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RESEARCH ARTICLE

Hunting for answers: Linking lectures with the real world using a mobile treasure hunt app

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Societal Impact Statement

Plants underpin our society providing food, fuel, medicines, clean air and water, positive mental health, and are central to biodiversity conservation. Despite this importance and an increasing need for people with plant-identification skills, many societies are becoming increasingly ignorant to the species with which they interact. To benefit both our undergraduates and the society they will enter, we applied mobile technology to improve plant identification and appreciation, while providing opportunities to practice transferable team work and verbal communication skills. Encouraging 'plant vision' will improve conservation efforts while increasing personal connections with green spaces, leading to mental health improvements for society.

Summary

- Despite the importance of plants to human civilization, many societies are becoming increasingly ignorant to the plants that inhabit their surrounding environment. A phenomenon known as 'plant blindness'. To address plant blindness in undergraduate students we designed an outdoor activity using a mobile phone app. Our aims were to identify the level of 'plant blindness' in our students; investigate engagement with the app and activity; determine if we can raise awareness of links between lecture content and real world scenarios; and assess the student experience as a result of the activity in large classes.
- The app chosen was ActionBound. Students were asked to find and photograph local examples of four plant families, along with identifying physiological benefits of features covered in lectures. Two different first year classes were exposed to this activity – *Plant Science* and *Life on Earth*.
- The *Plant Science* students (60% success rate for three families; 55 students) were less plant blind than *Life on Earth* students (less than 44% success rate in any of the four families; 200 students). Students engaged well with the activity with all groups submitting sensible attempts at the responses. Most students reported that the activity increased links to lecture material and all but one student reported positive experiences.
- Our students found the treasure hunt learning environment is a fun way to engage with the plant topics covered in lectures. In future iterations, we will more explicitly explain the links to potential careers and will address some of the logistical challenges faced in this first cohort.

KEYWORDS
collaborative learning, fun learning, inclusivity, large classes, mobile learning, plant blindness, situational learning, treasure hunt

1 | INTRODUCTION

Plants underpin everything that human societies are built on: food, fuel, medicines, clean air and water, carbon sinks, mental health, and are central to the preservation of biodiversity. However, many societies are losing the ability to recognise and 'see' plants in their surroundings, a condition termed 'Plant blindness' (Wandersee & Schussler, 1999). Plant blindness is a complex issue which is part of a broader discussion concerned with perceived disconnections with the natural world (Gelsthorpe, 2017; Prévot-Julliard, Julliard, & Clayton, 2015), despite demonstrable benefits to spending time with nature (Wells & Evans, 2003). While there are observable differences in how people visually process animals and plants (Balas & Momsen, 2014), this innate discrepancy is frequently reinforced by educational curricula, and how they are implemented in the classroom (Balas & Momsen, 2014; Balding & Williams, 2016). Even though children may recognise the importance of plants, they often fail to find them interesting (Fančovičová & Prokop, 2010). Given this background, it is perhaps unsurprising that plant blindness results in heavy conservation biases towards animals (Balding & Williams, 2016). Because of the importance of plants to our societies and for biodiversity conservation, it is crucial that we find ways to address this situation.

In the UK, 86% of A-level Biology students were unable to name more than three common wildflowers and 41% were unable to name more than one species (Bebbington, 2005). By the time students reach undergraduate level, they are better able to recall images of animals than of plants, even after they have taken a botany course (Schussler & Olzak, 2008). They have also acquired stronger mental links to animal subjects compared to plants (Balas & Momsen, 2014), resulting in low levels of student recollected learning about plants (Fančovičová & Prokop, 2011).

In 2018, an internet search returned 23 UK institutions offering plant-related programmes. None of them are labelled 'botany' preferring 'plant sciences' and many are nominally biology or biotechnology with a plant bias. In comparison, 86 UK institutions offered zoology (or animal science) degrees. This is in accord with the decline in both the study of botany and of its status, as reported by Drea (2011) and Stagg, Wahlberg, Laczik, & Huddleston (2009). This leads to fewer students studying plant-based subjects resulting in a struggle for the students to recognise common plants in their surroundings (Bebbington, 2005). To address this, we have applied an active learning model to introduce first year undergraduate students to plant families found around the Nottingham University campus while linking the plants they see to material covered in lectures.

Traditional higher education settings separate theory and practice (Tynjälä, Välimaa, & Sarja, 2003) and more attention is needed to improve integration of the two (Zydney & Warner, 2016). Our own students commented on this in course evaluations: 'I think there should be more coursework aimed at making it easier for students to link all the separate facts together' (*Life on Earth* 2016–2017) and 'Ideally more field walks so that we can see what we've learnt in the real world' (*Plant Science* 2016–2017). To improve these links 'in place' active, experiential situations where students work collaboratively are encouraged while allowing space for self-reflection on newly gained knowledge (Tynjälä et al., 2003). Active learning strategies have been demonstrated to improve student performance across science, engineering and mathematics subjects even when active learning only comprised 10–15% of class time (Freeman et al., 2014). If active and experiential learning can be used to link directly to theoretical material taught in lectures, it is our expectation that students will learn more about the plants around them—not just identification, but also a deeper understanding of how those plants grow and function.

Central to the scientific process in all fields of natural science are keen observational skills. In 2016, Pokémon GO was launched and revolutionised the use of mobile devices for observational activities. The object is to find, capture and tame virtual creatures spread around outdoor environments. The game has been downloaded more than 500 million times and is credited with popularising augmented reality games using the Global Positioning System (GPS) to locate the target creatures (Carter & Velloso, 2016). Along the same theme, treasure hunts require participants to find a list of items or features and are heavily dependent on observational skills. As a fun way to learn these skills, they have been used at a range of educational levels (Lu, Chao, & Parker, 2015) including at university level to help students find key services and locations (Lu et al., 2015) and for social networking events during orientation (fresher's week). In the context of plant blindness, treasure hunts have been used to increase awareness of the natural world, including plants in botanical gardens, mostly for primary and secondary school students (Kissi & Dreesmann, 2018). Here, we present the use of a mobile phone treasure hunt app for improving undergraduate student plant awareness while increasing links between lectures and practical content.

Our objective was to determine if using treasure hunt mobile software can improve student learning in large first year classes. Our specific questions were: (a) How 'plant blind' are our students? (b) How much will the students engage with the app and activity? (c) Can we raise awareness of links between lecture content and real world scenarios? (d) Will this benefit the student experience in large classes?

Throughout this article, we will refer to courses as an individual subject unit (also called modules) and programmes as the 3- or 4-year degree programme (called courses in some places) in which students enrol.

2 | MATERIALS AND METHODS

Ethics approval was sought from The University of Nottingham, School of Sociology and Social Policy (#BIO-1718-0003).

2.1 | University and course context

The treasure hunt activity was implemented in two first year courses (modules) for different classes of students at the University of Nottingham. *Life on Earth* runs a full year with 200 students (2018) in the School of Life Science, Faculty of Medicine and Health Science on the University Park campus. *Plant Science* runs in the spring semester with 55 students (2018) in the School of Biosciences, Faculty of Science on the Sutton Bonington Campus. For both courses, weekly lectures run until the 4th last week of term and the three plant practicals occur in the same time-slots for the last three weeks of the spring term. The first practical is the treasure hunt. The other two practicals are laboratory-based and not the focus of this paper. *Life on Earth* covers topics from each Kingdom and students are enrolled in a diverse range of programmes (Figure 1) including Biology (44%), Zoology (18%), Genetics (10%), Biochemistry and associated programmes (17%), Environmental Biology (6%), Neuroscience (2%), Natural Sciences (2%) and Tropical Ecology (1%). In contrast, *Plant Science* is a plant-specific course with a strong focus on model plants and correspondingly a high proportion of Biotechnology students (56%) followed by Environmental programmes (19%), Plant Science (11%) and Agriculture-based programmes (15%; Figure 1).

