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TEACHERS' EXPERIENCES AND VIEWS ON INTEGRATING CITIZEN SCIENCE  
APPLICATIONS INTO SCHOOL-BASED BIOLOGICAL EDUCATION

MA thesis

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## Abstract

This study explores teachers' experiences and perspectives on integrating citizen science (CS) applications into biology and environmental education in schools, aiming to understand their motives, strategies, and challenges, as well as the extent to which they incorporate citizen science into their teaching. Ten participants, school teachers with varying teaching experience across different geographic regions, were interviewed using semi-structured interviews. Inductive content analysis was employed for data analysis. The findings reveal that teachers commonly use CS applications as standalone tools, seeing them as beneficial for teaching and student learning. They prefer using these applications outside regular lessons to avoid curriculum constraints and challenges associated with phone use in schools. Surprisingly, even teachers actively engaged in CS activities themselves rarely involve students, possibly due to time constraints, lack of understanding of integration methods, or simply overlooking the opportunity.

**Keywords:** *teachers, citizen science, biological education, mobile applications*

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## 1. Introduction

Scientific literacy is defined by the OECD PISA Framework (2015) as the ability to engage with science-related issues and concepts as a reflective citizen. In a conceptual review of the importance of science literacy and strategies for its improvement, Babalola (2013) notes that attitudes towards science can significantly impact science literacy. Negativity, e.g. fear of science, may hamper understanding and achievement of learning goals. Therefore, the development of positive attitudes towards science is an important goal of science education, as it contributes to the development of scientific literacy. It has been shown that using involvement in science activities generally have a positive impact on the way children think about science and add value to the educational process, helping them to stop seeing science as boring and distant from life (Şener et al., 2015). In order to attract students to science, they must be taught to think like scientists through the discovery of the scientific process, they need to understand how science is connected to their lives. (George & Kaplan, 1998; Queiruga & Saiz-Manzanares, 2018). An easy way to engage ordinary people in science, improve their attitudes towards science, and make science more understandable and relevant is to participate in citizen science.

The involvement of students in citizen science (CS), including in the formal education sector, is seen as an attempt to address the crisis in science education (Harlin et al., 2018). Citizen science is an approach in which individuals participate in scientific research on a voluntary basis, rather than as paid professionals, helping researchers with data collection and analysis (Hecker et al., 2018).

Involving children in doing citizen science can engage them in meaningful and positive activities, can improve learning by getting them involved in research, help them acquire subject knowledge and change attitude to science. It provides unique opportunities for students to deal directly with real-world issues, such as the environmental crisis, as within citizen science projects they work as volunteers on collecting and analysing data in collaboration working with scientists.

Citizen science as a part of the educational process can be characterised as a constructivist and empirical approach, where first hand experience plays a crucial role in the learning process. This approach promotes developing scientific and environmental literacy and builds the potential to sustain a lifelong interest in science (Jenkins, 2011; Brossard et al., 2005).

To make data collection and analysis more efficient, engage more participants and make it easier for citizen science volunteers, mobile applications were developed. Citizen science mobile applications can be a valuable tool for implementing it in schools and can play a significant role in science education. This allows for an expansion of the learning space and makes learning materials

more interesting and meaningful for students. Studies have shown that young students have a positive predisposition towards using smartphones for educational purposes (Echeverria et al., 2021; Aristeidou, Herodotou, 2020; Rode, Torkar, 2023). However, despite its educational potential, citizen science applications are not widely used as a teaching tool by teachers, and research on its use in schools is limited. Much of the existing research on the impact of citizen science and technology on learning has focused on the higher education sector (Tsivitanidou, Ioannou, 2020; Aristeidou, Herodotou, 2020). Further research in this area is needed to explore the use of these tools in schools.

## **2. Theoretical overview**

### **2.1 What is citizen science - history and current status**

Studying large-scale patterns in nature requires collecting vast amounts of data, often from multiple locations over extended periods. One method of collecting such data is through 'citizen science (Bonney et al., 2009). According to the Oxford English Dictionary, citizen science refers to scientific work carried out by individuals without specialised training with or under the guidance of scientists, yet mostly in collaboration with scientific institutions. In a broader sense, it covers all forms of participation in scientific research, such as taking part in trials and experiments, completing surveys and questionnaires, taking part in interviews, keeping observation diaries, and more. More narrowly, citizen science is about participation, where individuals are valuable sources of information and researchers themselves, collecting information locally, taking part in data analysis and helping to solve scientific problems (Bonney et al., 2009; Haklay, 2018).

