frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 07 December 2023
DOI 10.3389/feduc.2023.1271789

OPEN ACCESS

EDITED BY
Shashidhar Venkatesh Murthy,
James Cook University, Australia

REVIEWED BY
Rajiv Kar,
Indian Institute of Technology Guwahati, India
Derek France,
University of Chester, United Kingdom

*CORRESPONDENCE
Janine Maddison
✉ j.l.maddison2@newcastle.ac.uk

RECEIVED 02 August 2023
ACCEPTED 24 November 2023
PUBLISHED 07 December 2023

CITATION
Maddison J, Bevan RM and Marsham S (2023) Developing a digital field notebook for bioscience students in higher education. *Front. Educ.* 8:1271789. doi: 10.3389/feduc.2023.1271789

Developing a digital field notebook for bioscience students in higher education

Janine Maddison*, Richard Martin Bevan and Sara Marsham

School of Natural and Environmental Sciences, Newcastle University, Newcastle upon Tyne, United Kingdom

Introduction: The use of mobile device presents both benefits and barriers. However, studies into the use of technology in fieldwork often focus only on either practitioner views or student views. Digital field notebooks (DFNs) are one-way mobile devices can be used to enhance fieldwork. Yet their use is limited to Geography, Earth and Environmental Science (GEES) disciplines, with students often playing a passive role during the development of DFNs. This research reports on the development of a DFN to enhance bioscience fieldwork in Higher Education (HE).

Methods: Using interviews, focus groups, and survey methods we investigated how both fieldwork practitioners and learners view the role of technology in the field. Working in partnership with students, we explored their experiences of using a DFN during fieldwork. Feedback was utilized to make changes to the DFN to support its integration within bioscience fieldwork.

Results: Overall, valuable developments related to content, technology, and pedagogy were made to the DFN, identifying value in a co-creation process. For example, students suggested the role of the DFN as a collaborative tool where individual entries were collated together. A workflow schematic and case study are presented for how a DFN can be used during bioscience fieldwork in HE.

Discussion: Although students identified place connection and the development of reflective practice as particular affordances, students did not identify any digital skill development opportunities when using the DFN. Additionally, although students suggested the DFN was easy to use, barriers remain for students in using a DFN. We suggest further research on the complex issues of permission and perceptions of value of mobile device use during fieldwork. Additionally, more explicit reference to digital skill developments should be made when using a DFN.

KEYWORDS

fieldwork, higher education, co-design, bioscience, digital skills, mobile devices, pedagogy

1 Introduction

The value of notetaking within bioscience fieldwork has been historically important (Greene, 2011) and still remains a key feature of most fieldwork in higher education (HE) (Knapp, 2011) with students encouraged to record objectives about the fieldwork, diagrams and descriptions about the site, numerical data, date, time, locational information, notes about the data and information about samples (Lewis and Mills, 1995).

Ensuring field data are accessible and reproducible through digitization (Wilkinson et al., 2016), can promote equitable fieldwork practice (Ramírez-Castañeda et al., 2022) with digital

species records from field notes a useful and growing practice within biodiversity research (Nelson and Ellis, 2018).

The analysis and evaluation of the content of student field notebooks have been used to identify student skill development (Peasland et al., 2019), provide insight into student affect (attitudes and emotions) (Treibergs et al., 2022) and for assessing learner understanding (Chua et al., 2020). This current paper defines a digital field notebook (DFN) as a catch all-term used to describe the use of an mobile device to collect both quantitative and qualitative data using in-built functions of the device and additional applications (apps). DFNs have been recognized as being useful within fieldwork by bringing together several fieldwork apps in one place with the additional abilities to geo-tag observations and the immediacy to present and analyze data within the field (France et al., 2015; Senger and Nordmo, 2021).

Mobile devices can be used in a variety of different ways within fieldwork, which support their use as a DFN. These can be summarized as:

- Existing functions- Simplistic use of existing functions of mobile devices such as camera, notes and communication methods (Scanlon et al., 2005; Hein et al., 2011).
- Geolocation- The availability of GPS within mobile devices enables quantitative and qualitative data to be geo-located (Welsh et al., 2012; Sebastián López and De Miguel González, 2020).
- Off-the shelf apps- These apps downloaded to mobiles enable a mobile to be used as a measurement instrument and/or a tool for data collection, e.g., lux meters, decibel meters and annotating photos (France et al., 2016; Cross et al., 2020).
- Customiseable apps- Apps that enable a user to personalize the function of the app to be suited to the purpose of their data collection, e.g., ArcGIS Field Maps (Bettinson and Bird, 2021; Phantuwongraj et al., 2021).
- Specialist features- Some specific models of mobile devices have in-built features which are not present on all mobile devices on the market, e.g., LiDAR function of iPhone 14 (Tavani et al., 2022; Zizka et al., 2022).

Utilizing apps on mobile devices is a quick and easy way to support learning within the field (Welsh et al., 2013, 2015) with opportunities to enhance the fieldwork via geo-location, communication and collaboration with data exchange (France et al., 2016; Phantuwongraj et al., 2021; Xie et al., 2021). Students have identified that using a mobile device during fieldwork supported the authenticity of the fieldwork data collection and provided a motivation for the data collection (Huffling et al., 2014).

A key affordance of using mobile devices within fieldwork include the saturation of mobile devices within the HE population. Students have an ever-increasing access to a variety of smart devices at their disposal, with the percentage ownership of the following devices amongst students within the UK (93% smart phone, 93% laptop PC and 67% Tablet) (Collins, 2022). Such high levels of ownership supports the recognized advantages of a 'Bring Your Own Devices' (BYOD) approach to fieldwork (Welsh et al., 2018; Clark et al., 2020). A BYOD approach coupled with institution led- digital poverty initiatives to tackle access and equity to digital devices means that the saturation of digital devices amongst students in HE is high.

Due to this saturation, mobile devices are a fieldwork technology that learners are already familiar with, requiring minimal onboarding to their use within fieldwork settings (Welsh et al., 2018). With learners themselves identifying that they know more about how to use mobile devices for learning than their professors (Pearson, 2015).

However, resource implications of using mobile devices in the field exist for some individuals and some departments (Fletcher et al., 2007). Additionally, despite BYOD initiatives, there is still an unwillingness for students to use their own device during fieldwork (Welsh et al., 2018) with concerns about damage preventing their use (Clark et al., 2020). Beyond the unwillingness there is an identified hesitancy to use technology in the field, with learners recognizing that mobile devices are distractors (France et al., 2016), with this distraction resulting in an overall reduction in the time spent on task within the field (Thomas and Munge, 2017). A barrier of using mobile devices in fieldwork is the capacity, knowledge and motivation of facilitators of fieldwork to embed technology use within fieldwork (Fletcher et al., 2007; Clark et al., 2020) with the hidden cost requirements of developing these technology enhanced fieldwork approaches (Thomas and Munge, 2017) also playing into this motivation.

These student and facilitator barriers inhibit a successful integration of mobile devices in fieldwork to enhance learning. Whilst practitioner-led frameworks such as The Pathways Diagram (France et al., 2021) present a working guide to support the adoption of mobile technology. The holistic reflection offered by combining a pedagogic framework with technological considerations within The Pathways Diagram is limited in its function as it remains practitioner focused. It relies on facilitators of fieldwork having the capacity, knowledge and motivation to embed mobile technology within fieldwork, additionally it does not incorporate the experiences of learners, which have been found to support the integration of technology (Rogers, 2020).

Students play a passive role in the majority of studies into DFNs, with them limited to giving feedback after using a DFN which has been provided for them during their fieldwork (Medzini et al., 2014; Lee et al., 2020;Senger and Nordmo, 2021; Xie et al., 2021). The mixed picture presented within the literature of the affordances and barriers of using mobile devices in fieldwork alongside this passive role presents an opportunity to work with students to design and integrate a DFN within bioscience fieldwork. This approach would aim to address the need for a more thorough reflection on the learning process of using a DFN (Senger and Nordmo, 2021). Additionally, although location-based functions of mobile apps have supported spatial thinking and understanding within Geography, Earth and Environmental Science (GEES) disciplines (Senger and Nordmo, 2021; Xie et al., 2021) this research seeks to extend this within DFN use within the biosciences.

Through an initial exploration phase this research seeks to bring together practitioner and student views of using digital tools during bioscience fieldwork (digital fieldwork). This information is used to better support the development and integration of a DFN within in-field fieldwork experiences. Garnering the saturation and familiarity of mobile devices this research works with learners as active participants who trial the DFN within the design phase. It aims to connect learners to the education development process through supporting the design, development and integration of a DFN within bioscience higher education fieldwork by exploring learner experiences of using a mobile device with tailored mobile app to create the DFN, this research aims to better understand how learners view and value the use of mobile devices as a tool to support digital notetaking within bioscience fieldwork. Specifically, this research aims to (1) analyze how fieldwork practitioners and learners view the role

of technology in the field, (2) investigate learners' experience of using the DFN during bioscience fieldwork within HE and (3) utilize these learner experiences to make changes to the DFN and support its use and integration with learners.

2 Methods

2.1 Context

This educational research can be defined as Action Research (AR), whereby digital tools have been developed by author one in response to both practitioner perspective and student voice outputs of an initial exploration phase and to address a specific challenge in fieldwork identified. Inspired by the arguments for AR by Papadopoulou (2020), this research will focus on actionable knowledge. With learners themselves active participants with their ideas contributing to change. Working in partnership with students (Healey et al., 2014), students are empowered and engaged in supporting an iterative design process of the digital intervention.

