogical techniques, which ultimately supports student learning.

In this research, we investigate how a) student competency in technology (i.e. everyday user versus occasional user) and b) sub-discipline (i.e. human geography versus physical geography) impacts student engagement with smartphone technology to support active learning. This research contributes to knowledge and discourse on geographical pedagogy using digital technologies. By deconstructing the student body to explore multiple lines of technology competency, this research can enrich student learning more effectively and not assume a homogeneous group of individuals. It also supports targeted strategies as to what exercises, courses, sub-disciplines, and thematic areas of geography are best to develop within the geographic pedagogy of active learning and smartphone GIS.

Project overview

Within our undergraduate and postgraduate programmes, we have multiple entry points for smartphone GIS applications. *GG1015 Applied Geography* introduces students to research techniques that we use in collecting and analysing spatial data. *GG6501 Introduction to GIS* is a postgraduate course that introduces students to the theoretical and practical aspects of GIS, while *GG6533 Spatial Ecology & GIS* is a practical course that uses pedagogical techniques such as seminar-style article discussion and the flipped

Table 1. Summary of key pedagogy articles in geography that use smartphone and/or mobile GIS applications to support learning.

Topic	Theme	Level	Technology Assessment	Active Learning	Main Findings	Software	Source
Sense of Place	HG	UG	No	Experiential Learning	Requires a high technical experience to use	ArcGIS for Collector	Pánek and Glass (2018)
Urban Geography	HG	UG	No	Active Learning	Active learning increased understanding, peer-learning observed, Collector for ArcGIS easy - ArcGIS Online hard	ArcGIS for Collector	Holloway et al. (2021)
Choice of Topic	TG	T	Yes	Inquiry-based learning	Younger teachers reached digital complexity quicker, and supports active problem-solving in the classroom	ArcGIS for Collector	Sebastián-López and de Miguel González (2020)
Choice of Topic	TG	T	Yes	Active Learning	Training of GIS related technologies supports teachers in secondary education	ArcGIS for Collector	Hong and Melville (2018)
Air Pollution	PG	UG & PG	No	Field-based learning	Increased knowledge of processes based on being in the field	No specific software	Park (2022)
Geology	PG	UG	Yes (one question)	Teacher-Centric	Location Based Services meets requirements, but not preferred in an unstructured format	No specific software	Ruan et al. (2021)
SDGs (Peace)	HG	UG	No	N/A	Training can be covered in 8–10 hours, from initial set up to presenting data	QField for QGIS	Anbaroglu et al. (2020)
Geology	PG	UG	No	Active Learning	This is a technical paper which aims to act as a teaching tool	Beepen for QGIS	De Donatis et al. (2016)
Census & Energy	HG	UG	No	Active Learning	Students gain valuable skills in primary data capture methods, data capture project management tools, and group work	ArcGIS Field Maps	Rossiter (2022)

Theme, HG = human geography, PG = physical geography, TG = teaching geography. Level, UG = undergraduate, PG = postgraduate, T = teachers.

classroom alongside GIS practical-led exercises in species distribution modelling. Table 2 provides additional details on the courses.

Learning objectives in the undergraduate *Applied Geography (GG1015)* module are aimed towards applying a range of transferable skills, conceptualising real-world problems, sourcing and interpreting datasets, developing introductory cartographic skills and data visualisation, and observing and interpreting geographic phenomena in the field. As the module goal for this course is to introduce the students to key methods and techniques for understanding and interpreting geographic phenomena, the learning outcomes remain overarching, but not necessarily focused on the specific technologies. Students generally in this module would not have GIS experience. For the postgraduate modules *Introduction to GIS (GG6501)* and *Spatial Ecology & GIS (GG6533)*, learning outcomes are much more grounded in the specific technology that is being used. For example, these include critically assessing how geographic information may be structured, organised, collected, and used in GIS, as well as explain and critically interrogate ecological data collected in the field. As such, students would have a much more varied GIS experience, with all learning the key GIS concepts throughout two semesters.

These courses provide an opportunity to assess a range of different thematic areas across geography. We opted to explore three thematic areas across the three modules: climate change vulnerabilities, accessibility, and biogeography (see Table 2). In the undergraduate module *Applied Geography GG1015* we explored thematic topics of climate vulnerabilities (Flood et al., 2018) and accessibility (Hall, 2019), to support the human-physical interests in the programme. Both topics align well with thematic courses provided in subsequent years of the programme, as well as research activities of the department (Hickey, 2011; Kenna, 2022). In the postgraduate module *Introduction to GIS GG6501*, we collaborated with Cork City Council to undertake a beta testing of their new smartphone GIS application to identify climate vulnerabilities around the city. In the other postgraduate module *Spatial Ecology & GIS GG6533* the students collected data of intertidal species of a local beach, advancing research undertaken by Holloway and Field (2020) specifically through the advantages provided by sub-metre locational accuracy of smartphone GIS and Global Positioning Satellites (GPS). Finally, to align with the departmental shift into the open-source GIS software at undergraduate level (Holloway, 2023) the undergraduate students utilised the QField for QGIS application for data collection, while the postgraduate courses used the ESRI software Survey123 and Field Maps to align with their course learning outcomes.

