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CITIZEN SCIENCE

Research Article

Changes in participant behaviour and attitudes are associated with knowledge and skills gained by using a turtle conservation citizen science app

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Abstract

1. Citizen science has become a popular way to collect biodiversity data and engage the wider public in scientific research. It has the potential to improve the knowledge and skills of participants, and positively change their behaviour and attitude towards the environment. Citizen science outcomes are particularly valuable for wildlife conservation, as they could help alleviate human impacts on the environment.
2. We used an online questionnaire to investigate the consequences of participating in an Australian turtle mapping app, TurtleSAT, on skills and knowledge gain, and test for any association between these gains and behavioural or attitudinal changes reported by the participants.
3. One hundred and forty-eight citizen scientists completed our questionnaire, mostly from the states of New South Wales and Victoria. TurtleSAT was the third most common source of correct answers about turtle ecology and conservation, after a talk about turtles and personal observations/research. Citizen scientists who participated more often were more knowledgeable about turtles than infrequent users. Self-reported gains in knowledge and skills were positively linked to attitudinal and behavioural changes, such as being more aware of turtles on roads. However, behaviour and attitude changes were not related to participation rate. Respondents also reported that after learning about the current decline in turtle populations, they adopted several turtle-friendly practices, such as habitat restoration or moving turtles out of harm's way, underlining the importance of increasing people's awareness on species declines.
4. The reported changes in attitudes and behaviours are likely to positively impact the conservation of Australian freshwater turtles. Engagement with citizen science projects like TurtleSAT may result in participants being more interested in the natural world, by learning more about it and being more exposed to it, and therefore contributing more actively to its protection.

KEYWORDS
education, public engagement, vertebrate

1 | INTRODUCTION

Citizen science, which encompasses projects involving a collaboration between professional scientists and volunteering citizens, is an important source of knowledge in many scientific fields (Bonney et al., 2016; Follett & Strezov, 2015; Theobald et al., 2015). Citizen science is a cost-effective way to collect data over large temporal and spatial scales, particularly in biodiversity conservation (Wiggins & Crowston, 2011). Citizen-collected data have led to important discoveries useful for the management of threatened species (Irga et al., 2018; Newson et al., 2016; Santori et al., 2018). However, citizen science is not only useful for data collection, but also for the positive effects it has on individuals who participate. Indeed, participation in biodiversity-related citizen science has been linked to greater scientific literacy, citizen empowerment, an increase in pro-environmental behaviour and a positive change in attitudes towards nature (Bela et al., 2016; Bonney et al., 2016; Cohn, 2008; Stepenuck & Green, 2015). For example, nearly 90% of participants in the Great Pollinator Project in the United States reported an increase in nature appreciation, and 55% were more interested in environmental issues, while 70% of participants in the New York City Coyote Project reported a positive change in attitudes towards coyotes, and 78% reported to have reduced their ecological footprint (Toomey & Domroese, 2013). Also, citizen scientists involved in the National Institute of Invasive Species Science citizen science program, in the United States, improved their ability to provide a valid sampling design and write a scientific question after participating (Crall et al., 2012).

Participation in citizen science can also enhance a connection to nature (Evans et al., 2005; Toomey & Domroese, 2013), which can develop as citizen scientists' environmental knowledge, observational skills and outdoor experience improve through participation (Schuttler et al., 2018). These are important successes of citizen science. Indeed, those who feel more connected to the natural world are more likely to have greater psychological wellbeing (Cervinka et al., 2011), as well as exhibit pro-environmental behaviour (Fretwell & Greig, 2019), which can be defined as 'behaviour that consciously seeks to minimize the negative impact of one's actions on the natural and built world' (Kollmuss & Agyeman, 2002, p. 240). With more citizens connected to their local environment, the negative human impact on wildlife may be reduced, and businesses and government decisions could be influenced positively, paving the way for more environmentally conscious policies (Lewandowski & Oberhauser, 2017; Measham & Barnett, 2008; Nisbet et al., 2009; Stepenuck & Green, 2015).

Knowledge of threatening processes to wildlife and of general conservation issues can be a precursor to pro-environmental attitudes, behaviour, and engagement with conservation (Hines et al., 1987). Several citizen science projects have increased their participants' knowledge on the subject investigated (Branchini et al., 2015; Haywood et al., 2016; Peter et al., 2019; Schuttler et al., 2018). Usually, people who volunteer to participate in citizen science are already interested in the topic, want to learn more about it, and want to contribute to the field (Van Den Geoghegan et al., 2016; Lewandowski & Oberhauser, 2017; Berg et al., 2009). Therefore, participants are likely to be receptive to learning from their experience doing citizen science (Lewandowski & Oberhauser, 2017), and this is reflected in the results of several studies. For example, >90% of participants in the Red Sea Coral Reef Monitoring Program in Egypt had greater knowledge of coral reef biology and human impacts on it after participating (Branchini et al., 2015). Some citizen science projects include workshops to train participants (e.g. Crall et al., 2012; Haywood et al., 2016; Jordan et al., 2011), while others provide the opportunity to learn by exposing the participants to new topics and activities (Masters et al., 2016). Indeed, there is evidence that even participating in online citizen science (e.g. Zooniverse) can increase scientific knowledge on the subject of the project (Masters et al., 2016).