It is underpinned by a pragmatic epistemological basis. In particular, a Deweyan pragmatism shared in Hammond (2013) whereby both our experiences form our sense of reality and acknowledge the role that a researcher plays in that. This collaboration between myself as both postgraduate researcher and fieldwork practitioner, and learners themselves strikes to ensure that outputs from this research are grounded in the experience.

A predominantly inductive approach is adopted with theories developed from the data rather than being imposed beforehand. Themes presented within this research represent what participants have communicated within the research, but there is an acknowledgement of the role that the researchers has played in constructing those themes.

2.2 Exploration phase

The purpose of the exploration phase was to capture interested parties' views, perceptions, challenges, and ideas associated with fieldwork and digital fieldwork and consisted of student focus groups, expert panel interviews and fieldwork practitioner surveys.

2.2.1 Student focus group

Four student focus groups were conducted with a total of 22 participants (FFG A-V) All focus groups lasted between 60 and 90 min. Three of the focus groups were in person during residential field courses with a total of 14 student volunteers from the same UK institution; six postgraduate students enrolled on a Habitat Monitoring and Assessment Module, three undergraduate year 2 Biology students and five undergraduate year 2 Marine Science students. Each focus group was conducted by author one, audio recorded with a whiteboard used to record participant contributions.

The fourth was an online focus group hosted via Zoom with eight members of the Field Studies Council (FSC) Youth Council who were invited to attend on a voluntary basis. The FSC Youth Council is a group of young student naturalists aged 16–25 from across the UK who act as representatives for other young people who engage with the FSC. This focus group was conducted by author one, with FSC's Youth Engagement Officer present. The focus group was recorded with a shared digital whiteboard used to record participant contributions.

Within each focus group students were asked to share the challenges and opportunities associated with in-field fieldwork and virtual fieldwork. Time was given for individual reflection, individual sharing, and group discussion. A copy of the focus group schedule is included within the Supplementary material.

Each focus group was transcribed and analyzed using the six-stage analytical guidance applied to reflective thematic analysis (Braun and Clarke, 2019, 2020) whereby the researcher is actively involved in producing themes from the data. A predominantly inductive approach was used, this was chosen as the research aims to classify and define views and perceptions so it is vital that codes can best represent what participants have communicated. Deductive analysis was essential to ensure that the open coding was relevant to the research aim to identify challenges and opportunities determined with both semantic and latent coding with frequency recorded using NVivo qualitative analysis software (QSR, 2020).

2.2.2 Expert panel interview

Ten interviews were conducted with identified 'leaders of the field' (utilizing direct knowledge of the fieldwork sector from author one) whose roles are shown in Table 1. Representatives from diverse HE institutions with contrasting fieldwork and digital teaching experiences were sought, alongside teaching and learning colleagues within subject associations and experts from industries involved with practical fieldwork and digital tools to support fieldwork. Participants were contacted directly by author one.

These semi-structured interviews enabled participants to share their background and experiences within fieldwork, as well as their views on the purpose, challenges and opportunities present within fieldwork and digital fieldwork. A copy of the interview schedule is included within the Supplementary material.

Each interview was transcribed and analyzed as outlined in 7.2.1.

2.2.3 Fieldwork practitioner survey

Open questions were used to capture practitioners' views on the challenges experienced and under-utilized opportunities within in-field and digital fieldwork. Closed questions were used for

TABLE 1 Job roles of expert panel.

Participant code	Role
EXP A	Industry (Environment Agency)
EXP B	Subject Association/Industry (Field Studies Council)
EXP C	Subject Association (British Ecological Society)
EXP D	Subject Association (Geographical Association)
EXP E	Higher Education (Cardiff University)
EXP F	Higher Education (Open University)
EXP G	Subject Association (Royal Geographical Society)
EXP H	Higher Education (Manchester Metropolitan University)/ Industry (Ecological Consultancy)
EXP I	Teaching and Learning Community
EXP J	Industry (ESRI UK)

participants to identify the purpose of digital fieldwork. The option responses for this closed question were informed by the themes and findings of the Expert Panel Interviews.

The practitioner survey was promoted through Newcastle University School of Natural and Environment Science Academic Groups, Newcastle University Teaching and Learning Groups, British Ecological Teaching & Learning Special Interest Group, Enhancing Fieldwork Network, Field Studies Council education network, Nature Friendly Schools education network, Geography and Science 14–18-year-old teacher networks and through Twitter. A copy of the survey is included within the Supplementary material. Fifty seven survey responses were received, 24 of which defined their job role as a Fieldwork Practitioner, 15 as a Teacher (School and College), eight as a HE Lecturer, four as Education Support within HE. five survey responses described their job role as 'Other' with job roles described as a combination of the existing categories, Education Officers or as Fieldwork Specialists for awarding organizations. A copy of this survey is included within the Supplementary material.

Closed question data were analyzed using descriptive statistics to determine key summary information about the data. Open questions were analyzed using the six stage analytical guidance applied to reflective thematic analysis (Braun and Clarke, 2019, 2020) whereby the researcher is actively involved in producing themes by organizing codes around a central organizing concept that is interpreted from the data. An inductive approach was used;

this was chosen as the research aims to classify and define views and perceptions so it is vital that codes can best represent what participants have communicated but deductive analysis was essential to ensure that the open-coding was relevant to the research aim with challenges and opportunities determined with both semantic and latent coding with frequency recorded using NVivo qualitative analysis software (QSR, 2020).

2.3 Design phase

The findings of the exploration phase are informed by the design phase where the DFN was initially developed in response to data from student focus groups, expert panel interviews and a fieldwork practitioner survey. The DFN was developed to better connect the classroom with the field, and offer a hybrid fieldwork delivery mode. The DFN consists of a tailored survey developed in ArcGIS Survey123 and accessed via the ArcGIS Survey123 app on a mobile device. This DFN was then trialed by a second group of learners via a process evaluation with feedback from these users used to re-develop and improve the DFN for future use.

The process evaluation was conducted with seven students from second year Marine Science programs at the same UK institution who were enrolled on a residential field course module (TiFPE A-G). Participation was voluntary, with all process evaluation activities taking place alongside the residential field course.

2.3.1 Trialing the DFN

On day two of the residential field course, student participants were provided with the link to the DFN and briefed on how to use the app. Students decided which device they wanted to use for the DFN (personal mobile device or tablet device provided). All students were offered the use of a waterproof case for the device. They were asked to use the DFN alongside the fieldwork tasks set by the fieldwork facilitators over the next 3 days.

2.3.2 Student user survey

Student participants completed a paper survey at the end of their residential field course. Using a mix of open and closed questions, it aimed to capture the student experience of using the DFN and gather feedback on the challenges experienced, what they liked, a reflection on the skills developed and suggestions for improvement to the DFN. A copy of this survey is included within the Supplementary material.

2.3.3 Student focus group

Two semi-structured in-person focus groups were conducted with author one facilitating on days five and six of the field course. One focus group had four participants and the other had three participants. This split was determined by participants' availability within the field course. The focus group questions were designed using a 'funneling' approach (Breen, 2006). Firstly, starting with general introductory questions, on students' experiences of the field trip, before asking about awareness, attitudes, and behaviors of using mobile devices in the field and trialing the DFN. Finally, attitudes to improving the app were considered. A copy of the focus group schedule is included within the Supplementary material.

The focus groups lasted around 60 min, were recorded and transcribed. The open questions within the survey and focus group data was analyzed using the six stage analytical guidance applied to reflective thematic analysis (Braun and Clarke, 2019, 2020) whereby the researcher is actively involved in producing themes by organizing codes around a central organizing concept that is interpreted from the data. An inductive approach was used as the research aims to classify and define opinions on using the DFN and suggestions for improvements, so it is vital that codes can best represent what participants have communicated. Yet deductive analysis was essential to ensure that the open-coding was relevant to the research aim of supporting the re-development of the blended fieldwork resources using both semantic and latent coding. These suggested areas of improvement identified within the process evaluation were grouped together using the categories of pedagogy, technology, and content development.