2.2 | Mobile application (App) 'ActionBound'

Due to the popularity of Pokémon GO and geocaching, we chose to design our activities using the ActionBound platform primarily because of its compatibility with a wide range of mobile phone models. Via the School of Biosciences, we purchased a 'Lecturer' License (€45 as of January 2019) in 'Colleges and Universities' under the 'EDU' Licence link from the Pricing page (https://en.actionbound.com/pricing).

The app allows privacy, requiring a QR code for access, ensuring locational security for our students. ActionBound offers multiple options including information pages (with text, sound, pictures or movies), missions (find-and-photograph, record text, verbal or video responses) and quiz-style questions (multiple choice or rearrange answers; Figure 2). Additionally, ActionBound allows multiple users to work together which was important because the activity has students work together in groups of 3–5 to enhance their learning experience and minimise the potential for technical challenges (they only needed one functioning app within their group). Once student teams submit their responses, the answers can be viewed by logging into the ActionBound platform. A summary of all team scores is presented on the main results screen and by clicking on a team the individual responses to each question are visible (Figure 3). Common misconceptions become very clear and can be clarified in a follow-up lecture or email to the class. Using these features, we designed the practical activity in three ActionBound stages.

2.3 | Setting up the activity

In the weeks leading up to the practical, the activities were programmed into the ActionBound App as three stages (see below for more details). These were updated in the days leading up to the actual practical based on what plants were becoming available at this fast-changing time of year.

The day before the practical the authors collected samples from six different trees on the respective campuses for use in the laboratory. The trees were labelled randomly A–F using tape and a permanent marker. In future, we will mark more locations to spread out the group (see results). At the end of the practical, the labels were removed.

The samples collected were labelled with tape (1–6), put in buckets containing a few inches of water to avoid wilting and stored in the cold room until the day of the practical. An example of each plant was placed on the laboratory benches where teams of 3–5 would work together during the practical. Two sheets of blank paper were also placed on each bench for the students to draw or write their dichotomous key.

The QR codes were printed and placed around the walls of the laboratory (or just outside the laboratory for *Plant Science*) so students could sign in as they arrived.

A team of demonstrators (PhD students) were trained (about one demonstrator per 16 students) regarding the activity and how to facilitate the student experience during the practical. At the beginning of the practical, the demonstrators were allocated to a specific set of benches to mentor during the practical so that students had a specific face to approach for the 3 hours (and interestingly so the demonstrators had less faces to worry about).

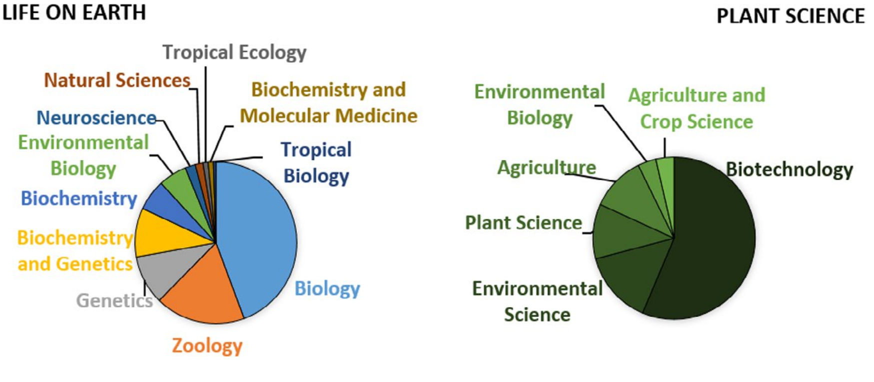

FIGURE 1 Course diversity for students of *Life on Earth* and *Plant Science*. *Life on Earth* had 200 students through the School of Life Sciences (Faculty of Medicine and Health Science), at the University Park Campus. *Plant Science* had 55 students through the School of Biosciences (Faculty of Science) at the Sutton Bonington Campus