Nevertheless, knowledge is not the only precursor to pro-environmental attitudes and behaviours, and it can have a limited effect on them (Kollmuss & Agyeman, 2002). For example, pro-environmental behaviours may require skills (that are additional to knowledge) to address environmental problems (Hines et al., 1987; Wiernik et al., 2018). Citizen science can improve participants' skills (Peter et al., 2019). For example, volunteers in Australia reported learning technical skills for bush restoration and sustainable living throughout their time as participants in environmental projects or in environmental groups (Measham & Barnett, 2008). Furthermore, citizen scientists might improve scientific skills such as animal species identification (Masters et al., 2016; van der Wal et al., 2016). Therefore, citizen science might be able to influence pro-environmental attitudes and behaviours not only by teaching participants about conservation problems, but also through training skills useful in scientific investigation and in addressing environmental issues directly.

Environmentally responsible citizens could, in the long term, help to curb environmental problems caused by direct human action (Walton & Hume, 2011), and possibly promote the recovery of threatened species (Shunula, 2002). Therefore, by increasing the knowledge and skills of participants, conservation-focused citizen science projects might be an important precursor to participants' pro-environmental change. Nevertheless, it is important to consider that participant outcomes, such as increased knowledge, are not often explicit goals of citizen science projects, and measuring them can be challenging (Bela et al., 2016). Moreover, there are examples where participation outcomes such as pro-environmental attitude or behaviour change are not detected despite an increase in knowledge (Brossard et al., 2005; Jordan et al., 2011); therefore, a translation from knowledge into action is not always present.

Here, we assessed how participating in TurtleSAT affected citizen scientists' knowledge on turtles, whether it taught them new skills or improved them, and whether it affected their behaviour and

attitudes towards nature, turtles, and conservation. TurtleSAT is an Australian turtle mapping app launched in 2014 to address large-scale questions in freshwater turtle conservation. While the primary project aim is to collect data on turtle abundance and distribution, TurtleSAT is a community programme that includes an outreach component, which is aimed at increasing participants' knowledge and awareness about turtles, alongside teaching them how to use the app. The project is largely self-directed, with most input from the scientists limited to social media messaging, public talks and traditional media interviews. In this study, we explored (a) whether citizen scientists adopted any turtle-friendly practices since learning about a turtle decline, (b) if a greater participation rate in TurtleSAT was associated with greater knowledge about turtles, (c) whether citizen scientists who participated more often felt like they gained more knowledge and research skills and (d) if knowledge level, participation rate, and the perceived level of skills and knowledge gained from TurtleSAT were associated with behavioural and attitudinal changes reported by the participants.

2 | METHODS

2.1 | The TurtleSAT project

In Australia, and particularly in its largest river system, the Murray–Darling Basin, freshwater turtles have greatly declined (Chessman, 2011; Van Dyke et al., 2018, 2019). TurtleSAT (www.turtlesat.org.au) is a citizen science project based on a smartphone and web-based app. This project was created to address large-scale questions related to freshwater turtle ecology and their conservation, such as the number and location of nests or mortality hotspots. Citizen scientists can participate in this project opportunistically across Australia, uploading a sighting whenever they encounter a turtle (dead or alive) or a turtle nest. Citizen scientists are recruited and kept informed through the TurtleSAT website, social media (Facebook, Twitter) and occasional workshops and public talks, which are organised both by the TurtleSAT team as well as community groups and government agencies that help to promote the project, particularly in the Murray–Darling Basin. The TurtleSAT website includes information about the project, about freshwater turtles in Australia and their current decline, details of the three species living in the Murray River (the priority species of the project), and instructions on how to get involved and use the app.

2.2 | Questionnaire and scores design

We built our web-based questionnaire on the REDCap (Research Electronic Data Capture) online system (Harris et al., 2009), which was hosted by The University of Sydney. Anyone who uploaded at least one sighting to TurtleSAT was invited to answer our questionnaire. We recruited respondents by advertising our questionnaire on the TurtleSAT social media channels, and by sending two e-mails to all TurtleSAT participants who provided their e-mail address upon registration to the project (University of Sydney Human Ethics approval 2017/981). The two e-mails were sent 11 months apart to maximise recruitment. Informed consent was obtained from all participants. The questionnaire was available online from the 7 June 2018 to the 11 September 2019, and was anonymous.

The questionnaire included five sections. The first part was aimed at quantifying prior knowledge about turtles and their threats, and the provenance of this knowledge. We first tested content knowledge by including a quiz made of four multiple-choice questions on turtle ecology and conservation (Table 1A), giving 1 point if the answer was correct, 0 if it was not. As nest predation is one of the leading conservation issues for turtles in Australia

TABLE 1 (A) Survey questions from knowledge test, with correct answers underlined, (B) Likert-scale questions for self-reported knowledge and skills gained by participating in TurtleSAT and (C) Likert-scale questions of behavioural or attitudinal change. The possible answers to the likert-scale questions were strongly disagree, disagree, neutral, agree, strongly agree