3 Results

3.1 How do fieldwork practitioners and learners view the role of technology in the field?

When asked to consider the purpose of digital fieldwork, four out of the five highest selected responses from fieldwork practitioners can be associated with using technology in the field (Figure 1). Wrap-around support which connects classroom and field, the development of subject specific digital skills such as GIS, providing spatial and temporal considerations, and promoting efficiencies in fieldwork can all be achieved using mobile devices in the field to collect and collate fieldwork data. This means that practitioners can identify value in digital fieldwork. This value is

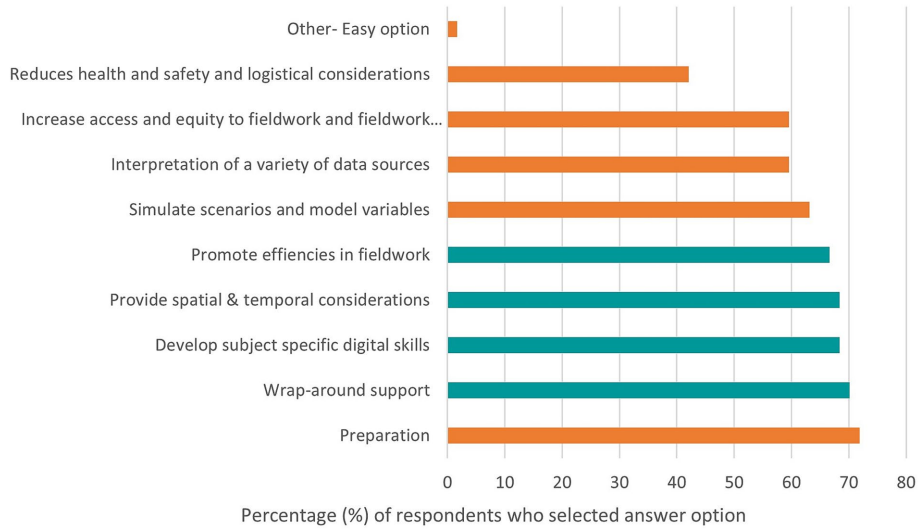


FIGURE 1
Percentage of respondents ($n = 57$) who selected each answer option in response to the question- What do you think is the purpose of digital or virtual fieldwork? Answer options in green are those associated with technology use in field. Answer options in orange are those not associated with technology use in field.

broad through enhancing what can be done during fieldwork (spatial and temporal data sets) expanding the objectives of fieldwork (digital skill development) and aiding in fieldwork logistics (cost and time savings).

Both learners and facilitators of fieldwork were asked to consider the role of technology in the field. The identified challenges and opportunities are shown in Table 2, with evidence from expert panel interviews, facilitator surveys and student focus groups to support these themes (Table 3).

Learners identified the opportunities of using location-based functions to support the logistics, efficiency and rigor of their fieldwork and for specific apps to support their identification skills. Facilitators of fieldwork recognized the role that technology could play in engaging the widest range of learners. Facilitators of fieldwork also identified that technology in the field using mobile devices was predominately a technology that learners were already comfortable with using, reflecting on the benefits of this endemic technology. Using mobile devices for augmented reality in the field was an opportunity identified by facilitators, with the technology supporting spatial, temporal considerations via modeling of variables and scenarios.

It is promising that both learners and facilitators recognized that technology in the field provides opportunities for a hybrid mode of fieldwork that uses both in-field and digital fieldwork tools to develop GIS and digital skills.

A lack of appropriate equipment (mobile device with access to mobile internet that learners are happy to use or availability of institution owned mobile devices that learners can loan as fieldwork equipment to use in the outdoor field environment) was a challenge identified by both learners and practitioners alike. This highlights that the digital divide, resource availability of digital devices and willingness to use personal devices in an outdoor setting is an access challenge recognized by both facilitators and learners within fieldwork.

TABLE 2 Learner and facilitator identified challenges and opportunities of using technology in the field.

	Challenges	Opportunities
Learners	Performance Views about technology	Apps Geo-location
Both learners and facilitators	Lack of equipment	Hybrid fieldwork approach GIS/Digital skills
Facilitators	Identification	Augmented reality Endemic technology Support engagement

Whilst learners recognized the opportunities that identification apps could bring to their fieldwork, facilitators of fieldwork identified the shortcomings of these apps, and how approaches to teaching with these apps needs to be altered to develop students critical use of these apps.

Within the exploration phase student focus groups learners identified specific performance issues of using technology in the field such as draining battery and inability to see screens both exacerbated by particular weather conditions during fieldwork (Table 3).

Personal negative views or perceived negative views about the technology were also an identified challenge by learners. Understanding that learners may hold negative views and perceptions and/or that they might think others do is important to consider when designing approaches to use technology in the field.

Learners shared the functions that they used their mobile device for during fieldwork; video, camera, social media, species identification and note taking. Three of the tasks that students identified they used their mobile for during fieldwork (video, camera, social media) are functions that they would already use in their everyday lives but applied in a fieldwork setting. Notetaking

TABLE 3 Evidence from learner focus groups, expert panel interviews and facilitator surveys to support identified challenges and opportunities.

Identified opportunities	Apps	*"Use of apps for identifying things. I feel like this has moved on quite a lot like getting better and better, I feel like that helps a lot." (FFG N)*
	Location	*"You could share everyone else's location…help us on selecting sites." (FFG R)*
	Hybrid	*"If you can upload the data to the cloud in the field, we can have someone who is not able to access the field…they can eyeball the data…give informed verification back to those in the field…inform the next bit of fieldwork." (EXP I)*
	GIS/Digital Skills	*"Digital at point of capture…synthesis of data and building understanding through the support of digital technology whilst still being in a place." (EXP J)*
	Augmented Reality	*"Look at the landscape, looking how different management in this landscape could look quite differently suddenly…ok let us turn off this feature so let us turn off grazing animals." (EXP H)*
	Endemic Technology	*"…endemic technology, so what I mean by that is that it allows students to use things which they are, they have natural ability to use. So their smart phones and things like that." (EXP I)*
	Engagement	*"Give it to the student that's not wanting to integrate, and you make them the data recorder, and suddenly they are the most important person…so you can use it as a link to engage." (EXP J)*
Identified challenges	Performance	*"In the cold battery drains quite quickly?" (FFG S)*
	Views about technology	*"Push back in conservation with sort of adopting technology…because they are out in the field and that's the enjoyable bit…they do not want things to become quicker, more efficient." (FFG R)*
	Lack of equipment	*"We struggle for access to computers to plan work and have no in-field recording equipment or apps." (Facilitator survey)*
	Identification	*"So yes, by all means use that technology (apps to support identification) but think of backing up, being critical I suppose of our thinking…" (EXP H)*

and apps to support species identification such as Seek from iNaturalist are apps with functions for specific use within a field setting. Of the five tasks identified, social media was the function that could be described as a distractor to the fieldwork learning task. The rest of the tasks were all on on-topic functions that support learners within their fieldwork tasks.

Based on these practitioner and student views of technology use during fieldwork a digital fieldwork approach was developed. This approach utilized a mobile device, because of its ease of use and ubiquity of these amongst the student population. Drawing upon specific functions of a mobile device identified (locational capabilities and photos), and existing use of a mobile device during fieldwork (note taking and species identification), a DFN was developed to to better connect the field with the classroom and offer a tool to support students notetaking during fieldwork.

3.2 What are learners' experiences of using a digital field notebook during fieldwork?

Five out of seven users found the DFN easy to use, but four out of seven users found using the mobile device in the field difficult. Whilst this represents the ease and functionality of the DFN itself, it presents a fundamental barrier of learners using mobile devices within fieldwork. After trialing the app learners reflected upon their likes and shared the challenges experienced.

Learners liked that the DFN provided a tool to support their reflection; *"Gave me time to stop and reflect." (TiFPE E- user survey)* Providing opportunity to consider the fieldwork itself but also how they were feeling in the moment; *"I was just looking around, like, yeah, I feel quite peaceful here. I would not have thought like that." (TiFPE F- focus group)*The ability to attach qualitative data to the DFN was supported students' reflections. *"Can attach pictures so I remember which site is which." (TiFPE A- user survey).*

The ability of the DFN to offer more than just data collection was highlighted; *"Each of the questions made me think more about the environment we were working in on a larger scale and context." (TiFPE C- user survey)* With students commenting on the DFN's role in connecting learners to the place shared; *"I found the questions quite humbling actually…And there was a lot of numbers on the sheet, but there is animals and actually I'm on a beautiful coast in Scotland not just on a random sediment shore collecting data…it felt like it mattered… like I'm not just counting numbers for no reason." (TiFPE D- focus group).*

Learners identified specific challenges with the functionality of the app, such as issues with logging out and editing previous entries to the DFN which can easily be remedied. However, some of the other challenges such as environmental barriers to using the DFN in the field are not so easily tackled.

Learners identified that the weather conditions of the fieldwork impacted their desire; *"Actually using the app in the field, like getting your phone out when it's cold and wet." (TiFPE C- focus group)* and ability to use the DFN during fieldwork, "*Cannot type when fingers are cold and wet." (TiFPE A- user survey)* with a preference for paper-based notes shared due to their ability to withstand the conditions of fieldwork better, a high level of flexibility offered with paper-based notes; *"On paper you can just do whatever you need to do."(TifPE E- focus group)* Interestingly students reflected on a challenge of the DFN being the permanency of the notes, with paper-based note taking in the field better supporting edits and revisions; *"It's easier to make mistakes on paper." (TifPE D- focus group).*

Finding time to use the DFN was another challenge identified by learners of using the DFN; *"In the field, rarely able to find time and remember to use the app."* (TiFPE B- user survey) With pressures of the

data collection and fieldwork assessments limiting their time to use the DFN; *"I wasn't thinking about the DFN because I was thinking about the assignments that had to be done and about the test…I feel like if it was like a formative field trip, we would use the app a lot more."(TiFPE D- focus group).*

Students commented on the separation of the fieldwork task and the DFN; *"Like it was two separate tasks really. Like we were doing the data, then we were doing that." (TiFPE C- focus group).*

3.3 How could learners' experiences of using a digital field notebook during fieldwork be improved?

A fundamental aim of learners trialing the DFN was to gather user feedback on improvements to the DFN. Feedback can be summarized into three overarching feedback themes related to pedagogy, technology, and content. Student voice was used to exemplify the sub-themes identified from the focus group and student survey (Table 4).