The involvement of the general public in scientific activities is not a recent phenomenon. For instance, Carl Linnaeus, Swedish biologist and physician who created the modern system of naming organisms, in the 18th century attracted a large number of volunteers for specimen collection. This participation of non-professionals in science led to the creation of valuable collections of animals, plants, rocks, and fossils, which can still be observed in natural history museums worldwide. In these days, citizen science is becoming more and more popular. (Miller-Rushing et al., 2020).

Citizen science covers various fields of knowledge such as astronomy, biology, biodiversity monitoring, environmental monitoring, public health, economics, archaeology, physics, engineering, earth sciences, and more, but the majority of citizen science projects focus on biology, conservation,

and ecology. (Hecker et al., 2018; Dickinson, 2010; Frigerio, 2021, Kullenberg & Kasperowski, 2016). Therefore, this thesis will specifically focus on these areas of citizen science.

Collaborations between professional researchers and volunteers often take the form of projects. Citizen science projects can vary in the type and degree of involvement of volunteers in the research project. There are three main types of citizen science projects: most of them use a 'contributory' approach, where scientists design the projects and citizens collect and analyse the data. In contrast, 'collaborative' projects allow citizens to make suggestions on project design and participate in data analysis, while 'co-created' projects involve participants actively engaging with scientists at all stages of the research (Bonney et al., 2009, Phillips et al., 2014; Lemmens et al., 2021; Haklay, 2018).

The most common form of citizen science involves data collection, which provides information that would not be available without the participation of volunteers. This requires minimal training for volunteers, and their interaction with scientists is limited. Another area where volunteer help is needed is data analysis, particularly when there is a large amount of raw data that requires categorisation or interpretation, such as photographs or other forms of data from passive recording devices. Careful manual sorting and checking of results after processing by algorithms is necessary as not all data can be processed automatically. This requires a significant amount of human labour.

There are now thousands of such projects around the world involving millions of people (Theobald et al., 2015). This growth has been primarily fuelled by rapidly developing digital technologies that easily and efficiently connect volunteers with the scientific community and their peers. It can therefore be observed that since the mid-2000s, a number of projects have emerged that utilise digital platforms for the purposes of observation, collection of data, and the subsequent processing of said data. In addition, it is becoming increasingly common for field-based observation projects (such as eBird) to be dependent upon digital platforms for the reporting of observations and the subsequent provision of feedback to volunteers (Kullenberg & Kasperowski, 2016).

## **2.2. Use of digital technologies in citizen science and citizen science applications**

The development of digital technologies and the widespread use of the internet facilitate connections between individuals and the scientific community, as well as between individuals themselves. Digital technologies create new opportunities for networking and bringing together people who wish to contribute to research. This has given rise to the development of citizen science (Tsivitanidou & Ioannou, 2020).

The use of smartphones and advances in technology provide new opportunities and directions for citizen science, as well as new mechanisms for engaging volunteers. Smartphones have given people constant access to the microcomputers, Internet, GPS systems, microphones and cameras, allowing them to take photos and record videos (Brenton, et al, 2018; Lemmens et al, 2021). Data, including images and audio recordings of the environment, can be analysed using smartphones. Organism identification is aided by an AI interface that proposes potential taxonomic groups, alongside a robust community of users who validate identifications and suggestions made by others. For the convenience of data collection and the improvement of interaction between volunteers and researchers, various citizen science applications have been developed (Mazumdar et al., 2018; Lemmens et al., 2021). Mobile apps are particularly useful for capturing field observations or when participants need to regularly access the app (Lemmens et al., 2021). Therefore mobile apps for citizen science are widely used in the environmental field for collecting data on noise and air pollution, as well as monitoring biodiversity (Skarlatidou et al., 2020) In biological sciences, these applications are commonly used to record the location of plants and animals, date and geo-reference phenological events (Lemmens et al., 2021). Users can make photographs, videos, or sound recordings of objects, determine their location using GPS, upload the data about living organisms to the app, and get assistance in identifying different species. For data to be scientifically useful, it must be validated (Pocock et al., 2015). Moderators or a community of experts can provide this validation. To simplify this process, mobile applications for citizen science can incorporate machine learning models that are trained to recognize species and suggest the most plausible options to participants (Lemmens et al., 2021). The information gathered is then sent to scientific databases for further analysis. In this way, amateurs can contribute to biological research through apps, which can also help people learn more about the world of living things around them by helping to identify organisms they see. This can lead to increased attention to what is happening in nature (Boone, Basille, 2019).