Table 2. Details of the courses involved in this research.

Course	Enrolment 2022–23	Programme	Fieldwork	Smartphone GIS software
GG1015 Applied Geography	232	BA Geography	Climate vulnerabilities and features of inaccessibility in Cork City, Ireland.	QField for QGIS
GG6501 Introduction to GIS	15	MSc Applied Coastal and Marine Management	Climate vulnerabilities in Cork City, Ireland.	ESRI Survey123
GG6533 Spatial Ecology & GIS	10	MSc Applied Coastal and Marine Management	Intertidal ecology at Myrtleville beach, County Cork, Ireland (approximately 25 km south-east of Cork City)	ESRI Field Maps

Undergraduate students collected data (including photographs) on 151 climate change vulnerabilities (Figure 1) and 296 accessibility considerations using QField for QGIS. This is compared to the postgraduate students who collected 51 climate change vulnerabilities and resilience features in the city using Survey123. During the intertidal surveys, postgraduate students collected spatial data on 31 transects collected by two groups using Field Maps.

Methods

A mixed-methods approach for assessing baseline technological and domain competency was implemented through pre-assessment of student ability related to the technical skills undertaken through the project work. Student recruitment consisted of all students being invited to participate in the baseline technological survey prior to the assignments being launched, before another invitation to participate in focus groups upon completion of the project. All students were asked to undertake the European Commission's DigiComp survey before focus groups explored in detail student experiences with both the technology and thematic area to understand qualitative information in gains.

In total, nine students completed the DigiComp survey, while 10 students participated in the focus groups. Due to the anonymity required through the ethical application process, we cannot state with certainty that these were the same students, but in the focus group students were asked to reflect on their DigiComp scores and their technological competencies. In the focus groups, we had 10 participants, which equates to ~5% of the students who took part in the projects across the three modules, which is in line with other focus groups in the discipline (Carlsen & Glenton, 2011; Conradson, 2013;

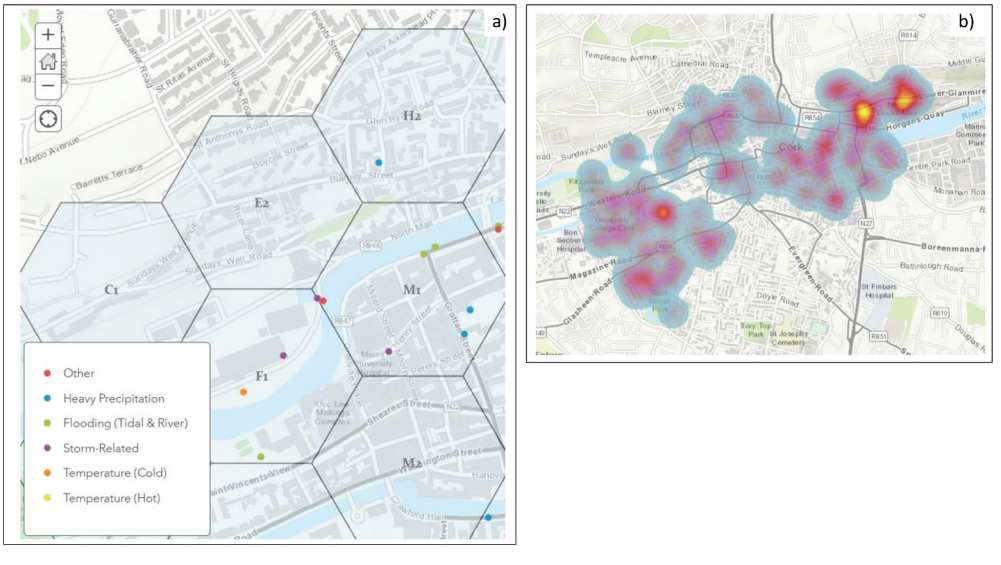

Figure 1. a) An example of the hexagon grid that student groups were assigned to in GG1015, with climate vulnerability points plotted, and b) a heatmap of all climate vulnerability points across the city from all the groups, presented through ArcGIS Online.

Holloway et al., 2021). We had an even split of five undergraduate students (partaking in GG1015) and five postgraduate students (partaking in GG6501 and GG6533). The undergraduate students had no prior GIS experience, while the postgraduate students on the taught MSc had a range of backgrounds, with some having completed GIS as part of their undergraduate programmes, while others had none. By the time they undertook the focus groups, the postgraduate students had completed two GIS modules and two remote sensing modules.