(A) Questions for 'knowledge level' (followed by question 'Where did you learn this fact?' from which we constructed the 'knowledge from TurtleSAT level')
Q1: Do you know when the Eastern long-necked turtle *Chelodina longicollis* nesting season is? (Choices: spring, autumn, winter, summer)
Q2: Can weather trigger freshwater turtle nesting? (Choices: Yes, rain; Yes, droughts; Yes, wind direction; No; I don't know)
Q3: How much have populations of common species of freshwater turtles declined in the last 40 years along the Murray River? (Choices: 69%–91%; 30%–50%; 9%–29%; There has been no decline, I don't know)
Q4: How many turtle nests do foxes destroy along the River Murray? (Up to 93%; Up to 53%; Up to 23%; Up to 3%; I don't know)
(B) Questions for the 'self-reported skill and knowledge gain score' (Likert-scale). Q1–Q3 are about skills gain, Q4 is about knowledge gain
Q1: Participating in TurtleSAT has improved my ability to identify freshwater turtle species
Q2: Participating in TurtleSAT has improved my ability to find turtle nests
Q3: Using TurtleSAT I developed new skills
Q4: Using TurtleSAT I learned more about turtles
(C) Questions on behavioural and attitudinal change (Likert-scale apart from Q5 yes/no)
Q1: Participating in TurtleSAT made me more aware of turtles on roads
Q2: TurtleSAT inspired me to participate in other citizen science/volunteering projects to help wildlife
Q3: After using TurtleSAT I am more interested in the natural world
Q4: After participating in TurtleSAT, I am more worried about Australian freshwater turtles than I was before
Q5: Have your attitudes towards turtles changed since you started participating in TurtleSAT?
Q6: By participating in TurtleSAT I feel like I am helping turtles

(Spencer & Thompson, 2005; Van Dyke et al., 2019), we focussed our questions on knowledge of this topic, including questions about nest season timing and what triggers nesting, and to what extent alien predators are an issue for turtle recruitment. We summed the results of these four questions, to create a variable henceforth called 'knowledge level'. Furthermore, if a citizen scientist answered correctly, they were asked where they had learned that fact, also in the form of a multiple-choice question (Figure S2). We then summed 1 point only for each correct answer learned from TurtleSAT, to create a 'knowledge from TurtleSAT level'. Moreover, we asked whether they had read information about Australian freshwater turtles and their decline on the TurtleSAT website, to evaluate how many citizen scientists were accessing the website specifically for information.

The second part was aimed at assessing whether knowledge of the current turtle decline inspired turtle-friendly behaviours. We asked the question 'what practices have you adopted since learning about the current freshwater turtle decline?', to which a multiple-choice answer was provided (Figure 1 for wording).

The third part was aimed at assessing whether the citizen scientists felt like they gained new skills and knowledge from participating in TurtleSAT. We posed four Likert-scale questions related to skill and knowledge gain (Table 1B) to construct a self-reported skill and knowledge gain score (hereafter: 's–k gain score'). This score consisted of the sum of the answers to the four Likert-scale questions, with responses coded as 1 for strongly disagree to 5 for strongly agree. The fourth part of our questionnaire included five Likert-scale questions and a closed (yes/no) question about attitudinal and behavioural change following participation in TurtleSAT (Table 1C). We define attitude as 'a feeling or opinion about something or someone, or a way of behaving that is caused by this', and behaviour as 'the way that someone acts or does something' (Cambridge English Dictionary, 2020). Therefore, we consider Q2 to indicate behaviour change, and the rest to indicate attitude change (Kollmuss & Agyeman, 2002).

Finally, the fifth part included a series of demographic questions to evaluate the diversity of our respondents, and how well they represented the entire pool of TurtleSAT participants. We also assessed participation rate by asking how many sightings they uploaded (with a multiple-choice question with 'one sighting', 'two to five', 'six or more' and 'I don't remember' as options). For the analysis, we excluded the 'I don't remember' answers, to compare more precisely different rates of participation. We chose the aforementioned categories as an indication of participation rate, with one sighting being the bare minimum participation, and 'six or more' representing an above-average user effort (average effort being 4.24 sighting per user, when excluding the most avid TurtleSAT user as an outlier with 3,279 uploads). A separate set of questions within the same questionnaire was analysed in Santori et al. (2020) to determine the reasons why participants left the TurtleSAT app after initial use.

2.3 | Statistical analysis

We used RStudio for all our statistical analyses (R version 3.6.1; R Core Team, 2019). We started by computing two Poisson regressions to assess whether the 'knowledge level', and then the 'knowledge from TurtleSAT level', were significantly associated with participation rate,