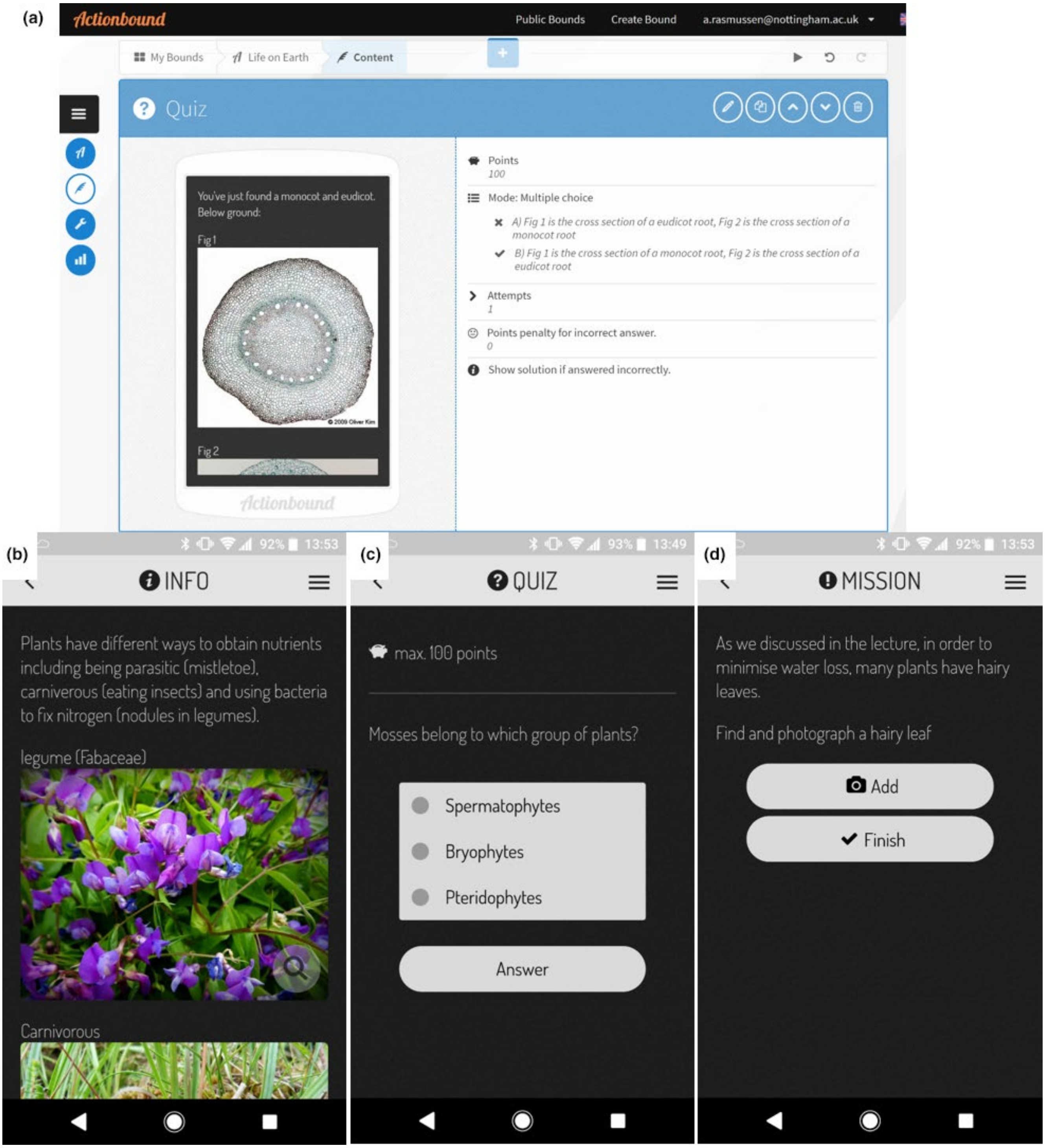

FIGURE 2 Computer (a) and mobile device (b–d) views of ActionBound. Questions can be created and edited by logging into the site on a computer (a). Question types can include information pages (b), multiple choice questions (c), missions including find and photograph (d), short answer or voice recordings

2.4 | Running the activity

As soon as students were settled in the laboratory, an introduction to the practical was given using Microsoft PowerPoint. This included an introduction to what a dichotomous key is using an example we made based on the lecturers in the module (male/female, red hair/not red hair and so on) and explanation of why it is important to understand the plants in our environment.

Stage one was a laboratory-based introduction to plant features where students created their own plant key with plant material (labelled 1–6) laid out on the benches. In the app, information was provided on opposite/alternate and simple/compound leaves

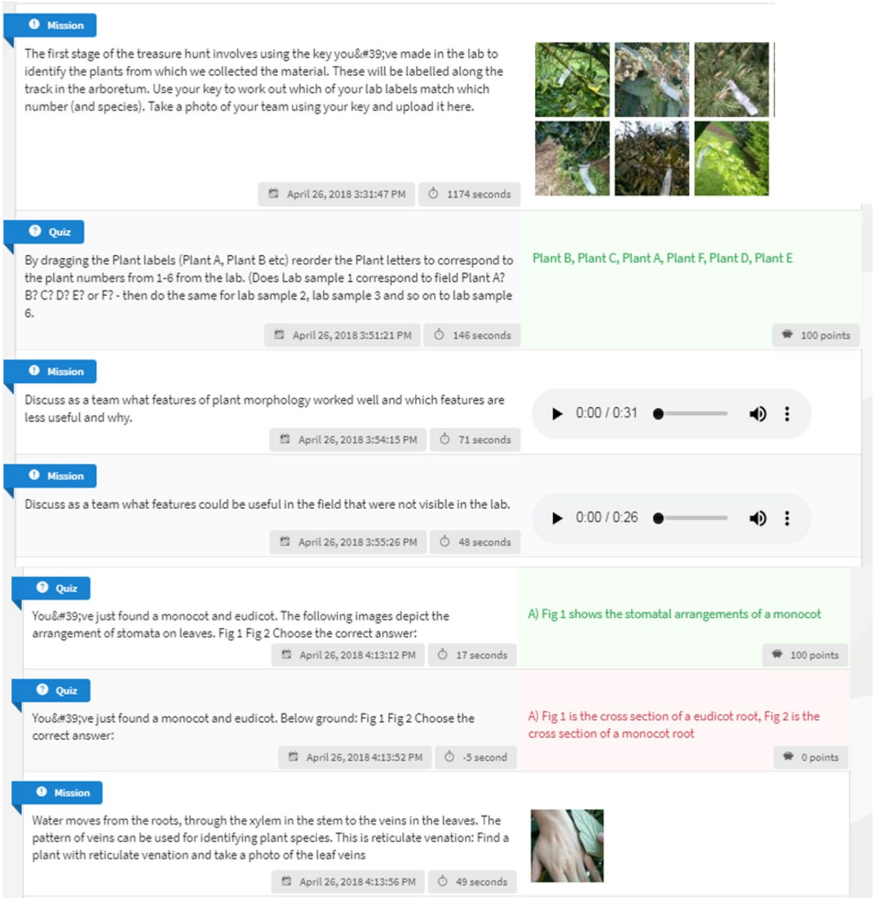

FIGURE 3 Submitted team responses can be viewed on the computer to the right of the questions. Correct answers show up green, incorrect answers red, images or videos as clips. Larger versions of the images can be seen by clicking on them and voice recordings can be listened to and downloaded as audio files

to help stretch their terminology while not overwhelming them with too many new words. At the end of Stage one, students were guided out of the laboratory by their demonstrator to the locations with labelled trees. In Stage two, students used their own plant key to identify plants growing in the environment and labelled A–F the day before. In the app, students were asked to match the numbers from the laboratory to the letters on outdoor plants. There were also questions asking them to voice record their reflections on what features worked well or not, and what additional features could be used on plants growing in the environment. Stage three involved a wider treasure hunt canvassing material covered in the lectures. This stage also contained the sections asking the students to locate plants in the four families based on some features and example pictures—these plants were not labelled (Figure S1). As Stage three began, the students were encouraged to roam further afield and demonstrators wandered between groups (not necessarily sticking to their 16). The students were asked to check in with their demonstrator as they finished the session to ensure all students completed the full task.

For *Life on Earth*, all three stages were created in the *ActionBound* app (Figure S1) to allow students to familiarise themselves with the technology while demonstrators and academic staff were present. For *Plant Science*, this was not possible due to the mobile-free and paperless laboratory zone. This meant the information and consent forms and QR codes were provided in the foyer as the groups headed outside after Stage one (the keys in *Plant Science* were written on laminated paper that could be sterilised before returning to the laboratory). In both classes, students were emailed prior to the practical and asked to download the app.

The practical was worth 5% of the course grades for *Life on Earth* students and if students engaged with the practical they received the full marks. This was specifically to encourage a safe learning environment where incorrect answers were a learning experience rather than a source of stress regarding lost marks. For *Plant Science*, two examination questions were directly linked to material covered in the practical but the practical itself was not worth marks.

2.5 | Evaluation

To evaluate the effectiveness of the activity at addressing our research questions, data were collected from submitted responses in the app and from student and demonstrator surveys. Student engagement was evaluated using overall group attempts at the treasure hunt questions, the duration of time spent engaged with the app hunt and length of the two voice-recorded responses. Student perspectives of engagement, links between lecture material and the real world and their experience of the treasure hunt were collected from survey questions. The first set of survey questions were embedded as the last three questions within the treasure hunt. Students were made aware these responses would not be anonymous and that they were welcome to skip those questions. In total, 14 groups from *Plant Science* and 44 from *Life on Earth* provided responses to these questions (two groups chose not to answer). The evening after the practical a link to an anonymous survey (SurveyMonkey) was emailed to all students (Table 1). Surveys were kept separate but the questions were identical for both *Plant Science* and *Life on Earth* (Table 1). The demonstrators from *Plant Science* also demonstrated for *Life on Earth* and all were sent an anonymous survey (SurveyMonkey) after each practical (Table 1).