From the user feedback related to pedagogy, three sub-themes were identified. Firstly, students felt that time to use the DFN alongside quantitative data collection during fieldwork was limited. With the reflective nature of the question prompts requiring students to make observations in the field, and then revisit, edit and add to post-fieldwork. Secondly, although the DFN was part of their fieldwork students were still hesitant to use the DFN in the field. Students shared that they were not sure whether they had permission from the facilitator of the fieldwork to be online during the session, viewing mobile use as a distractor in the field and something that is not allowed during an outdoor fieldwork session. Thirdly, students were not always able to identify the value of using the DFN with other aspects of fieldwork, e.g., quantitative data collection taking priority. Interestingly, students gave precedence to time developing their identification skills for a summative taxonomy assessment without recognizing the role that the species observations recorded in the DFN could play in developing those skills.

Students also gave feedback related to the content of the DFN. The first content sub-theme referred to generalized questions with the DFN, with students sharing that they did not always see the relevancy of these generalized questions to the specific fieldwork task and location that they were working in. Secondly, students gave feedback related to the extent and number of open questions within the DFN, with students suggesting more closed questions or multiple choices within the DFN. Thirdly students gave feedback on the required emotional literacy to engage with some of the question prompts in the DFN. Students suggested that not all students would know how to respond to the Nature Connection prompts, and would require some support with this.

There were two sub-themes related to technology feedback related to the DFN. The first related to a desire to input data into a single map rather than students adding observations to their own map. Students suggested that collaborating with other students through collating DFN observations into a single map provided the opportunity for peer learning through reflecting on their peers shared observations. Secondly, students identified that there were still barriers to using technology in the field environment, with mobile devices being difficult to use in cold and wet conditions in particular. In reflecting upon this summary of feedback during the user-testing, nine developments were made to the DFN (Figure 2) in direct response to the feedback themes

TABLE 4 Pedagogic, content and technology development feedback themes.

		Supporting evidence from student focus group
Pedagogic development	Time to reflect	*"I feel like if I filled them in afterwards they would have been more useful, more detail." (TiFPE A- focus group)*
	Permission to use	*"…it felt a bit rigid, getting our phones out and doing it…Like if I'm being honest out in the field, I would not want to do that…Like I do not mind writing stuff down if it I know it's going to be relevant later on. But maybe it it's drilled into use that you should not take them out in this kind of environment, weather and all this kind of stuff." (TiFPE C- focus group)*
	Seeing value in the app	*"…we were very time constrained this week. Like it was very much like, yeah I wasn't thinking about the app because I was thinking about the assignments that had to be done and about the test on taxonomy. I feel like maybe like if it was just a formative field trips, we would use the app a lot more." (TiFPE D- focus group)*
Content development	Applicability to fieldwork	*"Yeah yes, I guess, all the questions are quite general. If you are doing very different practicals at each place, some of the questions might be more relevant and you might do something where like none of the questions are really relevant…" (TiFPE E- focus group)*
	Streamline questions	*"I think one thing I was thinking about was maybe having more multiple-choice questions so it's like we could complete quickly." (TiFPE A- focus group)*
	Emotional literacy	*"Like again on the personal questions like you know… they are quite vague and when it comes to matters like that where you are vague it's very hard to get like the answer you are looking for or the right answer. And so, it's a bit like I do not know if like 'airy fairy' is right." (TiFPE B- focus group)*
Technology development	Single map	*"But it would be good to be able to engage with other people. Because it's just yours then. But it would be cool to see what other people said about it, how everyone's like links together, but I think that would be quite cool." (TiFPE C- focus group)*
	Removing barriers to using technology in the field	*"Again, in the field it's sometimes like pissing it down with rain, it's windy and it's cold and your hands are getting freezing, and it's hard to type. It sounds pathetic but like it's like what being in the field is like." (TifPE B- focus group)*

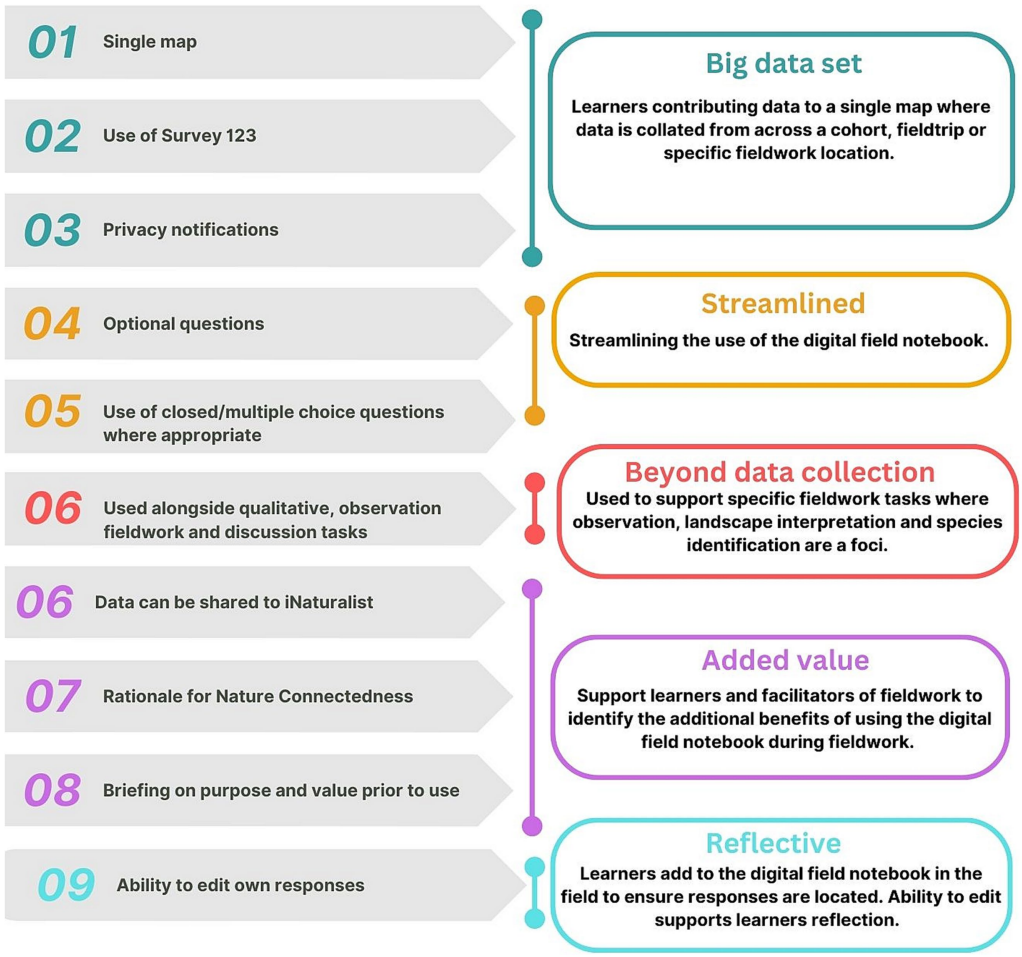


FIGURE 2
The nine developments made to the DFN based on feedback from the process evaluation. These developments can be summarized in supporting the DFN to collate a big data set, use streamlined questions, encourage reflection and landscape interpretation, better communicate a rationale of the DFN to learners and give the ability for learners to edit to support good reflective practice.

identified from the student feedback. In opting for a single map where all student entries are collated, and learners contribute to a DFN big data set. A privacy notification needed to be added to the DFN, so students could give informed consent before sharing DFN entries. Using ArcGIS Survey123 app as the host for the DFN meant that individual students did not need to sign-in to an account and could access to the DFN offline. Questions within the DFN were also adapted to provide a more streamlined user-experience. Questions were made optional, meaning that students could skip sections of the DFN entry, and where appropriate closed questions using categories were included. To support learners and facilitators to identify value in the DFN, questions related to species identification during fieldwork could be downloaded and shared with iNaturalist. Students' direct fieldwork observations can contribute to species records at a location. Questions within the DFN related to Nature Connectedness now include a brief rationale so students can develop a better understanding of the concept of Nature Connectedness and build awareness of the benefits of connecting with nature. A short briefing is now given to students prior to using the DFN where the benefits and rationale for using the DFN are shared. It is recommended now to facilitators of fieldwork that the DFN is used alongside qualitative observation-based fieldwork where facilitators can support students to engage with landscape interpretation and observation via discussion. This means that students do not feel this conflict between a quantitative fieldwork data collection task and adding reflective observations and species identification entries into the DFN. In maintaining the reflective nature of the DFN, users could then edit their own responses within the DFN. This means that students could add geo-located entries in the field but return to those entries post-fieldwork to add additional reflections and notes where needed. Based on user feedback Table 5 summarizes some 'Do's and Don'ts' when adopting a DFN in bioscience fieldwork.

This DFN was designed to connect the classroom with the field, a final case study template of the DFN as a digital fieldwork approach is summarized within Figure 3. Content of the DFN app was identified, alongside providing facilitator notes on the time and resources to implement the DFN, as well as identifying any remaining pitfalls, problems, or limitations of the DFN.

A workflow schematic (Figure 4) for the construction and use of the DFN identified specific roles that facilitators and student users of the DFN performed, as well as the transfer of information through the DFN. This schematic alongside potential additional uses of a DFN within bioscience fieldwork (Figure 5) may provide advice and inspiration for those wishing to implement a DFN within their own bioscience fieldwork.