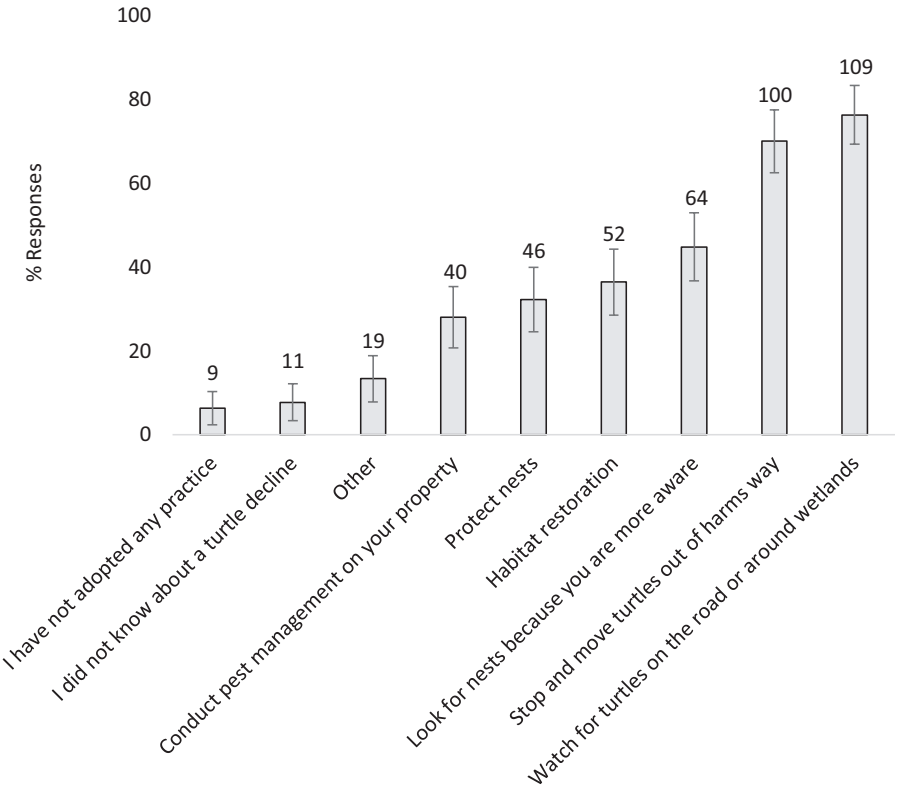

FIGURE 1 Percentage of respondents (±95% confidence intervals) who chose each option (respondents could choose more than one) as an answer to the question: 'What practices have you adopted since learning about the current freshwater turtles' decline?'. The following two answers have been shortened in the graph 'I have not adopted any practice *in aid of freshwater turtles*', 'I did not know about a turtle decline *up until now*'. The number above each bar is the count of respondents who chose that option ($N = 143$)

represented by the three categories of number of sightings uploaded. We assessed whether the 'knowledge level' and the 'knowledge from TurtleSAT level' were associated with how many turtle-friendly practices a participant adopted, by computing two Poisson regressions, due to our data being integer counts.

The 's–k gain score' had a Cronbach's α of 0.83 (95% CI 0.79–0.88). An exploratory factor analysis confirmed that the four questions used to develop the s–k gain score comprised one factor, and a confirmatory factor analysis reported our score having CFI = 1.000, $SRMR_{Mplus\ nomeans}$ = 0.018 and RMSEA = 0.000. Scaled values were the same as the unscaled ones. This analysis was computed with the R packages PSYCH (1.8.12; Revelle, 2018) and DEVTOOLS (2.2.0; Wickham et al., 2019). The answers to these four Likert-scale questions were all positively correlated with each other (Figure S1). We computed a Poisson regression to test whether the 's–k gain score' was significantly liked to participation rate. For each Poisson regression computed, we inspected residuals and Q–Q plots. Moreover, we tested for correlation between 'knowledge level' and 's–k gain score', and then 'knowledge from TurtleSAT level' and 's–k gain score', using Kendall's τ.

We tested whether a participant's 'knowledge from TurtleSAT level' and 's–k gain score' were linked to the statements/questions representing perceived attitudinal or behavioural change (Table 1C). For this, we first transformed Q1–Q5 to binary variables, with strongly agree and agree = 1; neutral, disagree and strongly disagree = 0. Then, we computed a logistic regression for each of the statements as the dependent variable, with the 'knowledge from TurtleSAT level' and 's–k gain score' as predictor variables. Because we expected 'knowledge from TurtleSAT level' and 's–k gain score' to be correlated, we computed separate logistic regressions, each with only one of them as the predictor variable.

To further assess and visualise the relative importance of each statement included in the 's–k gain score' (Q1–Q4, Table 1B) to behavioural or attitudinal change, we also transformed the answers to these four questions into binary variables (in the same way as for the attitudinal/behavioural change questions), and then computed a chi-squared test for each combination between them and the behavioural or attitudinal change binary questions (Table 1C). Finally, we tested for any association between behavioural or attitudinal change and participation rate. For this, we computed another series of chi-squared tests between participation rate and each of the behavioural or attitudinal change binary questions (Table 1C). For all multiple comparisons, we Bonferroni-corrected the critical α level.

3 | RESULTS

Of 157 questionnaires that were returned, 35 were partially completed and were included only in the analyses of questions for which they provided an answer. Nine questionnaires were returned to us with matching information and e-mail address of the respondents, and therefore we eliminated them as duplicates. N = 148 accounts for 14% of the total number of users who uploaded at least one sighting to TurtleSAT since its launch (N = 1,076) to the end of our questionnaire study. The total number of users was calculated on the 11 September 2019, by counting unique user IDs created upon upload of a sighting without registering, and e-mail addresses linked to user accounts. Since it is possible that the same user uploaded several sightings without creating an account, thereby creating an additional unique user ID at every upload, N = 1,076 might be an over-estimate. Forty-one per cent respondents selected New South Wales as the Australian state from which they mostly participated, and 31% selected Victoria (N = 139; Table S1). Out of the respondents who reported their gender (N = 139), 52% were female. The majority (63%) of respondents who reported their education level (N = 139) had a bachelor's degree or higher (Table S2). Eighty-five per cent of respondents said they uploaded live turtle sightings, 28% uploaded turtle nest sightings and 42% uploaded dead turtle sightings (N = 148). Twenty-four per cent of respondents uploaded one sighting, 35% respondents uploaded two to five, 27% respondents uploaded six or more sightings and 15% could not recall (N = 147).