We held two-hour-long focus groups that included one online focus group that had three attendees from the undergraduate programme and a second in-person focus group that had two undergraduate attendees and five postgraduate attendees. Finally, detailed email correspondence was provided from one undergraduate student who could not attend either of the focus groups. Note one undergraduate student attended both focus groups. These focus groups enabled us to acquire detailed feedback on the students' learning experiences for active learning in both the GIS and thematic areas. The schedule for the focus group was based on the Normalization Process Theory Toolkit (May et al., 2018), which took the following structure outlined in Table 3. Themes that were explored in an open format were personal experiences, motivations, discussion, implementation, and future technology usage.

Ethics approval was granted by the University College Cork Social Research Ethics Committee log-2022–246. Informed consent was sought from participants. Students were informed that participation in the research was voluntary and that they could withdraw at any stage. All information provided by participants was treated as confidential and anonymous, and consent was provided to use direct quotes that support research publications, dissertations, and/or conference proceedings.

Results

Focus groups identified three common themes: reflective technological thinking, educational experience in relation to technology, and uncertainty in the thematic topic. In the quotations, FG = Focus Group, UG = Undergraduate, PG = Postgraduate, and *p* = Participant.

Reflective technological thinking

The students responded in a divergent manner when discussing their digital literacy. Most students in the focus groups identified learning in their technology skillsets, as well

Table 3. The structure, themes, topics, and content of the focus groups following the normalization process theory toolkit.

Theme	Topic	Content
Views	Welcome	Context and Background, Aims of the Study, Introduction to the research team
Design	Personal Experience	Personal experiences with technology, GIS, and Geography Application Area. DigiComp scores.
	Motivations	Exploration of intrinsic and extrinsic motivations for partaking in the study
	Discussion	The role of technology in active learning and peer-learning
	Implementation	Details/Willingness/Concerns about the potential use of technology here
Future	Moving forward	Making plans for further technology in Geography teaching. What decisions need to be made
Experience	Closing	Opportunity to add further information and final thoughts

as identifying how active learning supported them in understanding the thematic application area:

- *"Work with GIS and improving my technology. I think they're the big two [things] I learnt" FG1 UG P1*
- *"You were able to make the different types [of spatial data] and stuff like that, and you know, this has some theory, has some purpose. And when your man came in to talk from the council and how they use it, it's all friendly stuff. That was very interesting." FG2 UG P2*
- *"Overall, I feel my skills improved having taken this module and I would feel more confident moving forward with GIS in the future" Email UG P10*

Despite this, student views towards the benefits of smartphone and desktop technology differed. Our expectation derived from previous research (Holloway et al., 2021; Pánek & Glass, 2018) was that students would prefer the smartphone GIS component to the desktop GIS component due to a familiarity of using mobile devices and the need for additional support on the desktop processing and analysis. Contradictory to this expectation, students presented the viewpoint that there was a preference for the desktop GIS post-data collection analysis when compared to the use of smartphones. There is often more technical expertise required for analysing the data through the different desktop GIS software than collecting spatial points and photos on a smartphone. However, discourse around this identified the predominant reasons for student apprehension to smartphone GIS were a willingness to adopt mobile technology and trust in data validity:

- *"I just find the whole thing [smartphones], like we're getting enough I tell you. Shouldn't be encouraging [people] to use them more. Suddenly you look, everyone has their phones straight out in front of them like. You could do the same with a pen and paper . . . But in terms of actually making the different maps, that was fine" FG2 UG P2*
- *"I feel like the smartphone is okay because we have the geolocation stuff so you can have coordinate points, but using it as a GIS, I have like trust issues with that because the source of error can be very big" FG2 PG P7*

Willingness to adopt new technologies could be rooted in one's technological competency. Through critical engagement with their baseline competencies, students reflected on their GIS learning. Again, viewpoints differed among students, with peer-to-peer discussion even generating post-assignment reflection on their openness to using and learning technology:

- *"Thing as well, like with the GIS stuff, I think it's like an effort thing. Like when I learnt GIS last year, me and my housemate both had the same teaching and everything like that. But his effort into it was just nowhere near as much as what mine was. And since then he still struggles [with GIS]" FG2 PG P1*
- *"Do I think I learnt many technological skills. No, because like this man said here, I didn't allow myself [to learn], I wasn't willing to. So yeah, I just probably didn't, I don't know. A mental thing really, I just rejected it straight away" FG2 UG P2*

An unwillingness to incorporate technology in learning could be due to students perceived technological competency, and the overriding opinion from students was that their technology skillsets were lacking prior to the analysis, and that completion of the pre-participation survey surprised them:

- "*I always feel like I'm bad at computers or maths for like rational stuff . . . So yeah, when the survey said you're pretty functional with technology. I was like, OK, wow." FG2 PG P7*

Discussion identified the need to consider technology learning as a dynamic entity, perhaps even a continuum. Students identified negative opinions of their technology skillsets, even when their baseline was quite advanced. This belief as to their ability to work with certain software or approaches could therefore provide hurdles in their openness to technological learning. This illustrates one of the difficulties in teaching GIS to large classes where the competencies are so varied, as most students are apprehensive about reaching that next level of expertise:

- *"Stuff like Word or Excel or most things [I'm good at], just not when R is put in front of me. When you give instructions like to solve spatial problems, that's great. When I have to do it myself, absolutely not. Give me SPSS any day." FG2 PG P1*

There is subsequently a heterogeneity in technological competencies across students, which critical evaluation and reflection pre- and post-learning can support. These quotes may also point to differences in the motivation of students.

Motivation has long been noted as guiding behaviour towards learning a particular goal. Extrinsic motivation builds on the concept that individuals are rewarded or punished, while intrinsic motivation looks to develop behaviours associated with positive feelings of interest, enjoyment, and satisfaction (Sansone & Harackiewicz, 2000).

- *"Well, I enjoyed it . . . It gave me kind of a perspective of what's to come within the study of Geography and things like that." FG1 UG P1*
- *"I think having experienced climate change, I'm very well versed with the change in living in areas that I have, including by the sea. And I know the issues with Cork, talk about building a wall, etcetera. They were obvious to me." FG1 UG P2*

Intrinsic motivations were subsequently voiced by the students, particularly when it came to the applied thematic areas of the course; however, it remained difficult to disentangle the role of diverging technology competencies and extrinsic motivations within the student body.

A tension between extrinsic and intrinsic motivation is somewhat embedded in tertiary education, with educators often citing holistic personal growth, deep learning, and development of transferable skills in students as one of the main aims of higher education, while students often place employability and assessment higher on that list (Meyer et al., 2018).

- "*I never used this thing before Saturday. But you just do what you have to do. You do what the team tells you, so you don't get marked down." FG2 UG P2*

Assessment has long been noted as enhancing extrinsic academic motivation; however, current research is suggesting that it instead raises anxiety and avoidance of challenging courses (Chamberlin et al., 2023). There was a substantial amount of apprehension regarding assessment within the courses. This was much more prevalent in the undergraduate module when students were emailing to ensure that their fieldwork had been recorded and uploaded so that they received the 20%-mark allocation. Focus groups also confirmed that playing it safe with the lecture slide examples was a strategy employed by students:

- *"Ticking the boxes. Doing exactly what the piece of paper is telling you to do" FG2 UG P2*

Therefore, exploring the role of technological competency should not be disassociated with conversations of student motivation, both intrinsic and extrinsic, particularly when the latter strongly links with assessment. This is further explored below, when the themes of educational experiences and thematic application area are discussed.

Education experience

Through sampling students at both undergraduate and postgraduate level, it exposed the need to consider lived academic experience as a benchmark for the training of smartphone GIS. This was particularly relevant for the MSc students and the need to consider axes of differentiation within student cohorts. These students voiced concerns about the safety of smartphones as data collection methods beyond these specific course assignments. The students were much more cautious of the technology failing in projects that had yet to come, with discourse centring on whether they would be using this technology in the future, particularly for their dissertations.

- *"Maybe because in my school years we used pen and paper, and I was like, what if something goes wrong and everything is lost? It's this like weird thing not trusting that the phone is gonna work" FG2 PG P7*
- *"The big thing on doing it on the desk before [referring to desktop GIS], I will definitely not be doing the habitat survey thing [referring to another GIS project] on my phone. I'll be printing it [the map] off. I'll be doing it like that" FG2 PG P1*

In the postgraduate modules, the students' problem-solved in the field. When the technology appeared not to be working, they also wrote down locations, coordinates, and features in notebooks. However, this in-field problem-solving was not necessarily evident in the undergraduate students:

- "*We went to the train station, and it didn't work, which meant we had to come back another day" FG2 UG P2*

- "*I'm aware people had issues downloading if they were on their data, which meant they had to go back" FG1 UG P2*

Perhaps, the most common mistake in the undergraduate course was from students opting to download the project file to their smartphones in the field. While this was clearly outlined in the instructions, in future iterations of this course, undertaking this step during the second briefing would alleviate the high rate of download issues that were observed. However, this issue was compounded by the fact that technical issues did arise in the field for all groups beyond their control, which highlights that such concerns by these students are valid. In the instance of *Introduction to GIS GG6501*, the Survey123 app had not been set up by project partners to sync all submitted points; therefore, while the data had been collected, it was not visible. Similar issues within *Applied Geography GG1015* were experienced within QField for QGIS:

- *"We divided across two phones and it still didn't upload on either to the cloud. I think its fixed now but I'm not sure" FG1 UG P3*
- *"I couldn't see all the other data points through the app" FG1 UG P2*

The technical issue with QField for QGIS was perhaps more problematic. Due to the ability to upload photographs with the points, the cloud storage limits for the account were reached very quickly. Data points were uploaded to the server but would fail to sync to the map document without extra storage being purchased. Therefore, despite QField for QGIS being the open-source software alternative compared to ESRI Field Maps and ESRI Survey123, the cloud server storage facilities and affiliated costs associated with expanding gigabyte storage are a hidden expense of adopting this technology. Such additional costs, which are still lower when compared to the alternatives, perhaps limit the effectiveness of this application for use within large classroom teaching, especially when photographs are a desired feature to provide geographic context and validation. Returning quickly to the observations from Fawns (2022), adopting technology (in this instance different software) within courses can be restricted by the resources available within the departmental programme. Therefore, any adoption of smartphone GIS needs to be budgeted accordingly, which is often a decision that is made prior to the academic year. The hidden costs of cloud-storage, coupled with the large file sizes of photographs and lack of additional budget available, caused in-field challenges as well as enhancing student anxiety, as evidenced above.

At the postgraduate level, there was an acceptance that there may have been bugs with the system, especially as the concept of a beta test for an external partner was embedded in the curriculum. The forward-thinking nature of how such devices could be used within GIS research demonstrated a critical understanding of wider GIS learning outcomes, such as critical assessment of how geographic information may be structured and organised (e.g. spatial data models, projections) in a GIS.

- *"I did have a better play with the app. So that's where new questions about like the Polygon came up. Yeah you can do the polygons, but I was like how precise can they be? They're not gonna be like mega precise because sometimes you do away, you'll tap there but it'll say you tapped down." FG2 PG P1*

Such developed discussions around GIS learning outcomes in the postgraduate courses highlighted a difference across the reliability of the GIS data collected within the thematic topics. Moreover, while reference to research methods is embedded in the learning outcomes of the undergraduate course (e.g. sourcing and interpreting datasets, developing introductory cartographic skills and data visualisation), technology is not explicitly mentioned. Therefore, undergraduate students may have considered that technology was separate to their core learning, which may have impacted their intrinsic and extrinsic motivations for learning the GIS skills. While the term "technology" is not used in the postgraduate modules, the experience of these students is such that the link between GIS and technology is well known; however, these results suggest that utilizing explicit references of technology in the learning outcomes of entry-level modules may be a necessity.

Uncertainty in thematic topic

Focus groups also highlighted the need to think critically about whether such smartphone applications are necessary for all data collection tasks across different application areas. There appeared to be a bias towards negative views on the use of smartphones that stemmed from the physical geography exercises (i.e. beaches, climate change vulnerabilities) compared to human geography exercises (i.e. accessibility), explicitly the locations of these exercises and the type of geographic phenomena that were being collected:

- *"Say you're in Myrtleville beach or in a natural environment doing field work where you're saying there's no corresponding location based on the satellite images, or with that you're just kind of, you're completely reliant on that and see through intuition" FG2 PG P1*
- *"Let's say everything goes wrong and you lose absolutely everything, you can't go back to the exact same locations [on Myrtleville beach] that you were and take the same picture, whereas like, if you need to go to Patrick St. to [a specific shop] or whatever you know you can see it, like you know you're there" FG2 PG P4*

However, even a continuum of uncertainty existed for the urban features in the city reported by an undergraduate participant:

- *"Not really [in response to whether also writing it on pen and paper would have helped]. You still need the precise location. Say you're halfway up Summerhill North with a blocked drain on your right, you'd be hunting around for it for ages" FG2 UG P2*

The use of reference points for derelict buildings, urban trees impacting accessibility, and significant landscape features that are easily identifiable in person or on maps meant that there was a lot more confidence in using smartphones for research in urban settings, specifically human geography. Even if the app crashed and data needed to be re-input, the perception that these were landmarks in the city meant the workload would not be as onerous. There appeared to be a sliding scale with human infrastructure, as the precise location of smaller features such as blocked drains were noted as being the exception to this observation. However, students noted that in rural or natural settings, such reference

points were missing, and as such the potential for fieldwork campaigns to be negatively impacted by technological crashes increases.