In addition to the previously mentioned benefits, digital technologies can be utilised as a tool for engaging non-traditional audiences in scientific processes, including school students. Furthermore, mobile technologies can be employed to enhance and extend the educational experience beyond the traditional classroom setting, as any student with a smartphone has the potential to become a citizen scientist (Tsivitanidou and Ioannou 2020). Such applications offer opportunities to develop new educational experiences that encourage scientific thinking (Price et al., 2012).

### **2.3 The educational potential of citizen science and its implementing into schools**

Citizen science was developed by scientists for their own purposes, primarily aimed at populating databases and meeting the needs of the scientific community, rather than for educational purposes. Professional scientists often involve citizen scientists in specific tasks or research steps and present the project results in publications and research papers. These articles are typically written for a scientific audience and published in specialised journals, which can make them inaccessible to a wider readership. However, learning is an intended or unintended outcome of citizen science participation. Citizen science has educational potential as it engages citizens in important scientific activities that address real-life issues and promotes scientific literacy (Kloetzer et al., 2021).

The European Citizen Science Association promotes the principles of citizen science, which emphasise inclusion and learning, and recognise its potential in the educational sphere (Bonney et al., 2009a; Haklay, 2018). CS projects often claim to influence participants' knowledge, attitudes and behaviour. Generally, volunteering for biology and environmental projects provides a diverse learning experience. Participants develop an interest and motivation to learn about the environment, develop environmental literacy, and become actively involved in solving environmental problems, as well as immersing themselves in the specifics of biological and environmental science to acquire research skills, increase engagement and interest in science and nature, motivation to participate, development of scientific process and inquiry skills (Jordan et al., 2012, Phillips et al., 2014; Ruiz-Mallén et al., 2016; Bonney et al., 2016; Aristeidou & Herodotou, 2020; Shah & Martinez, 2016). They increase their knowledge in specific areas of science such as specific fauna or flora, and specific scientific methods and improve their overall science education. For instance, participants in CS ornithology projects acquire bird identification skills, learn to observe, become familiar with the scientific research process, and derive satisfaction from expanding their scientific knowledge (Bonney, 1996).

A similar effect is observed among school children: according to various studies, participation in citizen science projects broadens their understanding of scientific research, builds self-confidence, critical thinking and independent learning. Other learning outcomes may include understanding of ecology, engagement and interest in science and nature, motivation to participate, development of scientific process and inquiry skills, environmental stewardship behaviours, scientific and environmental identity (Jordan et al., 2012; Phillips et al., 2014; Shah & Martinez, 2016; Ruiz-Mallén et al. 2016). Participation in citizen science has the potential to foster a lifelong interest in science among young

participants. It can have a beneficial impact on their future lives, as they develop self-confidence and a sense of responsibility for addressing scientific challenges (Jenkins, 2011).

Julia Kelemen-Finan and co-authors (2018) measured educational outcomes during the evaluation of a large citizen science project involving students aged 8 to 18. The students recorded hedgehogs, wild bee activity, birds, and butterflies in gardens. The results showed that the students' interest, motivation, and perceived mastery increased throughout the project. On the other hand, Brossard et al, (2005) showed that participants in a citizen science project are more likely to acquire knowledge (in this case about bird biology) rather than change attitudes towards the environment and in the participants' understanding of the scientific process.