TurtleSAT was the third most important content knowledge source, after 'a talk about turtles' and 'personal research or observation' (Figure S2). The overall 'knowledge level' was on average 2.43 out of 4 ($\pm$0.11 SE, median = 3, min = 0, max = 4), with 47 out of 156 respondents answering all four questions correctly. The 'knowledge from TurtleSAT level' was on average 0.52 out of 4 ($\pm$0.08 SE, median = 0, min = 0, max = 4), with five respondents answering all four questions correctly and having learned the answers on TurtleSAT. The 'knowledge from TurtleSAT level' was positively correlated with the statement 'Using TurtleSAT I learned more about turtles' (z = 4.488, p < 0.001; Figure S3). Participation rate in TurtleSAT was positively correlated with the respondents' 'knowledge level' (z = 2.736, p = 0.006), with respondents uploading 6 or more sightings having greater knowledge (Table S3). Participation rate was not, however, linked to the 'knowledge from TurtleSAT level' (z = 0.640, p = 0.522). Twenty-eight per cent of all respondents were not aware of the turtle information present on the TurtleSAT website. Sixteen per cent of respondents who uploaded only one sighting to TurtleSAT accessed the information on the website, compared to 49% and 35% of respondents who uploaded to TurtleSAT two to five or more than six sightings respectively.

Most of the respondents to our questionnaire claimed that they adopted turtle-friendly practices after learning about a turtle decline. For example, 109 respondents chose 'I watch for turtles on the road or around wetlands' and 100 chose 'I stop and move turtles out of harm's way' (Figure 1). The 'knowledge level' was positively associated with the number of turtle-friendly practices adopted (z = 4.193, p < 0.001), and so was the 'knowledge from TurtleSAT level' (z = 3.333, p < 0.001), suggesting a positive link between knowledge about turtles and the adoption of turtle-friendly behaviours. Participants who uploaded six sightings or more, adopted more turtle-friendly practices (z = 2.715, p = 0.007; an average of 3.62 practices adopted $\pm$ 0.27 SE), compared to participants who

uploaded one sighting (2.26 practices ± 0.34 *SE*) or two to five sightings (2.88 practices ± 0.24 *SE*).

Most respondents (70%) claimed to have learned more about turtles by using TurtleSAT, and almost half (47%) increased their ability to identify turtle species (Figure 2). Fewer respondents claimed to have learned new skills (34%) or improved their ability to find turtle nests (20%; Figure 2). After Bonferroni-correcting the α-level to 0.017, participation rate was not linked to the 's–k gain score' ($z = 2.089$, $p = 0.037$). The 's–k gain score' was positively correlated with both the overall 'knowledge level' ($\tau = 0.210$, $z = 3.273$, $p = 0.001$), and the 'knowledge from TurtleSAT level' ($\tau = 0.339$, $z = 4.912$, $p < 0.001$).

Most respondents claimed to feel like their participation in TurtleSAT helps turtles (84%), and they are now more worried about turtles than they were before participating (70%; Figure 3). After Bonferroni-correcting the α-level to 0.017, the 'knowledge from TurtleSAT level' was positively associated only with the agreement level to the statement 'after participating in TurtleSAT, I am more worried about Australian freshwater turtles than I was before' ($z = 2.394$, $p = 0.017$, Table S4). The 's–k gain score' was instead positively associated with all the statements representing self-reported attitudinal or behavioural change (Table S5). For example, the greater the 's–k gain score', the stronger the agreement with 'participating in TurtleSAT made me more aware of turtles on roads' (Figure 4).

Generally, respondents who claimed to have detected an improvement in either knowledge or skills (apart from 'Participating in TurtleSAT has improved my ability to find turtle nests'), also claimed to have changed their behaviour or attitude towards turtles (Figure S4). Respondents who submitted more sightings did not agree significantly more to any of the self-reported attitudinal or behavioural change statements, compared to respondents who submitted fewer sightings (Figure S4).