To evaluate the tone of comments provided by the students, we used Tone Analyser (IBM; https://tone-analyzer-demo.ng.bluemix.net/) which allocates tones (joy, fear, sadness, anger, analytical, confident or tentative) to each sentence and provides a value between 0.5 and 1 for the strength of tone. A value less than 0.5 means the text is not associated with a tone. Most frequently used words were plotted using the R statistical package (for full code and word table, see Code S1). At the end of the semester, students for *Life on Earth* were sent a course evaluation survey that covered the full year.

Two questions on the *Plant Science* examination were linked to the treasure hunt which allowed us to compare average marks

TABLE 1 Student and demonstrator survey questions and response options

Respondents	Survey questions	Response options
Embedded questions in treasure hunt		
Student teams (not anonymous) *Life on Earth*—43 responses (2 groups chose not to respond) *Plant Science*—14 group responses	How would you rate your treasure hunt experience?	Excellent/Good/Poor/Very poor
	Did the treasure hunt help you better understand/revise lecture concepts?	Definitely helped/Helped a little/Didn't really help/Definitely unhelpful
	Would you like the treasure hunt to be an informal competition with the winners being the team with the most correct answers in the shortest time?	Yes/No
Student SurveyMonkey		
Individual students (anonymous) *Life on Earth*—44 responses *Plant Science*—20 responses	How would you rate your treasure hunt experience?	Very negative/Negative/Positive/Very positive
	The treasure hunt helped me better understand and revise lecture concepts. How much do you disagree or agree with this statement?	Strongly agree/Agree/Neither agree or disagree/Disagree/Strongly disagree
	Did you experience any technical difficulties with the app?	Yes/No If yes please explain
	Rank the following style of question from favourite (1) to least favourite (4) - Find and locate (photo) questions? - Multichoice quiz questions (for example haploid/diploid type questions) - Short answer text questions (for example explain how the hairs on leaves help minimise water loss) - Voice responses	Ranking 1–4
	Any other comments on your treasure hunt experience?	Open text box
Demonstrator SurveyMonkey		
Demonstrators (anonymous) 11 responses	How do you think the students would rank the treasure hunt? Please provide any observations or comments in the box below	Positive/Neutral/Negative Open text box
	Please comment on anything the students struggled with during the practical	Open text box
	The training session provided before the practical prepared me adequately for the practical?	Strongly agree/Agree/Disagree/Strongly disagree
	What was the most helpful part of the training?	Open text box
	What was the least helpful part of the training?	Open text box
	Was there anything in the training that you would have liked covered in more detail or that was missing?	Open text box

awarded per question. The examination was composed of seven questions based on each general lecture topic. The first question was compulsory; student then could choose to answer four of the remaining six questions (Table 2). Questions 1 and 3 were linked to the treasure hunt and since Question 1 was compulsory the mark variation was higher for that question. To overcome this, we took all the pass marks (8/20 or higher) for all the questions.

3 | RESULTS

All students were able to successfully submit responses as part of 14 *Plant Science* and 48 *Life on Earth* student groups. Of those who responded to the anonymous survey (total of 64 respondents), only three reported technical challenges which included battery life (1) and a glitch in voice recording (2) which was rectified when they restarted the app.

3.1 | Student plant blindness

Students were provided with plant family descriptions and example pictures and then asked to find and photograph other species in the same family. *Plant Science* students had a much higher success rate (Figure 4a) for three of the four families compared to *Life on Earth* students. 93% of *Plant Science* students were able to find members of the Asteraceae (daisy) family and 86% found the Rosaceae (rose) family compared to 44% and 21%, respectively, for *Life on Earth* students. The Lamiaceae (mints) family was more difficult for both cohorts with 64% of *Plant Science* and 18% of *Life on Earth* groups finding correct examples. Interestingly, the groups in both courses were similarly able to find examples of Ranunculaceae (Buttercup) family meaning that the *Plant Science* students did much worse (36%) on this question while the *Life on Earth* groups did the second best on this question (35%).

Some students reported that finding the right plants was challenging (Table 3 comments 1, 6) and that they wanted the descriptions either before (19b) or after (2c) the practical. As a result, we provided this information again in a word document after the practical. In future iterations, we will do both. Other students highlighted that they enjoyed finding the right plants (8b, 9). The demonstrators also noticed that students 'struggled with identifying plants that they had never seen before' (Table S1; #19).

Our demonstrators (PhD students across plant, crop and environmental sciences) also indicate a level of plant blindness as 4/11 of the comments on positives about the training were linked to doing the treasure hunt themselves (Table S1; #24, 26, 29, 30), and of the 8 requests for next year's training, 5 wanted more information on plant traits (Table S1; #41, 42, 43, 44, 47), for supporting students in the laboratory to make the key.

3.2 | Student engagement

Students in both *Plant Science* and *Life on Earth* actively engaged with the ActionBound treasure hunt with all groups submitting their responses (even though *Plant Science* were not allocated marks based on participation). In both courses, the responses also contained sensible attempts at the questions (even though neither class were marked for their responses). The time students spent engaged with the app ranged from 42 to 68 min and from 45 to 136 min respectively for *Plant Science* (average 55 min) and *Life on Earth* (average of 103 min; Figure 4b). The duration difference between the two courses is because *Plant Science* students were only allowed to access their mobiles as they left the laboratory.

Two of the questions required voice recordings and the average length of those verbal responses were similar for both *Plant Science* and *Life on Earth* with students spending, on average, 10 s longer on the first voice recording (35 or 38 s respectively) compared to the second voice recording (24 or 25 s respectively; Figure 4b). These two questions were reflections on the traits they chose for their key (Voice response 1) and traits that might be useful when identifying plants in the field (Voice response 2; Figure S1). In the open-ended survey question, students reflected on their own engagement (Table 3 comments 7a, 8b, 15c, 16b, 20b and 20c). The demonstrators also reported 'Most of the students seemed to get involved and were really thinking about the questions' and 'Nice to see so many engaging with the tasks! Having it on the app is a lot better than paper, keeps people interested!' (Table S1).

In addition to the allocated practical time, two groups submitted second attempts in the following 24 hr after the *Life on Earth* practical. Students were sent links to study versions of the app containing

TABLE 2 *Plant Science* exam questions and number of responses to each question. Question 1 was compulsory while students could choose 4 from the remaining 6 questions. Question 1 and 3 (highlighted in bold) were covered in part by the treasure hunt

	Exam question	Number of responses
Q1	**Describe how water moves from the soil through the plant and into the atmosphere including listing the four main forces involved in water potential.**	**55**
Q2	Define what is meant by an essential and a beneficial element in plant nutrition, giving specific examples of the roles of each.	27
Q3	**Describe these two groups of plants: Bryophytes and Pteridophytes**	**33**
Q4	Explain the mechanisms by which chloroplast membranes absorb light energy and use it to generate ATP and NADPH	42
Q5	Discuss the mechanisms through which viral, bacterial and fungal plant pathogens are transmitted between plants	38
Q6	Describe why Arabidopsis thaliana is one of the best model species for classical genetics in higher plants?	48
Q7	Describe the key mechanisms that plants use to avoid self-fertilisation and the adaptations they use to maximise their chances of cross-fertilisation	31