This observation was also mirrored by an anecdotal observation in the preference for undergraduate students in *Applied Geography GG1015* to note accessibility issues (296) compared to climate change vulnerabilities (151). This could have been due to the differences in visibility between accessibility and climate change or as suggested above by FG2 UG P2 to do *"exactly what the piece of paper is telling you to do*". The instructional material (Supplementary Material) used a blocked footpath next to the geography building as an example, meaning students may have unconsciously undergone a bias towards these features. However, as evidenced below, students also suggested that this uncertainty may have been rooted in their thematic understanding of the topics:

- "*Climate change was harder. Hard to see extreme weather from the street level" FG1 UG P3*
- *"I suppose [we reported] more accessibility issues, but you do what you have in your environment like" FG2 UG P2*
- *"The accessibility points were much easier for us anyway" FG1 UG P2*

Or as one student noted through critical interrogation of other students work, an issue with reporting certain features as points when other spatial data models (e.g. lines) might have inflated the perceived number of features:

- *"You know, one group will point out every single step that goes up to a door or the next group. They might [report] a whole flight there. If they want. Point away" FG2 UG P5*

Therefore, there certainly seemed to be a preference for accessibility features that was identified in the results of the data collected and the focus groups. Where comparison across climate vulnerabilities can be made between undergraduate and postgraduate students (across GG1015 and GG6501), there is a substantial difference in the level of detail that would be expected between first-year undergraduates and postgraduates.

- *Just ticking the boxes. You know, uneven footpaths on your slides. So that's what everybody gears towards. Was there a second thing? FG2 UG P2*

Students were provided with a percentage of the grade for undertaking the survey. This reasoning was twofold, firstly to ensure that enough students undertook the assignment for it to work, as well as to provide credit for a necessary component of research, providing an extrinsic motivation. Moreover, the provision of 20% for data collection should also have negated some of the anxiety that students face in terms of assessment (Chamberlin et al., 2023), and this strategy has been found to reduce the fail rate in the module over the course of recent years. However, the prescriptive nature of the results may suggest that more transitional assessment criteria need to be developed so that engagement with the in-field collection is improved, as well as supporting the intrinsic motivation of the students to engage with both the technology and applied thematic

areas. Strategies for balancing the intrinsic and extrinsic motivations, as well as negating anxiety, are developed in the discussion.

All undergraduate students, except for two, who submitted their final report, discussed both climate change vulnerability and accessibility in their reports. Similarly, most students kept the two topics separate in their discussions and analysis. Only a handful considered the implications of climate change vulnerability and accessibility together, with these reports often demonstrating the highest level of critical thinking. The rationale for incorporating both topics was to provide interest in the thematic area for students and give them a wider exposure to different geographic applications, thus supporting intrinsic motivation. Through focus groups and reports, it appeared that most students did not consciously select one topic over another, but rather explored both. Importantly, active learning of the thematic area was reported, not always by students who discussed a desire to work with smartphones:

- *"You know, we don't really realize that there are inaccessibility issues for us walking down the street until we actually see them and study them. So I think it was quite eye-opening to have studied this to be honest." FG1 UG P1*
- *"I suppose even subconsciously, even if you're just walking down a footpath that's broken, you're more aware of that now." FG1 PG P2*

Discussion

The aim of this research was to investigate how technological competence of students impacted engagement with smartphone GIS, before further investigating whether certain thematic application areas were more suited to successful active learning, particularly in geographic research and fieldwork. This research identified that competency, or perceived competency, of technology played a role in students' willingness to utilise smartphone GIS, but that a consideration of their technological capabilities pre- and post-assignment situated their learning within the wider educational programme. Recognition of student motivation towards technological learning was identified through focus groups, and we suggest that this needs to be considered alongside understanding technological competency in student learning, particularly related to GIS. Educational experience, across degree levels (e.g. undergraduate, postgraduate) but also diversity across cohorts appears to contribute to knowledge and discourse on geographical pedagogy using digital technologies. The relative experiences of students', as well as future expectations (e.g. research projects, dissertations) manifested in their capacity to integrate smartphone and desktop GIS technology as a research tool. This ranged from a basic use of the technology and a discussion of their methods at undergraduate level to critical appraisal and alignment with learning outcomes related to GIS topics such as spatial data models at postgraduate level. Finally, this research identifies that smartphone GIS as a research methodology in large classes may be better suited to urban areas, due to the uncertainty in results in landscapes where significant landmarks are absent, as well as issues surrounding repeat accessibility, particularly in the event of lost data or poor connectivity that would warrant a return trip to the field. This is particularly relevant when smartphones are being used as an entry point to GIS. Importantly, this research supports targeted strategies as to what exercises, courses, sub-disciplines, and thematic

areas of geography are best to develop within the geographic pedagogy of active learning and smartphone GIS, with a homogenous approach to learning smartphone technology not recommended.