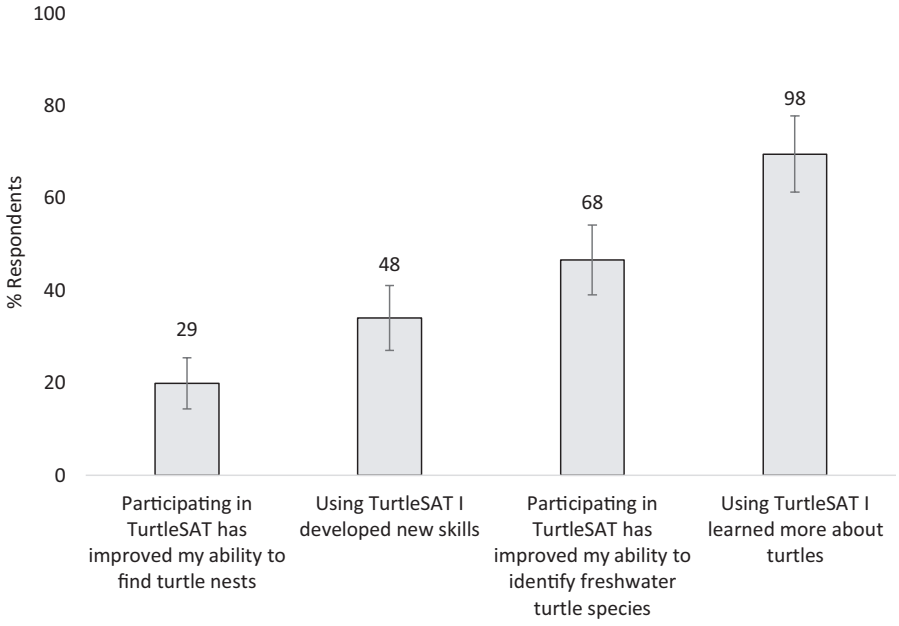

FIGURE 2 Percentage of respondents (±95% confidence intervals) who agreed or strongly agreed to each statement. The numbers above each bar represent the count of respondents ($N = 146$ for first and third statement from the left, $N = 141$ for second and fourth)

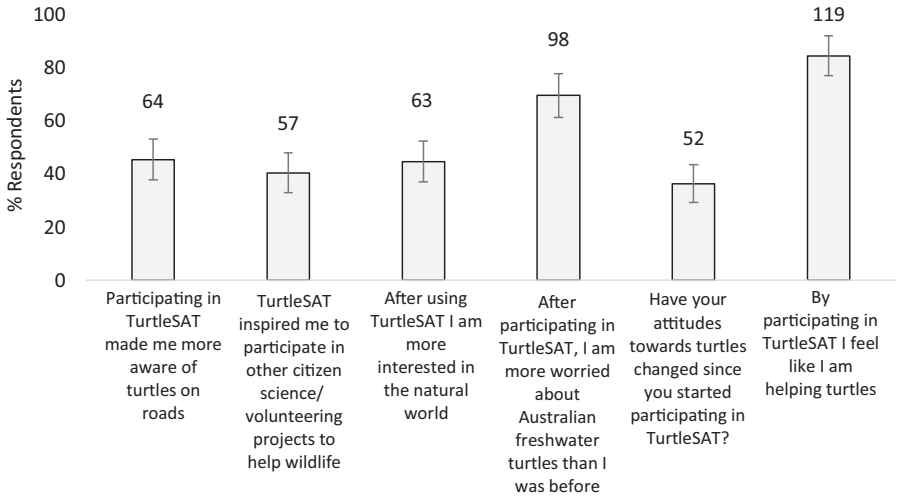

FIGURE 3 Percentage of respondents (±95% confidence intervals) who agreed or strongly agreed to each statement (or answered 'yes' to the attitudes question). The numbers above each bar represent the count of respondents ($N = 143$ for 'Have your attitudes changed…?' question, $N = 141$ each for all the rest)

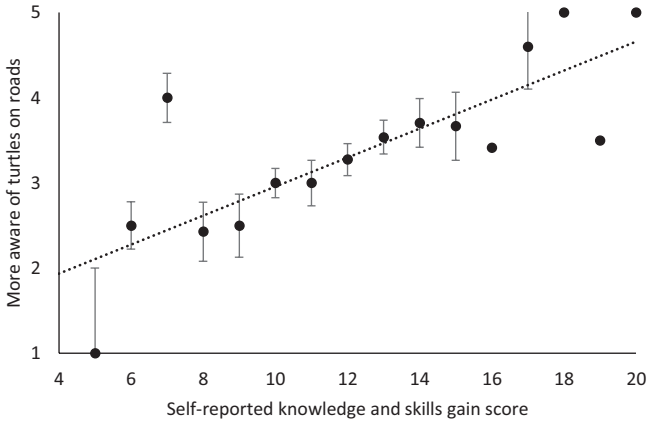

FIGURE 4 The greater the knowledge and skill gain score, the greater the agreement with the statement 'Participating in TurtleSAT made me more aware of turtles on roads' ($R^2 = 0.62$). The *y*-axis represents the Likert-scale coded as 'strongly disagree' = 1 to 'strongly agree' = 5. Error bars = *SE*

4 | DISCUSSION

TurtleSAT is a citizen science project that, alongside collecting data on turtle abundance and distribution, aims to increase participants' knowledge and awareness about turtles. Respondents to our questionnaire reported that the knowledge of a decline in turtle populations inspired the adoption of turtle-friendly practices. Furthermore, participants found TurtleSAT to be a source of knowledge about turtles, even though 'a talk about turtles' was the primary source of correct answers to our turtle knowledge test. Citizen scientists who uploaded more turtle or nest sightings were more knowledgeable about turtles compared to the ones who uploaded fewer sightings. Additionally, self-reported skills and knowledge gains were positively associated with the agreement level to statements of self-reported attitudinal and behavioural change related to freshwater turtles and their conservation, which suggests that learning new information and skills could encourage change that may be useful for environmental conservation. Our results support other findings that knowledge can be associated with, and possibly a precursor to, pro-environmental behaviour and attitude change (Campbell Bradley, 1999; Hines et al., 1987).