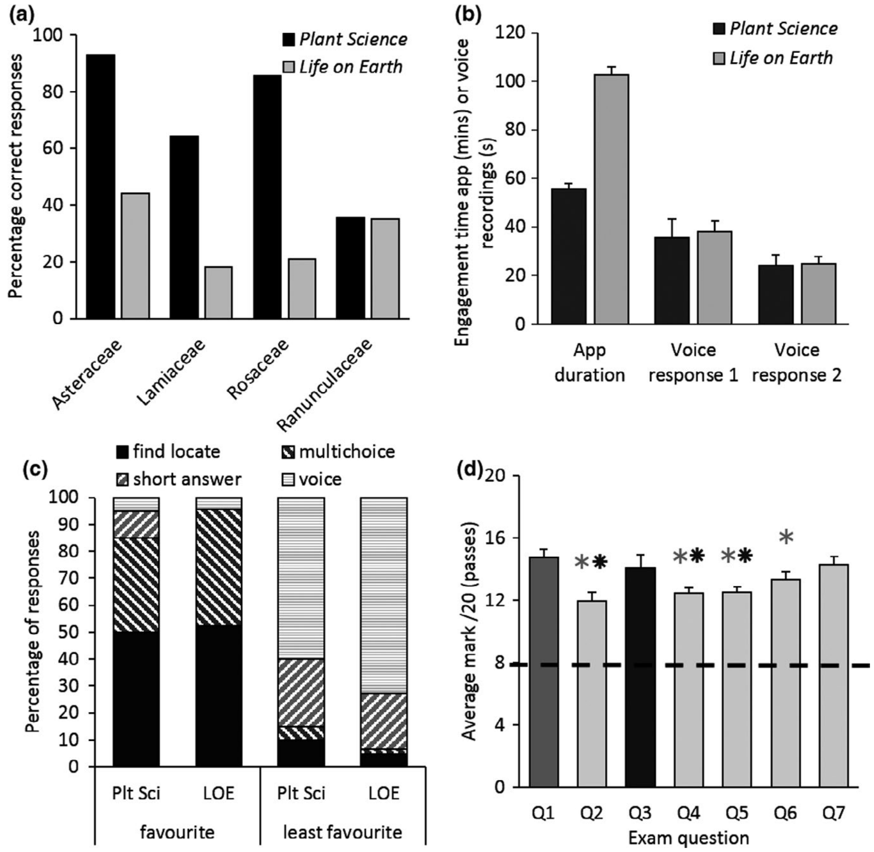

FIGURE 4 Plant blindness in first year undergraduate students enrolled in *Plant Science* (Plt Sci) and *Life on Earth* (LOE) based on correct identification responses (a), engagement times (b), preferred question types (c) and *Plant Science* exam marks (d). The percentage of groups with correct identifications (a) after students were provided with identifying features for four families and asked to find and photograph an example (Asteraceae—daisy family, Lamiaceae—mint family, Rosaceae—rose family and Ranunculaceae—buttercup family); (b) engagement times for the full app usage (in minutes) and for each of two voice recorded responses (in seconds); (c) student preferences for different question types; (d) average marks given per exam question for *Plant Science* students. Questions 1 and 3 were related to treasure hunt questions and Question 1 was compulsory so only pass marks (≥8/20) were considered for all seven questions. Light grey 6-pointed asterisks represent significant differences in average marks compared to Question 1 while dark grey 8-pointed asterisks represent significant differences in average mark compared to Question 3 (Students *t* test, $p < 0.05$). For *Plant Science*, there were 14 groups (non-anonymous), 20 individuals (anonymous survey) and 55 sets of exam results; For *Life on Earth*, there were 44 groups (non-anonymous) and 44 individual (anonymous) sets of responses

only Stage three (one for *Plant Science*, one for *Life on Earth*) a few weeks prior to the exams. The *Plant Science* study version was used 6 times between 8 and 23 May (*Plant Science* examination was the 23 May) while the *Life on Earth* study version was also used once even though the exam was not based on the practical.

Students were asked which type of question they preferred and in both cohorts the favourite style was 'find and photograph' demonstrating they liked the traditional treasure hunt style question. The second most popular question style was multiple choice, perhaps not surprising since they have many multiple-choice exams in semester 1 and the other practicals are evaluated using ROGO tests. Voice recordings were consistently the least favourite style of question with one student reporting in the open comments that they 'found the voice response questions quite awkward' (Table 3, comment 22).

Plant Science student grades: Questions 1 and 3 on the exam (full list in Table 3) were related to material covered in the practical. Since Question 1 was compulsory and all the others were optional (students had to choose 4/6 questions), the mark distribution was wider so we compared the average mark given for each exam question (above a pass threshold). Q1 and Q3 were significantly higher (14.8 and 14.1/20 respectively) than Q2, Q4, Q5 and Q6 (12, 12.5, 12.5 and 13/20 respectively; Figure 4d).

3.3 | Connecting lecture content to real environment

To determine whether students were more aware of links between lecture material and the practical, we specifically asked the students whether the treasure hunt helped them better understand and revise lecture concepts both in the embedded treasure hunt questions and in the anonymous survey (Table 1). Of the 13 *Plant Science* groups, all reported that the treasure hunt either helped a little (5 groups) or definitely helped (8 groups; Figure 5a). Of the 44 *Life on*

TABLE 3 List of student survey comments and their tonal code (and strength of tone). 26 students made comments across both *Plant Science* and *Life on Earth* resulting in 50 phrases and 81 tonal codes

	Open-ended responses	Tone (strength score)
Plant Science		
1	It was often quite difficult to know what kind of flowers we were supposed to photograph	Tentative (0.96); analytical (0.60)
2a	While I enjoyed the aspect of group work, having only one person using the app per team meant it wasn't always easy to read and digest the information given	Analytical (0.63)
b	As such, it was a bit more difficult for me personally to link some of the questions to previously taught material	Analytical (0.95); sadness (0.53)
c	Perhaps releasing the identification data especially, after the practical may be a good idea	Analytical (0.80); joy (0.54); tentative (0.92)
d	Overall it was an enjoyable practical, and I would recommend it for future years!	No tone
3	Great idea!!!!	Analytical (0.98); Joy (0.91)
Life on Earth		
4	Was quite long and the app did not allow us to see how far we were through the questions	Analytical (0.83)
5	I liked my group	No tone
6	I really enjoyed a more practical approach to learning lecture content, however it was sometimes hard to find the correct plant or feature around the lake needed when taking the photographs	Analytical (0.85); joy (0.72); tentative (0.71)
7a	It was very engaging practical, I think we should have been encouraged to take our time on the outside tasks rather than rushing through it and seeing it as a race	Analytical (0.62)
b	I think by taking my time I gained a better understanding of the information presented and will remember more of it	Analytical (0.87); joy (0.55)
8a	People who helped us were incredibly informative and definitely a more relaxed learning environment	Analytical (0.80); joy (0.85); confident (0.87)
b	Even though we knew we would get marks for participation, we still tried hard to get the right answers and look for the right plants	Analytical (0.93); sadness (0.54)
9	It was really fun, and a great new way of learning, especially the photo-questions since finding the flowers/leaves we learnt about was really fun and it felt more like working on a field (what some students want as a career)	Joy (0.82); analytical (0.78); tentative (0.60)
10	It was fun and different from the other practicals I've done this year in a good way	Joy (0.87); analytical (0.70)
11	Could do with improving the first part with the tree labelled - was rather confusing on what was going on make sure all plants can be found	Tentative (0.75); joy (0.69); analytical (0.51); confident (0.70)
12	Nice change from being in a lab	Joy (0.78)
13	A lot of fun, easy to do in groups really aids lecture content	Joy (0.91); analytical (0.82)
14a	The tags on the branches were impossible to find and the PhD students didn't know how far to go so we wasted so much time	Sadness (0.64);
b	It was really frustrating and that made it difficult to continue afterward	Sadness (0.53); anger (0.57); analytical (0.62)
c	Next time larger labels and/or tell the PhD students	Tentative (0.82)
15a	Thank you!	Joy (0.88)
b	Favourite practical ever.	Joy (0.72); confident (0.94)
c	Learnt the most too due to the low-pressure environment combined with useful questions on the app	Analytical (0.94); sadness (0.57)
16a	It was fun	Joy (0.88)
b	Way better than learning from lectures because no matter what you're moving whilst learning and you can't fall asleep outdoors and I remember a lot more	Joy (0.71); analytical (0.87)
17	Number the questions so you have an idea of how far through the task you are allowing you to allocate time accordingly	Analytical (0.85)