TABLE 5 Recommendations for implementing a DFN within bioscience fieldwork.

Do not	Do
Do not assume that learners will have access to or be willing to use their own mobile devices in the field.	Do consider adding mobile devices/tablets to the institution's fieldwork equipment. Ensure there is access to universal waterproof cases for learners' own mobiles.
Do not assume that learners will be able to use their own mobile data to access the DFN.	Do ensure that the DFN can work offline. Meaning the DFN can be downloaded to a mobile device using Wifi prior to departing into the field.
Do not expect that students will prefer using a DFN to paper-based notes.	Do share the value of using digital notetaking and the benefits of using the DFN over paper-based notes to support learners' uptake and usage of the DFN.
Do not just use the DFN in the field.	Do download data collected within the DFN post-fieldwork and share observations with others, e.g., via iNaturalist. Do use the DFN as a formative assessment opportunity to check students understanding of the fieldwork location and their skills in species identification. Do encourage students to review the dashboard of collated DFN entries as a peer learning opportunity to reflect upon their fieldwork experiences.
Do not create a new DFN for every fieldwork opportunity.	Do continue to add DFN observations into the single map. This will build a student curated big-data set of fieldwork observations which can be filtered by location and date.
Do not worry if learners are initially hesitant to add observations into the DFN.	Do ensure privacy notifications are shared, observations are posted anonymously, and learners are able to edit their own individual observations within the DFN.
Do not expect every student to contribute to the DFN.	Do set aside time within the fieldwork for students to enter observations in the DFN. Do use the DFN as a tool to support the engagement of some students who may be hesitant to participate during fieldwork.

4 Discussion

4.1 Incorporating student views during co-design

Feedback on the DFN from students who trialed it provided useful developments that improved the DFN, supporting the view that learners' experiences can enhance this technology integration. However, whilst technology and pedagogic considerations for integrating a mobile device in fieldwork are important (France et al., 2021) and recognized by learners within this research, the impetus to adopt the use of a digital tool within fieldwork should come from an identified pedagogic need to support a purposeful adoption of digital technologies (Edwards and Larson, 2020) and within this study learners did not always recognize the value of a mobile as a learning tool.

Participants within this study shared that their views of technology use was affected by their own experiences of using technology within education settings as well as the perceived views of technology by? the facilitators. Perception studies on mobile use within fieldwork and education tend to focus on either student views (Welsh et al., 2015, 2018) or facilitator views (Teo, 2009; Welsh et al., 2013; Gillies, 2016). Linking together of these two invested parties through a co-creation design process (Bovill and Woolmer, 2019) such as the one used to develop the DFN encourages a better understanding on the views and perceptions of mobile use in education, enabling facilitators of fieldwork to modify their behaviors to better communicate the value of mobile devices in their teaching and build students understanding of facilitators motivations in technology adoption allaying concerns that students may have about using technology in the field building respect, trust and sharing responsibility over the education development (Lubicz-Nawrocka, 2018).

Learners who trialed the resources suggested content, technology, and pedagogy developments that they believed would improve the experiences of using the DFN within fieldwork. Additionally, within the exploration stage of this research learners were able to suggest opportunities for technology use within the field. This is in contrast to another co-creation study whereby students could critique digital and technology enhanced learning within higher education but struggled in suggesting their own ideas (Gros and López, 2016). Allowing learners space and time for free-form exploration has been recognized as enabling *"spontaneous development"* where learners found alternative or more effective ways of using the mobile apps within fieldwork (France et al., 2016). The methods used within this current research enabled students' ideas to be incorporated into the conception of the DFN and in the developments made in response to suggestions from learners who trialed the app. It has been recognised that in co-creation processes of developing technology enhanced learning, co-creators can default to traditional roles of teacher as expert and student as novice; with teachers not honoring student voice within the co-creation process (Gros and López, 2016). The combination of responsive feedback mechanism process (Viswanath et al., 2019) adopted within this current research, and a postgraduate researcher facilitating the co-creation process may have enabled student experiences of the app and suggestions for improvement to be valued and incorporated within redesign. In enabling students to trial the DFN before giving feedback, new areas of challenge were identified not previously uncovered within the exploration stage of this research such as finding time within busy fieldwork schedules to use the DFN, as well as specific development suggestions related to the content, pedagogy, and technology development of the DFN. Although not surprising, it does emphasize the value in working with students and valuing student voice at exploration, design, and development stages of education development of this DFN.

Digital Field Notebook

Aim

- Support the connection between field and classroom.
- Provide opportunity for learners to develop GIS skills and grow a personal connection to a fieldwork location.

Technology required

- Mobile devices with location capabilities enabled.
- ArcGIS Survey 123 app.
- ArcGIS Dashboard.

Time to implement

- Creation of the digital field notebook proforma in Survey 123 (15 minutes).
- Briefing to students- Purpose, Download app/survey, build familiarity with app. (30 minutes).
- Post fieldwork creation of Dashboard to share collated entries from digital field notebook (30 minutes)

DFN content

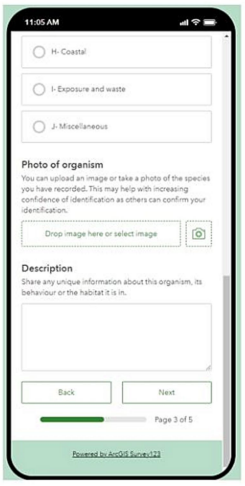
- Location
- Species ID & confidence of ID (self-assessment)
- Habitat classification
- Description of species behaviour and/or identifying features
- Photo
- Landscape interpretation
- Nature Connection

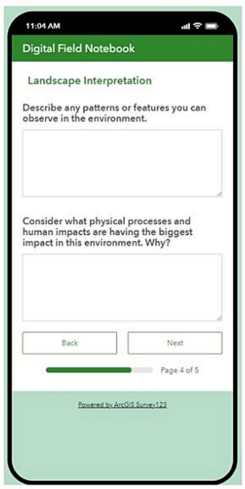
Evidence of effectiveness

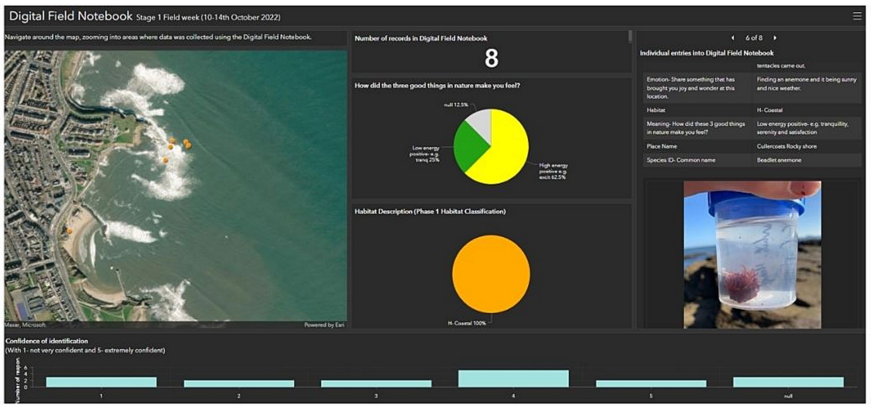
User-testing informed the re-developed digital field notebook.

Pitfalls, problems, limitations

- Environmental barriers to learners willingness to use mobile devices during fieldwork. remain.
- To use offline learners must download app and survey before beginning fieldwork.
- Mobile device must have location enabled.







Scan me to view an example of the Dashboard sharing the collated entries of the DFN

FIGURE 3
Case study of using a DFN during fieldwork.

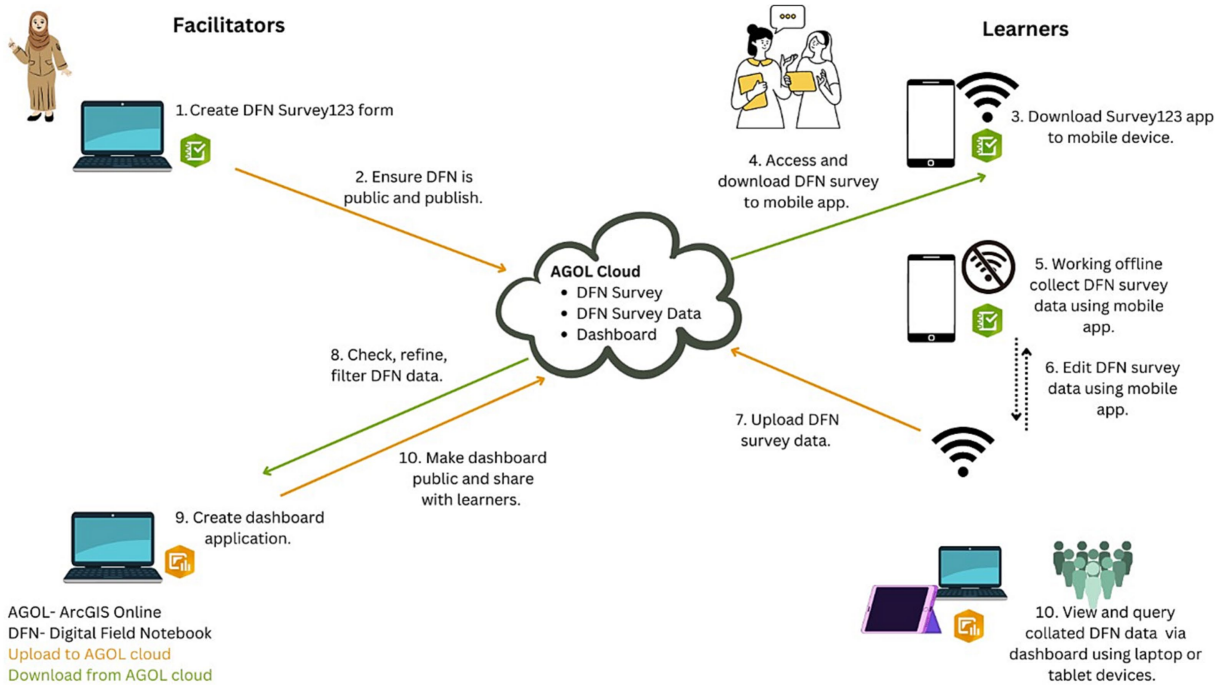


FIGURE 4
Workflow for constructing a digital fieldwork teaching tool using ArcGIS online (AGOL) tools. In this workflow the facilitator constructs and publishes the ArcGIS Survey 123 survey, to which the students are responsible for collecting and uploading data to the DFN. Facilitators use this collated data set to construct a dashboard for all students to view and query the collated DFN data.