However assessing the educational outcomes of participation in citizen science projects is a challenging task. According to Aristeidou and Herodotou (2020), in informal settings of citizen science, where participation is flexible and learning is based on free choice, it seems unfeasible to conduct a formal assessment of knowledge. In such educational settings, it is difficult to quantify outcomes before and after learning. The majority of projects lack evaluation and those that exist tend to rely on self-reporting methods (Peter, et al. 2019). In a 2019 study, Peter et al. conducted a literature review of the learning outcomes of CS initiatives focused on biodiversity projects. The researchers identified seven individual participant outcomes: knowledge, behaviour (e.g. conservation actions, involvement of others in conservation and monitoring activities, friendly behaviour towards wildlife, etc.), attitudes (towards the environment or towards science), skills, self-efficacy (such as accurate species identification), interest, and other personal outcomes. Tsivitanidou and Ioannou (2020) conducted a literature review and categorised the individual educational outcomes that can be achieved through citizen science using technology into four groups: cognitive (intellectual aspect of learning), affective (relating to interests, attitudes and values), manual or physical skills and behavioural skills (research skills, technical skills such as machining and materials handling, design documentation). The main learning outcomes reported in these reviews include changing behaviours and attitudes towards science, increasing general and thematic scientific knowledge, acquiring skills, and gaining a deeper understanding of the nature of science. In the context of school education, the concept of citizen science has additional potential. Citizen Science activities provide opportunities for children to get outdoors, interact with and participate in nature conservation, and help to translate abstract concepts into visual representations. Thus, CS can make school science education more meaningful and motivational, less

tedious and science more accessible to children (Trautmann et al., 2012; Makuch, Aczel, 2018; Jenkins, 2011; Braund & Reiss, 2006).

Finally, organising citizen science projects for students can also benefit teachers and change the nature of the school itself. Engaging students with the natural world through citizen science approaches can be a meaningful context for students of all ages (Paige et al., 2015).

There is already a significant amount of research indicating positive results from the integration of citizen science applications into university natural history courses (Hernawati et al., 2020; Mech et al., 2022; Unger et al., 2021), but there is much less research on the implementation of citizen science in secondary education. For instance, Rode & Torkar's (2023) recent systematic review on the use of iNaturalist in biology education analysed 16 papers. Out of these, only 2 focused on high school students. However, several conclusions can be drawn based on existing research.

Review on this topic by Tsivitanidou and Ioannou (2020) found that citizen science projects in schools are most often related to biology, conservation and ecology. A number of case studies in the literature describe experiences of the development of citizen science projects in schools. For instance, a common way is to take part in BioBlitzes. These are events where volunteers assist in documenting species within a designated area for a predetermined period, typically lasting between 2 to 24 hours. BioBlitzes provide an opportunity for public participation and data collection for scientific research. The scientific goal of BioBlitzes is to record biodiversity data. These activities are easy to organise, making them suitable and accessible for school children. (Roger & Klistorner, 2016; Lorke et al., 2021).

#### **2.4. Challenges in implementing citizen science in schools**

The literature identifies critical challenges to the successful implementation of citizen science projects in schools, with one of the main challenges being the need to balance scientific and educational goals. Scientists often fail to consider the potential use of their projects in school education or assume that involving schools requires a substantial amount of time and effort (Makuch, Aczel, 2018; Phillips et al., 2018; Harlin et al., 2018; Gray et al., 2012).

Implementing citizen science projects can be challenging, especially if the scientific question requires specialised skills and knowledge. This may require additional training for participants. Proposed assignments should be designed to provide scientific interest and educational potential while avoiding a mismatch between the scientific goals of the project and the educational goals of teachers. This can be challenging because the questions of interest to scientists do not always align with the

student learning outcomes specified in state education standards (Shah & Martinez, 2016; Harlin et al., 2018; Owen & Parker, 2018).

The second challenge is providing adequate teacher support (Makuch & Aczel, 2018; Shah & Martinez, 2016; Harlin et al., 2018). This is due to teachers' lack of understanding of how to effectively integrate citizen science into the classroom. According to Owen & Parker (2018), teachers prioritize activities that align with their curriculum, develop student skills, and provide meaningful learning experiences, all of which can be assessed. When it comes to the extra effort required to implement new practices, overworked teachers often face time constraints and lack adequate administrative support.