4.1 | A link between knowledge of a turtle decline and conservation action

Most of the respondents identified turtle conservation practices that they have adopted since learning about the current freshwater turtle decline, ranging from habitat restoration to moving turtles out of harm's way. Also, the greater the knowledge acquired specifically from TurtleSAT, or the greater the participation rate, the more numerous the adopted practices were. These results suggest an association between our respondents' knowledge about turtle conservation issues and conservation action, as well as a potential association between information learned through citizen science and a positive behaviour change, which could be beneficial to threatened species. As conservation issues are deeply linked with human behaviour (Berger-Tal & Saltz, 2016), increasing peoples' awareness and inspiring behavioural change could be crucial for species recovery and, in this case, for countering the decline of freshwater turtles in Australia.

4.2 | Sources of knowledge: Citizen science and outreach events

Similarly to other studies (e.g. Masters et al., 2016), we found a significant association between participation rate and level of knowledge, with respondents contributing more to TurtleSAT replying correctly to more questions about freshwater turtle ecology and conservation. However, we found no association between knowledge learned specifically from TurtleSAT and participation rate. This possibly indicates that more knowledgeable respondents tended to participate more, as their previous knowledge about turtles and their plight might have inspired them to contribute to TurtleSAT. Alternatively, participation in TurtleSAT could have motivated citizens to search elsewhere for information on turtles, or encouraged more field observations that then led to the right answers to our questions. Nevertheless, the TurtleSAT app and website were the third-most reported source of correct answers, showing that the project was a platform where participants reported having learned about turtles. 'A talk about turtles' was instead where the respondents learned most correct turtle facts, a result that underlines the importance of scientific communication and outreach. Outreach events can have positive impacts, for scientists as well as the audience, which can be inspired to find out more about science and the topic presented (Clark et al., 2016). Our results suggest that public talks are effective in successfully teaching turtle ecology and conservation facts. Nevertheless, knowledge on its own is unlikely to directly result in pro-environmental attitudes and behaviours, as several other factors have influencing roles, such as environmental awareness and concern (Chan et al., 2014). To maximise its impacts, outreach methods other than public talks should be used depending on the audience (Busse et al., 2015).

Many other citizen science projects also reported an increase in knowledge among their participants (Haywood et al., 2016; Peter et al., 2019; Schuttler et al., 2018). While various projects include several hours of training (Crall et al., 2012; Jordan et al., 2011), TurtleSAT is mostly self-directed, apart from occasional outreach events, call-outs and reminder posts on social media. Despite being self-directed, TurtleSAT could still be an important educational tool, with 70% of respondents claiming that by participating they learned more about turtles. However, even with a positive correlation between the level of agreement to this statement and the TurtleSAT knowledge level, the average of correct answers to the turtle ecology and conservation quiz learned on TurtleSAT was low. Since the knowledge level score was comprised by four questions, this score was possibly not comprehensive enough to wholly

represent a participant's knowledge gain, which could have included other information about turtles, or an increase in knowledge of a different kind. It is also possible that the self-reported knowledge gain by the participants was overestimated (Dunning, 2011; Mahmood, 2016). The discrepancy justifies some caution when drawing conclusions on the effectiveness of a citizen science app such as TurtleSAT in educating people about turtle conservation, particularly its effect on factual, scientific knowledge. Indeed, it is important to underline that the four knowledge questions tested only factual knowledge, while other types of knowledge were not represented by our questions, but are still important for conservation. Participating in citizen science may also foster a connection with, create, or improve other types of knowledge, such as indigenous and traditional knowledge (Benyei et al., 2020), which can be very useful for environmental management (Lehébel-Péron et al., 2016). Future research should recognise and include other types and sources of knowledge by using a more comprehensive approach. In the future, the TurtleSAT program could strengthen its current educational approach by organising more local/online workshops, creating a turtle-related newsletter and setting up an interactive online space for participants to share knowledge and experiences.

4.3 | TurtleSAT as a source of new skills

A minority of respondents reported an improvement of their skills, which aligns with other studies that report a greater increase in conceptual knowledge compared to practical skills (Jordan et al., 2011; Sickler et al., 2014). For example, only 20% of respondents felt that participating in TurtleSAT improved their ability to find turtle nests. Finding turtle nests is difficult, as it requires monitoring nesting females, and nesting is often nocturnal (Spencer, 2002). In further research, it would be valuable to evaluate the improvement in specific skills during a workshop (e.g. Jordan et al., 2011), and either ask more questions about the acquisition and improvement of specific skills, or organise a practical test (Sickler et al., 2014). In the future, TurtleSAT and its participants may benefit from adding to the app an element of practical training, either virtual or in-person, upon user sign-up.

4.4 | Self-reported attitudinal and behavioural changes regarding turtles and their conservation

More than half of our respondents reported having changed their behaviour or attitude towards turtle conservation and nature because they participated in TurtleSAT. These results suggest a potentially important link between a positive learning experience—both theoretical and practical—and personal change, which could have a positive impact on freshwater turtle conservation. For instance, most respondents reported that by contributing to TurtleSAT they feel like they are helping turtles, which could represent an important feeling of empowerment in turtle conservation. Moreover, almost half of the respondents reported being more aware of turtles on roads because of their participation in TurtleSAT. Considering that mortality on roads is a significant problem for freshwater turtles in Australia (Santori et al., 2018; Spencer et al., 2017), this is a remarkable result of citizen science, and could help greatly with turtle conservation.