4.2 Beyond data collection to skill development

The scaffolded questions within the DFN provided an opportunity for reflective practice. Reflective fieldwork diaries are different to traditional field notebooks, encouraging a move to interpretive and analytical writing (Dummer et al., 2008). Despite learners recognising the value of reflective practice in fieldwork, this reflexivity was found to be harder to embed, with learners citing difficulties in balancing this reflection with the need to collect the quantitative fieldwork data for a specific fieldwork task. This may be due to the quantitative nature of fieldwork associated with bioscience and ecology disciplines or learners struggling to identify the value of reflective practice. Reframing the reflection, where this reflection informs planning, next steps and future research could better support learners to see the links between reflection and data collection (Lee et al., 2020).

The development of digital skills such as GIS skills have been identified as reasons for introducing technology within fieldwork both within this research and within the literature (Welsh et al., 2013; France et al., 2016; Bos et al., 2021; Phantuwongraj et al., 2021; Xie et al., 2021) with the development of digital literacies supporting students' employability post-HE (Peacock and Bacon, 2018) through the development of graduate attributes (Derounian, 2017). The location-based functions of mobile apps have supported spatial thinking and understanding of spatial relationships in geology and geoscience (Senger and Nordmo, 2021; Xie et al., 2021). The DFN within this current research provides an opportunity for spatial interrogation of fieldwork data within a bioscience context, with the potential for learners to acquire 21st century skills (Huffling et al., 2014). However, whilst adding to the growing literature on how using digital technologies in fieldwork provide opportunities to develop digital skills, this research has identified that these were not recognized in the feedback by students trialing the DFN within the study. This identification of digital skills and the application of GIS skills within fieldwork remains a challenge to be addressed when using DFNs in fieldwork.

4.3 Being collaborative in the field through data collation

Three of the developments to the DFN made in response to design phase user feedback from the student user survey and student focus group resulted in the opportunity to create a student authored big data set of observations. There is a recognition that field trips provide an opportunity for students to build and develop communities of practice (Streule and Craig, 2016) and an increased connectedness to the fieldtrip cohort (Walsh et al., 2014). Carefully designed group tasks within fieldwork have been identified as providing opportunities for those learners that might be on the periphery of a community of practice an inbound trajectory into the collaborative group environment (Wenger, 1998). The presentation and sharing of collated entries to the DFN provided an inclusive opportunity for collaboration across the fieldtrip cohort. The remote collaboration afforded by the DFN could support a hyperlocal model of fieldwork (Venter et al., 2020) whereby all learners; regardless of where they are situated for the fieldwork; can contribute to the collated set of observations building a community of remote learners.

FIGURE 5
Potential additional uses of a DFN to inspire fieldwork practitioners to use a DFN to enhance bioscience fieldwork.

In-field peer-peer and peer-facilitator communication using mobile apps can either be synchronous (France et al., 2016; Lee et al., 2020; Xie et al., 2021) or asynchronous (Phantuwongraj et al., 2021; Senger and Nordmo, 2021). A judgement on the affordances and possibility of synchronous communication relies on the need for mobile signal. In some field situations where mobile signal is unavailable or where it is not appropriate for learners to use their own data on their own devices, asynchronous offline communication is preferred. Mobile apps such as ArcGIS Survey123 allow both offline and online collaboration to support knowledge transfer (Lee et al., 2020) using mobile devices either synchronously or asynchronously within the field.

Most of the studies into mobile use within fieldwork focus only on the functionality of the device and app within the field environment (Hein et al., 2011; Huffling et al., 2014; France et al., 2016) Like Phantuwongraj et al. (2021) where collated geological maps were shared back to students via a ArcGIS Webmap application, this research shares the DFN collated data entries of reflections, species records and environmental observations back to the students using ArcGIS Dashboards. This use of a DFN as a digital tool to link classroom and field and support collaboration in-field within biosciences is a particular affordance, one which is not well explored within bioscience fieldwork and can be used to support the integration of technology within fieldwork.

4.4 Adding value to fieldwork through place connection

Learners recognized that the connection to a place was an affordance of using the DFN, adding value to their fieldwork experience. Providing context through a variety of scales via connection to a local community, local issue, or to a wider environment scale problem has been identified as a tool to support the fieldwork learning environment (O'Connell et al., 2020). Such a focus on context and place supports learners to develop understanding about the place alongside the development of fieldwork knowledge and skills. Although the DFN provides a digital-interface to engagement with the place; which may be seen as a distractor (Thomas and Munge, 2017), it also provides an opportunity to grow students interactions with nature itself through the targeted landscape interpretation and nature connection questions within the DFN, a recommendation within Nature Enhanced learning approach (Brookfield, 2021).

Question prompts within the DFN provide scaffolded support for learners to engage with a fieldtrip location. It offers learners the opportunity to add qualitative data to their fieldwork notes in response to the following questions; (1) Describe any patterns or features you can observe in the environment. (2) Consider what physical processes and human impacts are having the biggest impact in this environment. Why?

These question prompts seek to address the challenge of observation fieldwork whereby if unprompted students miss key features of the environment (Kent et al., 1997). In using these question prompts learners engage with and interpret the landscape themselves. This removes one-way transfer of knowledge from expert to novice often found in observation fieldwork with fieldwork facilitators interpreting the landscape for students. These prompts have the potential to demystify the interpretation process associated with observational style fieldwork. Learners recognized the DFN's ability to support their connection to the place and viewed this positively.

Developing a student's sense of place within fieldwork can be a strategy to recruit and retain under-represented minorities in ecology (Bowser and Cid, 2021), widen participation in the geosciences (Ward et al., 2018) and promote inclusive practice (Morales et al., 2020). The DFN provides an opportunity for students to contribute their own sense of place with this collation of authentic voices enabling learners to access a diverse collection of learners' understanding of sense of place within a fieldwork location. This improvement to observation fieldwork can build a sense of community within fieldwork, as learners connect with a landscape and with each other (Jolley et al., 2018) with the value of this recognized by learners within this research.

4.5 Ease of use versus hesitancy to use

Within this study a complex narrative surrounding how learners view the use of technology in the field emerged. Ease of use, permission to use and hesitancy to use are all identified facets of this. Suggestions for overcoming the human perception barrier to using technology include the use of simple technology that is seamlessly integrated (Welsh et al., 2013). Although learners identified that the DFN was easy to use, the barriers and willingness to use a mobile device during fieldwork remained an issue for learners. This was not identified as being an issue with the durability of the mobile device itself, but rather the environmental conditions making using the mobile device challenging. Similar findings of using a DFN in polar conditions were identified (Senger and Nordmo, 2021). Although seemingly trivial, cold fingers were identified as an issue for learners using this DFN during a less extreme UK environment of fieldwork in winter months, when this research occurred.

Learners trialing the use of the DFN commented on their lack of awareness of a mobile device as a learning tool. While able to identify pedagogic benefits of using the DFN, they had reservations about using it based on their previous educational experiences with technology. This is supported by other research which found that students did not recognize pedagogic value of mobile devices for fieldwork (Welsh et al., 2015). This is in direct contrast to Huffling et al. (2014) who found that learners viewed technology as an extension of the scientific tools they were already using. Additionally, learners shared a hesitancy to use mobile devices in education settings, based on real or anticipated reactions of the facilitators of fieldwork and the expected norms of mobile use in educational settings.

Some research identifies that learners have a high acceptance of using mobile devices within geological field practice (Xie et al., 2021). Yet other studies find that mobiles can be viewed or perceived by learners as a distracting technology which learners use when not engaged with the learning task (France et al., 2016; Derounian, 2017). Although learners within this study; when reflecting on mobile phone use during fieldwork; predominantly had on-topic uses, even on-topic mobile use can be seen as a distractor with it reducing time spent at each fieldwork location (Phantuwongraj et al., 2021). Learners within this study identified that the use of a mobile device during fieldwork could contribute negatively to how a learner was viewed by facilitators. The perceived or real negative reactions of facilitators to mobile use in higher education settings has been identified as problematic in classroom humanities HE, where staff-student confrontations and impact on teacher-student relationships were identified as both a threat and drawback of using mobile devices (Derounian, 2017) and in clinical settings where there is a difference in norms of use between educators, clinical teams, patients and students (Harrison et al., 2019). Although it is possible to create and integrate useable, effective mobile learning opportunities within fieldwork such as the DFN, barriers to their acceptance exist for some learners in some environmental and teaching and learning conditions. Highlighting a complexity around permissions, norms and accepted behaviors of mobile devices during bioscience fieldwork in HE.