Our results somewhat contradict the narrative in geographic pedagogy that smartphones are becoming a predominant teaching tool in the discipline (Holloway et al., 2021; Pánek & Glass, 2018; Rossiter, 2022). Care should always be taken when generalising across cohorts and year groups, particularly given the fact that some of the dominant voices in the focus group were negatively inclined towards technology in general (Smithson, 2000), as well as the small sample size of students. When different moderator approaches were implemented in focus group dynamics, certain individuals who had not spoken a lot did, and often spoke positively towards the use of smartphones:

- *"Yeah, but it's a great tool to just take a photo in the field, you couldn't do that with pen and paper" FG2 PG P6*

Therefore, we refrain from any generalising statements that the paradigm has shifted against the use of technology, and in particular smartphones in geographic teaching. However, recent research has identified technology fatigue in students since the onset of the COVID-19 pandemic (Al Mulhim, 2023; Amponsah et al., 2022; Bullock et al., 2022), and results here suggest an indication that students may not be as inclined towards technology as previous cohorts were, even within our department and university (Holloway et al., 2021; Reen et al., 2021; Taylor, 2023). Despite this, students evidenced that there was still a desire to leave the classroom and experience fieldwork, as well as observe how the city council were using smartphones in their government work, which suggests that a balance may be needed in terms of traditional and digital fieldwork:

- *"It allowed me to see that geography is not just sitting there in a lecture hall or classroom learning the theory" FG1 UG P1*
- *"You know, when we did that stuff for the City Council, that was really cool and we got to tell you our opinions. I thought using the phone was really handy." FG2 PG P4*

All students identified through self-reflection in the focus groups an increase in their technological skills; however, this upskilling did vary across individuals, alongside their own perceptions and motivations to improve their technology usage within Geography modules. Moreover, most undergraduate students completed the minimum requirements for the assignment, collecting the data in a group with a smartphone and generating maps from this data. All postgraduate students completed all aspects of the work. Therefore, from an observational perspective, all learning outcomes for the course related to technology were met, with gains observed across the cohort. However, the perception of these gains was identified at the focus groups, with many students admitting surprise at their technological competencies or being dismissive of their capabilities, particularly in relation to the "next" level of required competency (e.g. the example of Excel/SPSS to R for statistical analysis). Such results speak to a level of imposter syndrome in students' technological skills, which is where a person is unsure of

themselves and their abilities, resulting in performance anxiety, attempts at perfectionism, depression, and burnout (Clance & Imes, 1978).

- *"Like I do not get it. I'm a touch typer. Give me things to type all day long. Give me a map to make, it just makes no sense. For me it's just that bit harder . . . Like it's not the computers or instructors' fault, it's just me" FG2 PG P4*

Apprehension with STEM (Science, Technology, Engineering, and Math) subjects is well documented, but understanding about its triggers, duration, and prevalence is limited (Chakraverty, 2020). Research in postgraduate students has identified that occurrence, attribution, and identity are the three most common domains related to imposter syndrome in STEM, with overestimation of other individual's abilities a key feature (Chakraverty, 2019).

- *"Uh, yes, I probably failed miserably [in response how the participant did in the DigiComp survey]. No, no, I didn't quite fail. But I say my scores were a little bit low compared to others coming straight out of school" FG1 UG P2*

Through self-assessment of technological competency prior to the learning, the goal was to first capture baseline knowledge for students, but a secondary by-product was a self-reflectance of their ability with technology. In total, nine students completed both the DigiComp survey and the focus groups across the full cohort. This number was relatively small; however, upon reflection the survey was 87 questions, which meant the detail in these questions could be considered qualitative in nature. Rather than implementing a pre- and post-learning comparison to assess quantitative gains to echo and build upon the work by Sebastián-López and de Miguel González (2020), we used these results in our focus groups to encourage students to reflect on their technological competency, which as seen above effectively served as a discussion pathway for students to self-reflect. The survey's primary aim is for EU citizens to reflect as to whether they are "ready" for a digital shift, meaning while it provides a baseline of technological competency for the public, perhaps it is not wholly suitable for use in student surveys given the length of the survey and the perceived high workload students currently experience (Kenna, 2023). Therefore, we suggest alternative methods, such as bespoke surveys, to ascertain baseline technology competency.

Another purpose of the pre-assessment DigiComp survey was to increase intrinsic motivation in students towards working with technology, although it could be noted that a poor technology score could have demotivated students from engaging with the assignment. When coupled with the post-reflectance on their willingness to learn that was outlined in the focus groups, our results suggest that such techniques could be beneficial to student learning, although these need to be tailored to individual students, and perhaps focused on the topic of study (i.e. specific to GIS not general technology competency). This enables a quick identification of measurable and incremental gains from the student's perspective, supporting both competency and intrinsic motivation. This concurs with learning in other disciplines, particularly the medical and dental professions (Rajashekhar et al., 2022) but given the continuum of technological learning identified in the focus groups that there is always a "next" technology to learn, especially

within the GIS domain, research is needed to explore how best to support student progression within this continuum to optimise their capacity for intrinsic engagement with technology to support geographic learning. While embedding GIS within geography curriculums to promote spatial cognition is well established (McInerney, 2003), the plethora of software and devices has perhaps congested the discipline. Clear pathways for students in how they advance their software skills are perhaps needed to alleviate imposter syndrome in relation to smartphone GIS.