(Continues)

TABLE 3 (Continued)

	Open-ended responses	Tone (strength score)
18a	The requirement to find small pieces of tape in the plants made it less about identification and more about spotting a hard to find tag	Sadness (0.53); analytical (0.83)
b	Also, because we all set off together, there was just a queue of people at each tagged plant waiting to see the label	Joy (0.54); analytical (0.88)
c	If there were many more tagged plants (the same 6 just more of each species) around the lake then it might solve this	Tentative (0.90); analytical (0.72).
19a	Too much text in the app	No tone
b	It would be better if there will be time in the lab for reading information about plants, plus it will be better if every single person will be provided with information about plants not only the person that was using the app	Analytical (0.88)
20a	I'd just like to say that this practical was really fun	Tentative (0.91); joy (0.79); analytical (0.65)
b	It was a great change of pace to be outside, looking at real things and applying theory and collective knowledge!	Joy (0.65)
c	It was challenging but I also came away from the experience with a lot of knowledge cemented to tangible visual memories	Sadness (0.51); analytical 0.67)
d	Thank you!	Joy (0.88)
21a	There are a couple of things I would say: 1) I think it would work better if everyone used the app and it was as a piece of coursework where you were marked on if you got the right answer or not because it would incentivise everyone to think about it more and be more involved	Analytical (0.81)
b	If you have about a week to find some of the more difficult plants e.g. Parasitic and research what you could look for, I think this would aid our learning more	Analytical (0.94); tentative (0.75)
c	2) If the activity is going to be carried out in groups, it should be groups of choice/friendship groups, because that way each person would get more input and it would be more fun	Analytical (0.72); joy (0.79)
d	3) The tags on the trees for the first part were really hard to spot	Analytical (0.64)
e	I think they should have been a bit bigger	Analytical (0.72)
22	I found the voice response questions quite awkward and would have preferred to just write responses down rather than having a slightly staged conversation in the group	Analytical (0.94); tentative (0.72)
23a	It was fun! a really interesting and different practical	Joy (0.89); analytical (0.72)
b	Thanks ☺	Joy (0.78)
24a	I understand that the forms needed to be signed but it was very frustrating having to sit for an hour when making the key took 5 min	Anger (0.56); analytical (0.60)
b	I enjoyed the actual treasure hunt outside	Confident (0.92); joy (0.56)
25a	I enjoyed all aspects thoroughly and all the demonstrators were extremely helpful	Confident (0.98); joy (0.76); analytical (0.84)
b	Therefore the ranking is not an accurate reflection of how felt as I enjoyed all activities and didn't hate or dislike any of the aspects of today's practical	Joy (0.55); tentative (0.78); analytical (0.80).

Earth groups, only 1 reported that the treasure hunt did not really help while all the others reported that the treasure hunt helped (a little = 26, definitely helped = 17; Figure 5a). These trends were repeated by individuals in the anonymous survey with just 2 out or 44 students saying the treasure hunt did not really help them better understand lecture concepts for *Life on Earth*. The majority of students reported that the activity helped but the percentage split for strongly agree and agree changed with a reduction from 61% to 25% for strongly agree in *Plant Science* and a drop from 39% to 20% for *Life on Earth*.

In the open-ended comments, students commented on the relevance of the practical to lecture content or the real environment. Positive examples include comments 9, 13, 16b, and 20b (Table 3) where students volunteered information about enhanced lecture learning from the treasure hunt activity. Several students also reported things that made it difficult to make the most of the link for example only having one app between the group (2a, 2b, 19b; Table 3) Respondent 6 reported both the value for learning lecture material and a challenge to their learning.

3.4 | Student experience

To determine whether students enjoyed the activity we asked them to rate their treasure hunt experience as well as conducted text tone analysis on the open comments. The survey responses were very similar for the embedded questions and the anonymous survey. All *Plant Science* students reported excellent (50% embedded questions; 45% anonymous survey) or good experiences (50% embedded; 55% anonymous survey). For *Life on Earth*, one group reported a poor experience, while in the anonymous survey all the students reported very positive (30% embedded questions; 36% anonymous survey) or positive (68% embedded questions; 64% anonymous survey) experiences. It is possible that none of the students who reported a bad experience chose to fill out the anonymous survey. The group who reported a poor experience did not engage with the voice recordings but otherwise did better than many of the other groups, so it is impossible to determine from our data set why these students had a poor experience.

The positive experience reported by students is also reflected in analysis of their open-ended comments (Figure 5c–f). Combining the comments from all the students across both courses the R frequency analysis shows positive words such as 'fun' (8 uses) and 'enjoyed' (5 uses) were in the top 12 most commonly used words (Figure 5c). Other words in the top 12 include plants (7 uses), learning and think (6 uses each). These top 12 words were tested for associations with other words (Code S1) and of note 'really' used 8 times was most commonly associated with 'fun' (0.72 correlation) and 'like' (0.64 correlation). All words used more than twice are shown in the word cloud (Figure 5d).

When we conducted the tonal analysis, of the 50 sentences (resulting in 81 tone scores) from 26 student comments, analytical (34) and joy (23) were the two most common tones. Sadness and anger were only reported in 7 or 2 sentences respectively (Figure 5e). Additionally the tone was stronger for positive compared to negative tones with analytical, joy and confident being 0.78, 0.75 and 0.88 respectively compared to 0.55 and 0.57 for sadness and anger