5 Conclusion and next steps

In working with students and facilitators of fieldwork this research has uncovered how these interested and affected parties view the role of technology in fieldwork. Key opportunities of the role of technology include location-based functions, improving efficiencies in fieldwork, identification support, engaging learners during fieldwork and the opportunity to develop GIS skills and digital competencies. Identified challenges include access to digital device and available of mobile data alongside specific performance issues of using technology outdoors in a fieldwork setting.

A DFN was designed to meet the needs of both learners and facilitators of fieldwork and enhance the fieldwork experience

through linking of the classroom and field. This research demonstrates value in co-creation using student voice to design and develop the DFN. It uncovers the experiences of seven students who used this DFN during their bioscience fieldwork. The students who used the DFN identified key features of the DFN which added value to their learning during the fieldwork. These included the role of the DFN to support reflective practice and the development of their sense of place and engagement with the fieldwork location through using the DFN.

The experiences of these students and their feedback also provide areas of redevelopment and improvement to the DFN. In particular the creation of a collaborative DFN using a single map, where all DFN entries are collated together providing a peer learning opportunity. Based on this user-testing, this research summarizes a case study of the DFN, presents a workflow to construct a DFN, shares advice to practitioners on implementing a DFN and offers examples of additional uses of a DFN within bioscience fieldwork.

Although the DFN is an example of a mobile GIS, and both learners and facilitators of fieldwork identified the development of digital skills such as GIS an opportunity when integrating technology in fieldwork. The learners who trialed the DFN did not identify digital skill development as a key feature of using the DFN. The development of digital literacies is often a factor pushing the integration of technology in fieldwork. This research suggests more needs to be done to make these digital skill development opportunities explicit to learners and explore further the factors that could support or inhibit digital skill recognition and development when using a DFN in fieldwork.

This research adds to the literature on student views on the integration of technology in fieldwork by uncovering complex issues regarding permissions, perceptions and identified value in using a DFN within bioscience fieldwork which warrants further research.

This research however, remains an illustrative not representative example of a DFN in bioscience fieldwork. Although the exploration phase captured a broad range of interested and affected parties views on technology use within fieldwork. The user-testing involved a small number of students from a single institution, and the experiences of these students in using the DFN may not be generalized in other contexts. Further research is needed on the impact of using a DFN within bioscience fieldwork contexts. In particular how effective the tool is at connecting the field with the classroom, and the impact of a DFN used to develop a sense of place during fieldwork.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Faculty of Science, Agriculture and Engineering Ethics Committee Newcastle University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any identifiable images or data included in this article.

Author contributions

JM: Conceptualization, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. RB: Supervision, Writing – review & editing. SM: Supervision, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work was funded by School of Natural and Environmental Sciences, Newcastle University.

Acknowledgments

The authors would like to thank all students for their valued contributions which supported the design and development of the DFN. Additional thanks to members of the expert panel for giving their time and expertise in interviews within the project.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1271789/full#supplementary-material

SUPPLEMENTARY DATA SHEET 1
Design phase student focus group schedule.

SUPPLEMENTARY DATA SHEET 2
Design phase student user survey.

SUPPLEMENTARY DATA SHEET 3
Exploration phase expert panel interview schedule.

SUPPLEMENTARY DATA SHEET 4
Exploration phase fieldwork practitioner survey.

SUPPLEMENTARY DATA SHEET 5
Exploration phase student focus group schedule.

References

Bettinson, M., and Bird, S. (2021). Collaborative fieldwork with custom Mobile apps. *Lang. Document. Conserv.* 15, 411–432.

Bos, D., Miller, S., and Bull, E. (2021). Using virtual reality (VR) for teaching and learning in geography: fieldwork, analytical skills, and employability. *J. Geogr. High. Educ.* 46, 1–10. doi: 10.1080/03098265.2021.1901867

Bovill, C., and Woolmer, C. (2019). How conceptualisations of curriculum in higher education influence student-staff co-creation in and of the curriculum. *High. Educ.* 78, 407–422. doi: 10.1007/s10734-018-0349-8

Bowser, G., and Cid, C. R. (2021). Developing the ecological scientist mindset among underrepresented students in ecology fields. *Ecol. Appl.* 31:e02348. doi: 10.1002/eap.2348

Braun, V., and Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qual. Res. Sport Exerc. Health* 11, 589–597. doi: 10.1080/2159676X.2019.1628806

Braun, V., and Clarke, V. (2020). One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qual. Res. Psychol.* 18, 1–25. doi: 10.1080/14780887.2020.1769238

Breen, R. L. (2006). A practical guide to focus-group research. *J. Geogr. High. Educ.* 30, 463–475. doi: 10.1080/03098260600927575

Brookfield, K. (2021). Nature-enhanced learning' and geography education. *J. Geogr. High. Educ.* 46, 327–342. doi: 10.1080/03098265.2021.1926938

Chua, S., Switzer, A., Hartman, K., Bhatia, N., and Koh, J. (2020). Assessing undergraduate learning in earth science residential fieldwork. *Asian Journal of the Scholarship of Teaching and Learning* 10, 69–88.

Clark, K., Welsh, K., Mauchline, A., France, D., Whalley, B., and Park, J. (2020). Do educators realise the value of bring your own device (BYOD) in fieldwork learning? *J. Geogr. High. Educ.* 45, 1–24. doi: 10.1080/03098265.2020.1808880

Collins, D. (2022) The student device Useage report. The Open University. Available at: https://www.learninginnovation.info/smart-tech/student-device-usage-report-april-2022 (Accessed May 18, 2023).

Cross, P., Douglas, T., de Fanti, A., Tapper, N., and Wilkins, M. (2020). Apps supporting fieldwork. *Interaction* 48, 28–30.

Derounian, J. G. (2017). Mobiles in class? *Act. Learn. High. Educ.* 21, 142–153. doi: 10.1177/1469787417745214

Dummer, T. J. B., Cook, I. G., Parker, S. L., Barrett, G. A., and Hull, A. P. (2008). Promoting and assessing 'deep learning' in geography fieldwork: an evaluation of reflective field diaries. *J. Geogr. High. Educ.* 32, 459–479. doi: 10.1080/03098260701728484

Edwards, R. C., and Larson, B. M. H. (2020). When screens replace backyards: strategies to connect digital-media-oriented young people to nature. *Environ. Educ. Res.* 26, 950–968. doi: 10.1080/13504622.2020.1776844

Fletcher, S., France, D., Moore, K., and Robinson, G. (2007). Practitioner perspectives on the use of Technology in Fieldwork Teaching. *J. Geogr. High. Educ.* 31, 319–330. doi: 10.1080/03098260601063719

France, D., Lee, R., Maclachlan, J., and McPhee, S. R. (2021). Should you be using mobile technologies in teaching? Applying a pedagogical framework. *J. Geogr. High. Educ.* 45, 221–237. doi: 10.1080/03098265.2020.1773417

France, D., Powell, V., Mauchline, A. L., Welsh, K., Park, J., Whalley, W. B., et al. (2016). Ability of students to recognise the relationship between using mobile apps for learning during fieldwork and the development of graduate attributes. *J. Geogr. High. Educ.* 40, 182–192. doi: 10.1080/03098265.2016.1154931

France, D., Whalley, B., Mauchline, A., Powell, V., Welsh, K., Lerczak, A., et al. (2015). "Display and recording: e-books and field notebooks" in *Enhancing fieldwork learning using Mobile technologies*. eds. D. France, W. B. Whalley, A. Mauchline, V. Powell, K. Welsh, A. Lerczak, et al. (Cham: Springer), 47–64.

Gillies, C. G. M. (2016). To BYOD or not to BYOD: factors affecting academic acceptance of student mobile devices in the classroom. *Res. Learn. Technol.* 24:30357. doi: 10.3402/rlt.v24.30357

Greene, E. (2011). "Why Keep a Field Notebook?" in *Field notes on Science & Nature*. ed. M. R. Canfield (Cambridge, MA London, England: Harvard University Press), 251–276.