Many citizen science projects and platforms offer educational resources to help teachers teach, uploading their materials online for teachers to review or create forums for teachers to discuss work. Some programmes even offer professional development sessions and workshops, but it is rare for schools to be actively involved by organisers of citizen science projects (Aristeidou et al., 2023; Phillips et al., 2018). However, simply inviting teachers to use support materials and guides is insufficient and rarely results in their active participation in the project (Harlin et al., 2018). For citizen science programs to be widely available to schools, they must provide appropriate instructional materials and clearly described methods for measuring educational outcomes. Teachers should ensure that projects have clear and concise descriptions and provide easy interactivity for students of different ages and backgrounds (Owen & Parker, 2018). Teachers incorporating CS into their instructional practices may need to adjust the curriculum to avoid overloading students with extra schoolwork and demotivating them (Shah & Martinez, 2016). Engaging school children in citizen science programmes, which require significant effort and resources, as well as the willingness of teachers to accept the uncertainty of the research process, can be challenging due to the issues mentioned above (Gray et al., 2012; Holøs, et al., 2016). According to teachers, making the task meaningful and ensuring that students experience the entire scientific process can be challenging (Aristeidou et al., 2023).

## **2.5. Teachers' motivation**

In the context of these complexities, it becomes pertinent to inquire as to the motivating factors that drive teachers to engage their students in citizen science. A number of studies have investigated the motivation of volunteers in citizen science. It is an important area of research in citizen science: for the success and sustainability of such activities, understanding people's motivations for participating in citizen science programmes and engaging volunteers is crucial. People participate in citizen science for

various reasons, including an interest in and a desire to learn about the project topic, a desire to help, a desire to protect the environment, and a desire to contribute to scientific research. In their 2021 study, Robinson and colleagues identified the following motivations: values, personal development, career and recognition, social and recreation. It was also noted that citizen scientists value the opportunity to interact with and learn from scientists, and seek feedback on the actual progress of the project and its overall outcomes (He et al., 2019; Roger & Klistorne, 2016).

Teachers have additional motivations, such as incorporating citizen science to add novelty to their teaching, for professional development, and to use mobile and other technologies with their students (Aristeidou, et al., 2022). Teachers may be motivated to engage in citizen science activities with their students by a desire to provide them with authentic scientific research experience or by offering learning opportunities that facilitate the development of students' knowledge and skills through hands-on experience (Doyle et al., 2017). Educators see this as an opportunity for students to engage with topics that are not otherwise accessible in the classroom or laboratory (Hecker et al., 2018). Also teachers may participate in citizen science activities with their students to engage them in authentic scientific enquiry activities. However, there is little research on the motivation of teachers to take part in citizen science, and it tends to focus on a particular group of teachers (Aristeidou, et al., 2022).

## **2.6. Using Citizen science applications for education**

A number of studies have highlighted the potential of mobile applications, when used in combination with a CS approach, to enhance traditional field-based biology classes. They can serve as a valuable complement to such classes and are used, for example, in BioBlitz activities, to enrich outdoor learning and create virtual herbaria (Tsivitanidou, Ioannou, 2020; Mech et al., 2022; Echeverria et al., 2021; Rode, Torkar, 2023). Mobile applications offer an opportunity for individuals to become citizen scientists by collecting various data during their daily routines (Shah, Martinez, 2016). Introducing these tools into the school curriculum can be an effective way to inspire students to learn about biodiversity in a fun and engaging way. It can also help students better understand some of the abstract and theoretical concepts included in the curriculum (Gray et al., 2012). Students perceive this approach as an effective way of learning about biodiversity, leading to increased curiosity, interest, and engagement with nature (Echeverria et al., 2021).

When considering the use of mobile devices by children, it is important to take into account potential technical barriers, such as connectivity issues or parental restrictions, as well as behavioural

factors, such as the tendency for children to become easily distracted (Orr, 2010). Teachers and parents may have prejudices against using phones at school. Additionally, some countries have implemented bans on students bringing mobile devices onto school premises (Echeverria et al., 2021; Aristeidou & Herodotou, 2020; Tsivitanidou & Ioannou, 2020). It is crucial that digital tools are accessible and user-friendly for all users, including those who may not be proficient in technology (Price et al., 2012). Research suggests that when students encounter a new application, they may feel uncertain, so it is essential for teachers to provide detailed instructions on how to use it correctly and an overview of its functions. However, teachers themselves may encounter similar issues and must possess adequate skills to work with new technologies and provide students with support in using these applications. They need to possess sufficient skills to work with new technologies and provide students with support in using applications (Aristeidou & Herodotou, 2020; Echeverria et al., 2021).