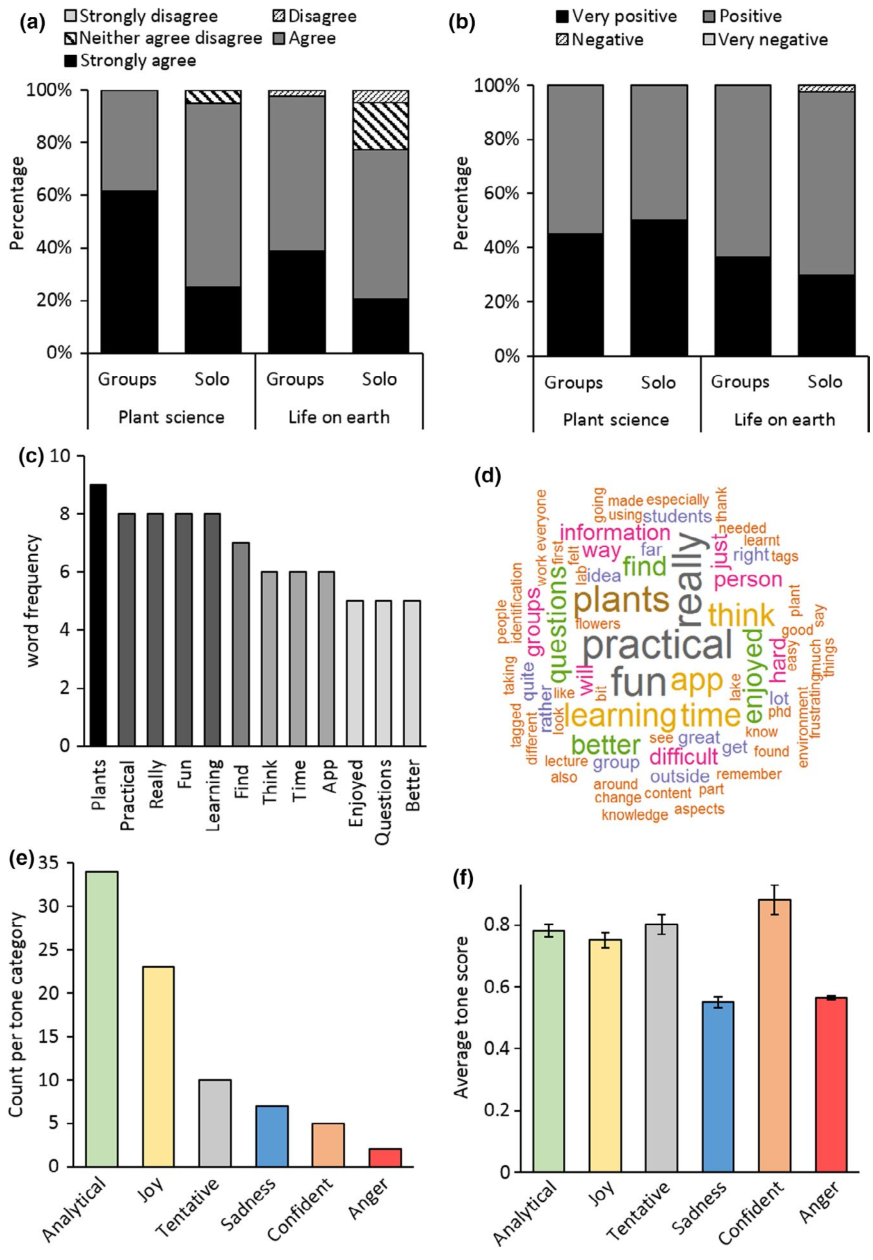

FIGURE 5 The student experience. (a) Student responses to whether the treasure hunt improved links between lecture material and practical. Non-anonymous group responses were from questions embedded in the treasure hunt app (4-point scale), anonymous 'solo' responses were from SurveyMonkey (5-point scale); (b) student experiences of the treasure hunt. Both groups (not anonymous) and solo (anonymous) questions had 4-point scale; for a and b, there were no responses for strongly disagree (a) or very negative (b); (c) word frequency for open-ended comments (words that came up 5 or more times); (d) word cloud showing all words mentioned twice or more (R statistical package); (e) frequency of times a particular tone was allocated to open-ended comments; and (f) the average strength of those tones (Tone Analyser). For *Plant Science*, there were 14 groups (non-anonymous), 20 individuals providing 3 open-ended comments (anonymous survey); For *Life on Earth*, there were 44 groups (non-anonymous) and 44 individuals providing 22 sets of open-ended comments (anonymous)

respectively (with 0.5 being the minimum tonal threshold; Figure 5f). Examples of 'joy' comments (Table 3) include 3, 6, 8a, 9, 10, 12, 13, 15a, 15b, 16a, 16b, 20a, 20d, 21c, 23a, 23b and 25a. 'Sadness' was seen in responses 2b, 14a, 14b and 18a, and 'anger' in 14b and 24a. There were several sentences coded as 'sadness' which are questionable as they present positive comments: 8b (0.54), 15c (0.57), and 20c (0.51). All three are close to the lower threshold for the tone analysis and to ensure a conservative interpretation we have left them in our analyses.

The demonstrators also reported 'Almost all students seemed to enjoy it and many voiced this', 'they seem to enjoy every bit of the practical session' and 'Students all seemed to enjoy being outdoors' (Table S1).

Finally, in the end-of-year course evaluation survey for *Life on Earth* which used University of Nottingham generic evaluation questions, one student specifically referred to the activity in the open comments section: 'I especially enjoyed all the plant science lectures and practicals. The treasure hunt was the best learning activity'.

4 | DISCUSSION

In order to determine the level of plant blindness in our first year undergraduate students, while also increasing engagement, improving links between lectures and practicals and enhancing the student experience, we introduced a plant treasure hunt using mobile technology. The universality of mobile phones has led to an increase in their use in learning situations (Chiu, Pu, Kao, Wu, & Huang, 2018; Gan, Li, & Liu, 2017) reviewed elsewhere (Gan et al., 2017; Zydney & Warner, 2016). One of the advantages of mobile technology is that learning can take place outside the classroom and at any time (Chiu et al., 2018; Gan et al., 2017; Zydney & Warner, 2016). This is ideal for studying plants within the natural environment and at an individualised pace, which should enhance natural learning processes (Chu, Hwang, Tsai, & Tseng, 2010; Zydney & Warner, 2016).

Selecting the right app is important to maximise appropriate functionality and flexibility in learning styles while minimising technical challenges to best integrate theory with practice (Zydney & Warner, 2016). Across our two sessions (250 students and 62 groups), there were only three reports of technical challenges, none seriously interrupting their learning. Similarly, there were no technical challenges reported by Kissi & Dreesmann (2018) who used the same app on tablet computers with 10- to 16-year-olds in a botanical garden. In this study, they report the students were already well versed in mobile technology and no associated anxiety was detected before the start of the activity. A mobile app designed for use on PDAs was used to help children learn how to use plant keys; however, half the students reported technical challenges (Huang, Lin, & Cheng, 2010) which can interrupt the learning process.

One of the challenges reported by our students was that it was hard for the whole group to see the information when only one mobile was used. Others have reported that mobile technology is not conducive to team work (Chiu et al., 2018; Zydney & Warner, 2016); however, we found many of our students liked the group aspect of the treasure hunt and although small screens were an issue, many groups were seen sharing out actions and taking it in turns to see the screen.

An advantage of the ActionBound app is the range of questions possible allowing information to be provided in multiple formats, reaching each student in different ways. For example, observational 'find and photograph' (hairy leaves) followed by short-answer responses of how the photograph applies to a deeper understanding of topics (such as water use efficiency). This is a two-tier design where the second tier of the question requires a deeper understanding of the topic (Chu et al., 2010). Elementary school students provided two-tier questions (via mobile device) expressed more positive attitudes to learning compared to a control (via text book) (Chu et al., 2010). The mobile learning system was programmed to provide prompts to guide the individual until they achieved the correct responses providing a personalised learning speed (Chu et al., 2010). In our activity, the students work together and teach each other (peer learning), working at their own team rates providing additional benefits including deeper understanding and longer retention of information (Biggs, 1999; Oakley, Felder, Brent, & Elhajj, 2004; Rasmussen, Rossini, & Kuchel, 2011; Wood, 2009) through being taught by peers with a similar scientific vocabulary and by articulating newly formed knowledge in a way to teach peers. Additionally, these communication and teamwork skills are increasingly important for employability (Biggs, 1999; Rasmussen et al., 2011; Wood, 2009).