Gros, B., and López, M. (2016). Students as co-creators of technology-rich learning activities in higher education. *Int. J. Educ. Technol. High. Educ.* 13, 1–13. doi: 10.1186/s41239-016-0026-x

Hammond, M. (2013). The contribution of pragmatism to understanding educational action research: value and consequences. *Educ. Act. Res.* 21, 603–618. doi: 10.1080/09650792.2013.832632

Harrison, A., Phelps, M., Nerminathan, A., Alexander, S., and Scott, K. M. (2019). Factors underlying students' decisions to use mobile devices in clinical settings. *Br. J. Educ. Technol.* 50, 531–545. doi: 10.1111/bjet.12579

Healey, M., Flint, A., and Harrington, K. (2014). *Engagement through partnership: students as partners in learning and teaching in higher education*. York: HEA. Available at: https://www.heacademy.ac.uk/engagement-through-partnership-students-partners-learning-and-teaching-higher-education

Hein, W., O'Donohoe, S., and Ryan, A. (2011). Mobile phones as an extension of the participant observer's self: reflections on the emergent role of an emergent technology. *Qual. Mark. Res. Int. J.* 14, 258–273. doi: 10.1108/13522751111137497

Huffling, L., Tomasek, T., Matthews, C., Benavides, A., Carlone, H., and Hegedus, T. (2014). Using mobile devices in field science. *Sci. Teach.* 81, 35–40. doi: 10.2505/4/tst14_081_06_35

Jolley, A., Kennedy, B., Brogt, E., Hampton, S., and Fraser, L. (2018). Are we there yet? Sense of place and the student experience on roadside and situated geology field trips. *Geosphere* 14, 651–667. doi: 10.1130/GES01484.1

Kent, M., Gilbertson, D. D., and Hunt, C. O. (1997). Fieldwork in geography teaching: a critical review of the literature and approaches. *J. Geogr. High. Educ.* 21, 313–332. doi: 10.1080/03098269708725439

Knapp, S. (2011). Techniques: records in the field. *Nature* 474, 280–281. doi: 10.1038/474280a

Lee, H., Stern, M. J., and Powell, R. B. (2020). Do pre-visit preparation and post-visit activities improve student outcomes on field trips? *Environ. Educ. Res.* 26, 989–1007. doi: 10.1080/13504622.2020.1765991

Lewis, S., and Mills, C. (1995). Field notebooks: a student's guide. *J. Geogr. High. Educ.* 19, 111–114. doi: 10.1080/03098269508709293

Lubicz-Nawrocka, T. (2018). Students as partners in learning and teaching: the benefits of co-creation of the curriculum. *Int. J. Students Partners* 2, 47–63. doi: 10.15173/ijsap.v2i1.3207

Medzini, A., Meishar-Tal, H., and Sneh, Y. (2014). Use of mobile technologies as support tools for geography field trips. *Int. Res. Geograph. Environ. Educ.* 24, 13–23. doi: 10.1080/10382046.2014.967514

Morales, N., O'Connel, K. B., McNulty, S., Berkowitz, A., Bowser, G., Giamellaro, M., et al. (2020). Promoting inclusion in ecological field experiences: examining and overcoming barriers to a professional rite of passage. *Bull. Ecol. Soc. Am.* 101, 1–10. doi: 10.1002/bes2.1742

Nelson, G., and Ellis, S. (2018). The history and impact of digitization and digital data mobilization on biodiversity research. *Philos. Trans. Royal Soc. B Biol. Sci.* 374:20170391. doi: 10.1098/rstb.2017.0391

O'Connell, K., Hoke, K., Berkowitz, A., Branchaw, J., and Storksdieck, M. (2020). Undergraduate learning in the field: designing experiences, assessing outcomes, and exploring future opportunities. *J. Geosci. Educ.* 69, 387–400. doi: 10.1080/10899995.2020.1779567

Papadopoulou, M. (2020). Supporting the development of early years students' professional identities through an action research programme. *Educ. Action Res.* 28, 686–699. doi: 10.1080/09650792.2019.1652196

Peacock, J., and Bacon, K. L. (2018). Enhancing student employability through urban ecology fieldwork. *Higher Educ. Pedag.* 3, 440–450. doi: 10.1080/23752696.2018.1462097

Pearson (2015) *Pearson student Mobile device survey 2015*. Pearson. Available at: https://www.pearson.com/content/dam/one-dot-com/one-dot-com/ped-blogs/wp-content/pdfs/2015-Pearson-Student-Mobile-Device-Survey-College.pdf (Accessed May 18, 2023).

Peasland, E. L., Henri, D. C., Morrell, L. J., and Scott, G. W. (2019). The influence of fieldwork design on student perceptions of skill development during field courses. *Int. J. Sci. Educ.* 41, 2369–2388. doi: 10.1080/09500693.2019.1679906

Phantuwongraj, S., Chenrai, P., and Assawincharoenkij, T. (2021). Pilot study using ArcGIS online to enhance students' learning experience in fieldwork. *Geosciences* 11:357. doi: 10.3390/geosciences11090357

QSR (2020). *NVivo (Version 13), [Computer software]*. QSR Internation Pty Ltd. Available at: https://support.qsrinternational.com/nvivo/s/

Ramírez-Castañeda, V., Westeen, E. P., Frederick, J., Amini, S., Wait, D. R., Achmadi, A. S., et al. (2022). A set of principles and practical suggestions for equitable fieldwork in biology. *Proceed. Natl. Acad. Sci. U. S. A.* 119:e2122667119. doi: 10.1073/pnas.2122667119

Rogers, S. L. (2020). Cheap, accessible, and virtual experiences as tools for immersive study: a proof of concept study. *Res. Learn. Technol.* 28, 1–15. doi: 10.25304/rlt.v28.2416

Scanlon, E., Jones, A., and Waycott, J. (2005). Mobile technologies: prospects for their use in learning in informal science settings. *J. Interact. Media Educ.* 2:Art-23. doi: 10.5334/2005-25

Sebastián López, M., and De Miguel González, R. (2020). Mobile learning for sustainable development and environmental teacher education. *Sustainability* 12:9757. doi: 10.3390/su12229757

Senger, K., and Nordmo, I. (2021). Using digital field notebooks in geoscientific learning in polar environments. *J. Geosci. Educ.* 69, 166–177. doi: 10.1080/10899995.2020.1725407

Streule, M. J., and Craig, L. E. (2016). Social learning theories—an important design consideration for geoscience fieldwork. *J. Geosci. Educ.* 64, 101–107. doi: 10.5408/15-119.1

Tavani, S., Billi, A., Corradetti, A., Mercuri, M., Bosman, A., Cuffaro, M., et al. (2022). Smartphone assisted fieldwork: towards the digital transition of geoscience fieldwork using LiDAR-equipped iPhones. *Earth Sci. Rev.* 227:103969. doi: 10.1016/j.earscirev.2022.103969

Teo, T. (2009). Modelling technology acceptance in education: a study of pre-service teachers. *Comput. Educ.* 52, 302–312. doi: 10.1016/j.compedu.2008.08.006

Thomas, G. J., and Munge, B. (2017). Innovative outdoor fieldwork pedagogies in the higher education sector: Optimising the use of technology. *J. Outdoor Environ. Educ.* 20, 7–13. doi: 10.1007/BF03400998

Treibergs, K. A., Esparza, D., Yamazaki, J. A., Goebel, M., and Smith, M. K. (2022). How do introductory field biology students feel? Journal reflections provide insight into student affect. *Ecol. Evol.* 12:e9454. doi: 10.1002/ece3.9454

Venter, Z. S., Brousse, O., Esau, I., and Meier, F. (2020). Hyperlocal mapping of urban air temperature using remote sensing and crowdsourced weather data. *Remote Sens. Environ.* 242:111791. doi: 10.1016/j.rse.2020.111791

Viswanath, K., Synowiec, C., and Agha, S. (2019). Responsive feedback: towards a new paradigm to enhance intervention effectiveness. *Gates Open Res.* 3:781. doi: 10.12688/gatesopenres.12937.1

Walsh, C., Larsen, C., and Parry, D. (2014). Building a community of learning through early residential fieldwork. *J. Geogr. High. Educ.* 38, 373–382. doi: 10.1080/03098265.2014.933402

Ward, E., Dalbotten, D., Bueno Watts, N., and Berthelote, A. (2018). Using place-based, community-inspired research to broaden participation in the geosciences. *GSA Today* 28, 26–27. doi: 10.1130/GSATG366GW.1

Welsh, K., France, D., Whalley, B., and Park, J. (2012). Geotagging photographs in student fieldwork. *J. Geogr. High. Educ.* 36, 469–480. doi: 10.1080/03098265.2011.647307

Welsh, K. E., Mauchline, A. L., France, D., Powell, V., Whalley, W. B., and Park, J. (2018). Would bring your own device (BYOD) be welcomed by undergraduate students to support their learning during fieldwork? *J. Geogr. High. Educ.* 42, 356–371. doi: 10.1080/03098265.2018.1437396

Welsh, K. E., Mauchline, A. L., Park, J. R., Whalley, W. B., and France, D. (2013). Enhancing fieldwork learning with technology: practitioner's perspectives. *J. Geogr. High. Educ.* 37, 399–415. doi: 10.1080/03098265.2013.792042

Welsh, K., Mauchline, A., Powell, V., France, D., Park, J., and Whalley, B. (2015). Student perceptions of iPads as mobile learning devices for fieldwork. *J. Geogr. High. Educ.* 39, 450–469. doi: 10.1080/03098265.2015.1066315

Wenger, E. (1998) *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press

Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., et al. (2016). The FAIR guiding principles for scientific data management and stewardship. *Scientific Data* 3:160018. doi: 10.1038/sdata.2016.18

Xie, Y., Gao, G., Niu, N., and Wang, Y. (2021). Exploration and practice of the use of mobile devices to assist in general geological field practice. *J. Geogr. High. Educ.* 47, 210–226. doi: 10.1080/03098265.2021.2006614

Zizka, A., Joerger-Hickfang, T., Imhof, S., and Méndez, L. (2022). LiDAR sensors in smartphones can enrich herbarium specimens with 3D models of habitat at high precision and little cost. *Taxon* 72, 233–236. doi: 10.1002/tax.12861