## **2.7. Research objectives and questions**

Previous research shows the potential of citizen science in education, and there's also evidence that using CS applications in schools can have educational benefits, but most of it focuses on assessing student learning outcomes from participating in citizen science projects, neglecting teachers' experiences and outcomes from other ways of using CS applications. There is little research on how teachers use these applications, why they adopt them in practice, and how CS activities fit into existing curricula.

Therefore the aim of this paper is to examine the experience and viewpoints of teachers regarding the incorporation of citizen science applications in biological and environmental education in schools, main motives of using it, strategies and challenges, how they perceive the impact on students and the extent to which they engage in citizen science when using these mobile apps. This paper develops around five research questions:

- What strategies do they use to integrate apps into the classroom?
- What are the main interests that teachers have articulated for using apps in the classroom?
- What are their perceptions of the impact of using apps on students?
- What are the challenges in incorporating these apps into teaching?
- To what extent do teachers engage citizen science when using citizen science applications?

### **3.Methods**

#### **3.1. Research design**

The aim of the study was to discover and understand teachers' experience and viewpoints on the use of citizen science mobile applications. To achieve this goal and answer the research question, qualitative research methods were chosen. Qualitative methods utilise texts, words, and conversations to develop concepts that contribute to understanding social phenomena, allowing researchers to explore and analyse how people make sense of their experiences (Bernard, 2005; Yauch and Steudel, 2003). A qualitative method was justified for this study because relatively little is known about teachers who use citizen science applications in the classroom, and such an approach allows for a deeper understanding of their experiences, hearing their opinions (Hammarberg et al., 2016).

#### **3.2. Semi-structured interviews**

The method of semi-structured interviews was chosen to collect data on teachers' experiences. The interviews were used to obtain rich data to better understand the experiences of teachers using citizen science applications to work with their students. Semi-structured interviews allow researchers to capture a multitude of perspectives on the subject under study. Interviewing is about inquiring about what cannot be observed: feelings, intentions and thoughts. This method focuses on meanings, beliefs, relationships, values, and motivations (Rocha, 2021). Thus, interviews are used to understand other people's perspectives. Participants' own words are the best way for researchers to understand their experiences. They can describe their feelings, experiences and views on a topic. (Kvale, 1996).

Furthermore, this method provides a high level of flexibility while maintaining structure, which makes it easier to organise and analyse interview data (Azungah, 2018; Bowen, 2009). In this method, interviews are based on predetermined questions, but the interviewer can modify questions, clarify wording, and ask additional questions for clarification as needed. In contrast to unstructured interviews, they follow an interview guide or script with key themes and provide structure through a pre-prepared protocol. This allows the researcher to focus on the topics discussed without being restricted to a particular format (Rocha, 2021; Taherdoost, 2022).

The interview protocol was developed and piloted in Russian before the research began. It was slightly refined after the first interview was conducted. The final questions were then translated into English. The interviews included open-ended questions on the main components of the research

question. To gather information about the teachers' backgrounds, the interviews included questions about their age, teaching location, teaching subject, grade level, student level and previous experience with computing applications. Follow-up questions were used where necessary to obtain a more detailed, richer response and/or to clarification. The interview protocol can be found in Appendix 1.

### **3.3. Recruitment and sampling**

The study involved biology and environmental science teachers from elementary, middle, and high schools who are already using citizen science applications in their classrooms. Announcements were posted on social media platforms such as Facebook Teachers Community pages and forums on citizen science platforms and the citizen science associations to recruit participants.

Interviews were conducted with 10 biology/life science teachers. Participants were selected using non-probabilistic judgmental sampling combined with snowball sampling. Non-probabilistic sampling is applicable to qualitative research that aims to study real phenomena rather than make broad generalisations and statistical inferences about a large population. Judgmental or purposive sampling is a strategy in which specific participants are deliberately selected to obtain important information that cannot be obtained by other means. Purposive sampling is used when access to potential respondents is difficult, as in this case when it is difficult to find a large number of teachers using citizen science applications and time to search is limited. This method was complemented by snowball sampling, in which participants were included in the study as the interviews progressed, based on recommendations from other respondents (Rocha, 2021; Taherdoost, 2016). To meet the sampling criteria, participants had to be actively teaching life sciences in schools and using citizen science applications in their teaching.