4.1 | Plant Blindness in first year undergraduate students

Using the treasure hunt app, we were able to identify plant blindness levels in our undergraduates and unintentionally in our demonstrator team during their training. In *Life on Earth*, even at their best, only half the groups were able to identify an example of a plant from each of four common families (roses, daisies, mints and buttercups) that they will pass in their surroundings on a daily basis. *Plant Science* students did much better at plant identification questions than *Life on Earth* students even though both groups had been similarly primed to use observational skills when making their own key and engagement times with the app were similar. This difference is likely to be related to the diversity of students enrolled in the *Life on Earth* module covering broader Biology, Zoology and Environmental science programmes as well as biochemists and neuroscientists (Figure 1). Students already with an interest in plant types (such as those in the Plant Science degree programme) may enter our courses with a wider range of experiences looking at plants which they then transfer to their wider teams during the activity, improving the success rate of the *Plant Science* course group responses.

Although we cannot determine directly if the activity has improved plant awareness in our undergraduates, others report the positive value of close observation of plants in the laboratory or field for school students (Fančovičová & Prokop, 2011; Nyberg & Sanders, 2014). A classroom study where school students were asked to learn and then identify toxic (or non-toxic) plants on a touch screen found that younger children were quicker to identify the plants compared to adolescents and that female students were faster than male students (Prokop & Fančovičová, 2018). Our study is unable to separate genders since the teams were mixed and we did not ask students to identify their gender in the survey (which will be addressed in future iterations). In addition, our study was based on hands on, outdoors activities using growing plant material rather than images. Targeted plant-based biodiversity activities where students search for, identify and investigate local flora increases recognition and appreciation for plants increasing the likelihood that students will see plants in their daily lives (Balas & Momsen, 2014; Freeman et al., 2014; Lindemann-Matthies, 2005). Balas & Momsen (2014) argue this can be applied to undergraduate teaching using campus flora as we have done here.

Undergraduate plant blindness has prompted a number of higher education initiatives in other institutions using mobile apps to map the flora around their campuses (Cheung, Wardle, & Quinnell, 2015). The Campus Flora app for the University of Sydney includes more than 200 plant species around the campus and includes further detail about the species and provides 'trails' that can be targeted for either undergraduate learning or for use with wider communities (Cheung et al., 2015). Ward, Clarke, Horton, & Ebert-May (2014) found student knowledge, skills acquisition and attitudes to plant research improved by engaging undergraduates in genuine research that eventually resulted in published papers. Our treasure hunt activity falls between these two examples by getting students to find local plant families while asking them more detailed questions about the plants they are finding, all within a single practical session embedded in a general first year biology (*Life on Earth*) and a *Plant Science* course.

4.2 | Student engagement and the student experience

Increasing student engagement is widely accepted as a core component to increasing learning (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008; Prince, 2004). Furthermore, in the context of plant blindness, as discussed above, longer engagement times with plant material improves future plant awareness (Balas & Momsen, 2014; Lindemann-Matthies, 2005). We found our students were highly engaged with the activity—and aware of their own level of engagement, demonstrated by their comments, our observations (including demonstrator comments) and the use of the app leading up to the exam. This high level of engagement is likely to be related to multiple factors including the ease of using their own devices, the diverse question types, the low pressure learning environment, being in the environment and the availability of the app leading up to the exam (just-in-time learning).

Even though previous research suggests students need to perceive value and relevance to embrace mobile learning (Crompton & Burke, 2018), our students were highly engaged for relatively small rewards. In *Life on Earth*, students were allocated full marks for entering sensible responses regardless of whether they were correct and in *Plant Science* there were no marks associated with the practical (but students were informed it would help with the exam, still a month away). The high level of engagement for comparatively low benefits could be a result of the 'fun' aspect of the learning activity enhancing intrinsic motivation (Ryan & Deci, 2000; Svinicki, 2004). 'Fun' was one of the most used words in the open-ended comments and it is well established that fun learning environments promote engagement and enhance deep learning (Tews, Jackson, Ramsay, & Michel, 2015). Fun, joyful learning environments reduce anxiety and increase motivation by creating positive social environments, preparing the mind to be more receptive to new information and ideas (Garner, 2006). The positive or very positive experiences reported in the survey questions, and the strength and frequency of positive tones, demonstrates that our students were enjoying the learning environment created.

It is interesting to note that even though many of the open-ended comments refer to improvements that could be made, almost everybody reported positive experiences. These suggestions are often coded as 'analytical' tones and suggest that good experiences triggers excitement at being involved in further improvements, knowing that they personally would not benefit from these suggestions.

The student suggestions highlighted the main issues impacting on their experience were linked to logistical challenges such as the bottleneck caused by 200 students descending on the same lake area in *Life on Earth* (comments 11, 14 and 18) or the time required for 200 consent forms to be counter-signed (comment 24a). We have learnt from this first iteration of the practical and will use multiple areas, and an online consent (or not) in place of paper forms.

A final note regarding the student experience that should be made is the benefits of being outdoors for mental health. Not only does the relaxed environment benefit learning, the health benefits of being outside are well known. In particular concentrating on green space and wildlife rich areas is demonstrated to have positive influences on mental health (Bird, 2007). Reducing stress and improving the mental resilience of our undergraduates is an important aspect of student welfare (and inadvertently of the student experience).

4.3 | Can we raise awareness of links between lecture content and real world scenarios?

The student perceptions of links between lecture material and practical content were positive. Although we still have improvements to make, more than 75% of the students reported that the activity improved understanding of the lecture material and several made comments about the link to lectures in the open-ended comments. Of particular note is the student comment regarding that plant surveys and field work are a career option that some students will choose (Table 3, response 9). To improve these links, future iterations of the treasure hunt will reformat each section with research or industry-related scenarios. For example, the plant ID section will be set as an environmental consulting team who need to identify the plant families present for an impact statement for a new development proposal. These observational and critical thinking skills are key for employability in any science sector role.

In addition to core knowledge, transferable skills are built into this activity. Not only do they work in teams (mentioned previously), the voice recording (and short answer) discussions require students to think on their feet, condensing their thoughts on the go and articulating those thoughts in the response. These are important employability skills, not least for interviews. Our students enjoyed the voice recordings the least of all the question types, however we did not highlight the benefit of these skills which will be improved in the next cohort.

5 | CONCLUSIONS

In summary, we were able to identify the level of plant blindness in our first year undergraduates while engaging the students in an outdoor treasure hunt using mobile technology. The students reported the activity was a positive experience and in many cases helped them better understand the lecture content. Future improvements centre around removing logistical challenges (form signing and label access) and more explicitly linking the content with real-world scenarios. Additionally we will provide the plant trait and family information prior to the practical and encourage students to have a look before the practical to improve challenges associated with screen visibility. The fun, low pressure nature of the activity encouraged strong engagement and can be summed up by the following student comment:

> It was a great change of pace to be outside, looking at real things and applying theory and collective knowledge! It was challenging but I also came away from the experience with a lot of knowledge cemented to tangible visual memories.

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AUTHOR CONTRIBUTIONS

AR: ethics, data analysis, development of content in the app, running both sessions, drafting the manuscript, convenor for *Plant Science*; TH: provided sections of text and editing of the manuscript, convenor for *Life on Earth*. SL: provided support with teaching both sessions and countersigning forms as well as providing some text for the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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