The discussion arising from the focus groups that students thought they would be docked marks for not putting in specific vulnerabilities was an important consideration to disentangle the technological competency with intrinsic and extrinsic motivations. Below is an unsolicited excerpt from the focus group where a student details a past experience with another module:

- *"I will say you do slightly get marked down. If you don't do what they want you to do, you get marked down . . . because I didn't do what he wanted me to do, I lost marks" FG2 PG P1*

This suggests that past lived experiences, particularly in secondary and tertiary education, are so embedded in students that implementing assignments where there is not necessarily a correct answer, or even a feature, can lead to a paradoxical undertaking of the assignment. This is perhaps wider than smartphone GIS, with a significant body of research dedicated to this generation of students. Students have been documented to perceive that the primary focus of higher education is grades (Vallade et al., 2014), with McAllum (2016, p. 364) stating that "Grades matter to Millennials", and Howe and Strauss (2000) noting that a core characteristic of Millennials is a pressure to achieve. In a similar vein, Szabó et al. (2021) note that Gen Z students are opting for a preference for lectures and examinations, which in part could be due to the expectation that students may score higher marks in exams than coursework (Bridges et al., 2002). Therefore, given the importance that the interviewed students placed on grades, perhaps an ungraded approach, where no letter grades or marks are given to students could be applied. This has been suggested by scholars, particularly as an alternative in a technological realm of pedagogy (Ferns et al., 2021); however, student feedback over several years of similar exercises has praised the low-stakes award of marks for fieldwork, and in exercises where data collection is imperative to completing a bigger assignment, we would have reservations about the efficacy of such an approach.

Instead, considering a Transparency in Learning & Teaching (TILT) approach might provide various opportunities to overcome this. For example, discussion of goals and learning styles was undertaken prior to the assignment as a rationale for undertaking fieldwork, although the concept of co-creation in the assessment could be a method to further the active learning in the thematic application area. Focus group discussion even identified how such collaborations could work:

- *"You could give them, like, you have to have three things and then you must have five other things that you pick yourself. So like you have to show a cracked footpath or like an area of one of those things. Like three basic things, then going through yourself and [finding] five other things that you think could be of interest" FG2 PG P4*

Students could also be polled during the first briefing, through other smartphone applications such as Sli.do to generate a list of their "top" features. This would also align well with emerging literature that emphasises the role that students can play in the co-creation of knowledge (Cook-Sather & Matthews, 2021), but such approaches place additional workloads on instructors to refine the backend of the GIS application to support student learning for subsequent cohorts.

The lack of trust in smartphone GIS to support postgraduate research was a surprising result, especially given that in previous years several postgraduate students have used such applications to support their dissertation research. Given changes to the curriculum in recent years through remote learning enforced by the pandemic, one of the practical exercises that was dropped from the curriculum was the first part of a two-week practical where the students initially set up the ArcGIS for Collector App (now Field Maps) on a topic of their choice, before undertaking data collection the following week. Subsequently, the lack of "trust" identified by students in the use of such a survey for their own research may originate from a lack of experience in how one establishes a survey in a GIS framework. Therefore, instructors need to define whether the primary learning outcome of the smartphone GIS is the thematic application area or GIS.

Conclusion

Smartphones are only going to become more embedded in geography curriculums in the coming years, and our research aimed to gather insights from different student cohorts to guide best practice for optimised implementation. As student feedback illustrates, technology learning should be considered a dynamic entity, perhaps even a continuum. Students identified negative opinions of their technology skillsets, even when their baseline was quite advanced, such as using SPSS or touch-typing. This highlights the need for clear and concise learning outcomes related to technology learning in the module description, as well as a clear road map to measure incremental upskilling as a self-reflectance tool by students. The lived experience of students also plays a key role in their motivations and desires to learn and utilise technology. Students that wanted to learn GIS were more open to the challenges of working with such technology, while those that were placing emphasis on extrinsic motivations such as grades were seen to be "playing it safe". This will support technological teaching in the GIS domain, but also presents challenges as instructors will need to ensure that material can react to changing cohorts and the changing motivation of cohorts as this shifts with changing societal pressures. Motivation and assessment remain strongly interlinked within smartphone GIS, but also across tertiary education, and this research highlights the need for GIS professionals to engage with the burgeoning literature in this field. Finally, we highlight the need to think critically about whether such smartphone GIS applications are necessary for all data collection tasks across different application areas, with a preference for human geography exercises identified by students, primarily in response to risk mitigation of lost data in research projects, as well as clear and identifiable landmarks in cityscapes.

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