Participation rate was not associated with the level of agreement to the attitudinal and behavioural change statements. Therefore, the quality of the experience that a participant has within citizen science, or just the act of participating, might be more impactful than the frequency of participation. Participating in citizen science, particularly if the project has a conservation focus (such as TurtleSAT), could be perceived as a pro-environmental action in itself, promoting a self-reinforcing cycle where the participant then may feel more environmentally responsible, may have more positive attitudes towards the environment, and ultimately may change their behaviour (Toomey & Domroese, 2013). It would be valuable to explore this relationship in detail with further study, perhaps expanding the 'participation rate' variable to an open-ended question, or using a different metric for participation rate. Indeed, someone could be participating often in TurtleSAT, and yet encounter turtles or find nests very rarely.

The s–k gain score was strongly associated with a participant's agreement to each behavioural and attitudinal change statement. This relationship may indicate that the more knowledge and skills the participants felt like they gained from their experience in TurtleSAT, the more their attitudes and behaviours were impacted. However, the s–k gain score is a self-reported metric, and self-reported data are not reliable or accurate in all circumstances (Buhlin et al., 2002; Short et al., 2009). Indeed, the claimed skill and knowledge gain might reflect a participant's passion and/or enjoyment of the project, and not an actual gain of skills and knowledge, particularly if a participant was already skilled and knowledgeable before joining the project. However, self-reported metrics can be useful and valid (Chan, 2009; Ramo et al., 2011), including when students report their perceived learning progress (Benton et al., 2013). Interestingly, the level of participants' knowledge learned on TurtleSAT was associated only with one of the attitudinal change statements. This may be because, as discussed previously, our 'knowledge learned from TurtleSAT' level did not include all that the participants could have learned, while three of the four statements comprising the s–k gain score were about an improvement in skills.

The s–k gain score and the knowledge from TurtleSAT level were positively correlated, therefore their relationship with attitudinal or behavioural change needs to be interpreted with caution. Nevertheless, all statements of self-reported skills and knowledge gain claimed by participants were positively linked to behavioural or attitudinal change. These results suggest a potential for citizen science to improve pro-environmental attitudes and behaviours by offering a positive learning experience, and this hypothesis is worthy of being examined further.

4.5 | Study limitations and future research directions

We are experiencing a mass extinction event caused by human expansion and unsustainable practices (Ceballos et al., 2015), which require a behavioural change across society to rectify. Strategies for changing behaviour by informing the audience of an issue can be strengthened through direct, practical experience (De Young, 1993; Stern et al., 2017), and can create positive changes in people's habits (Walton & Hume, 2011). Here, we have gathered evidence that TurtleSAT was recognised by participants as a platform where they learned about turtles, and through which they helped turtles. Our results support the possibility that TurtleSAT has been a positive influence on attitudinal and behavioural change of participants, the extent of which is correlated with how much participants felt they gained in terms of knowledge and skills while participating. Some of the attitudinal and behavioural changes reported here may lead to practices that could be beneficial to turtle conservation, particularly if widely adopted.

We acknowledge the limitations of our study, particularly the relatively small sample size and the absence of pre-participation data. New citizen science projects should therefore include a pre-participation assessment, perhaps as part of an online account creation, to then benefit from this information in any later research on participation consequences. Furthermore, we have relied on self-reporting, thus a future study that measures knowledge and skills improvement objectively would increase our confidence in these conclusions. Moreover, some previous research work has observed the opposite of what we detected, that is, that knowledge level was not a precursor of pro-environmental behaviour (Kempton et al., 1995). Pro-environmental behaviour change is very complex and has a variety of influencing factors including demographic, economic, social and cultural influences (Kollmuss & Agyeman, 2002), which were not included in our study. Therefore, future studies should evaluate the association we have observed in the context of such other factors.

Based on the associations we detected between learning and both attitudinal and behavioural changes, we recommend that scientists managing citizen science projects consider ways to create a more focused educational experience. Citizen science projects like TurtleSAT, which are largely self-directed, rarely reflect upon their impact on participants (Bela et al., 2016). However, we found that this type of citizen science still has the potential to inspire positive change despite its limitations, and could be improved by strategically including learning objectives in the data collection process. Creating a more direct link between social media, the project's website and the scientific literature might render information more accessible (Santori et al., 2020). Organising workshops on specific scientific skills, such as species identification, might support the skill improvement that currently is limited. Also, including regular evaluations of participation outcomes, such as the survey conducted in this study, would be valuable for identifying project strengths, weaknesses and impacts on participants. A comparison between projects with differing types of outreach activities could identify the relative importance of differently structured educational components on participant outcomes. Finally, to ensure a lasting contribution of citizen science to environmental protection, future research should focus on techniques that allow for long-term retention of any behavioural and attitudinal changes in participants.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

AUTHORS' CONTRIBUTIONS

C.S., R.-J.S., M.B.T. and J.U.V.D. conceived the project and designed methodology; C.S. collected the data and led the writing of the manuscript; C.S. and R.J.K. analysed the data. All authors edited the manuscript draft and approved its publication.

DATA AVAILABILITY STATEMENT

Data deposited in the Dryad Digital Repository https://doi.org/10.5061/dryad.1g1jwstv8 (Santori et al., 2021).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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