Ten participants were school teachers from diverse geographical locations with varying teaching experiences. The teachers worked in primary, middle, and high schools and had from 1 to 6 years of experience using citizen science applications in their classrooms. The majority of them taught biology or environmental science (in primary school) and some additional elective subjects. The teachers' ages ranged from 26 to 65 years old. The demographic data and background information is presented in Table 1 (in Appendix 2). The interviews were ethically conducted as described by Kvale (1996). All interviews were voluntary for the teachers, with no risk to themselves, their students or their careers. For ethical reasons, the confidentiality of all interviewees was strictly maintained. Participants' names and other personal details remain anonymous and they are referred to in this paper as the numbers listed in Table 1. They were informed of the purpose of the study and the main features of the

design, and signed an informed consent form to participate in the study (see in Appendix 3).

### **3.4. Data Collection**

Data collection started on 22.03.2024 and was completed on 27.04.2024. During this time, 10 interviews were conducted and data collection was completed at this stage as saturation was reached. Each interview lasted 30-60 minutes and was audio-recorded for transcription. The interviews were conducted face-to-face and via the Zoom platform, conducted in English and Russian, and were recorded, transcribed, and subsequently analysed. Participants signed an informed consent form (see Appendix 3) and were given copies of the transcripts and asked to give feedback on the accuracy of their interviews.

### **3.5. Data Analysis**

Thematic analysis was used to analyse the interview data.. This method was chosen because it is a flexible approach to analysing textual data, allowing for the analysis of data collected from various sources and in different formats, including surveys, interviews, and existing publications. This method allows for the identification of important themes or categories in the data set and provides a rich description of social reality (Braun & Clarke, 2006). It involves six stages: (1) familiarisation with the data by transcribing interviews and re-reading, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report (Braun & Clarke, 2006). Given the limited knowledge about the use of citizen science applications in the classroom, this study used inductive coding (moving from the particular to the general) (Azungah, 2018). Open coding was conducted, which involved grouping individual fragments, paraphrasing, and briefly summarising content. The research questions were used to guide the analysis when creating themes. Categories were freely created to describe each. (Azungah, 2018; Braun & Clarke, 2006).

## **4. Results**

The objective of this study was to examine the experience and viewpoints of school teachers regarding the incorporation of citizen science applications in environmental education in schools. This chapter presents the findings of the qualitative analysis of the interviews. Based on the interview data, the following themes were identified: the teachers' strategy; the teachers' motivation, interest and aims; the learning outcomes; the advantages, challenges and limitations of the new method in comparison to traditional methods and the engagement of citizen science.

#### 4.1. Strategy

The theme of "Strategy" consists of the following codes: Incorporating apps into the curriculum; Learning environment; Learning context. In this topic, teachers talk about how they have used citizen science mobile applications with their students.

The interview data indicated that teachers utilise CS apps at all school levels. All the teachers I spoke with referred to these apps as "species identification tools," however, there was significant variation in how they used them. Sometimes teachers linked the use of apps to specific topics within the curriculum. In this scenario, they typically use them in classroom lessons (where they bring materials) or conduct lessons outdoors. However, more often, teachers mentioned using these apps for various additional activities not directly related to the curriculum. This can occur in different learning settings - during outdoor lessons, school walks, excursions, and even expeditions (sometimes mandatory, sometimes not). In such situations, teachers focus on familiarising students with biodiversity using the apps.

Teachers also observed that the ability to utilise apps in an educational setting is contingent upon the curriculum followed by the school in question. For instance, another teacher from Montenegro (P9) indicated that she only employs apps in one of the two educational institutions where she is employed: *"In one school, the curriculum is mainly skills-based. So it doesn't matter what kind of material we use, I can do my lessons outside as much as I want. And in the other school there is a standard programme which is quite rigid, so we do not walk around as much. We just go through the programme and we only go out occasionally. So in the first school there is a lot more use of apps"*.

In addition to the educational tasks mentioned above, teachers can encourage students to use the apps to collect data for their own projects, research or study experiments, practising the species identification method. Only two of them mentioned that they use them specifically for collecting data for a CS project.

#### 4.2. Teachers' interest and aims

Interest in this case refers to the reasons why teachers are interested in using apps in the classroom, their motivation and goals. The reasons why teachers were interested in using apps in teaching varied, ranging from personal interests (such as an interest in biodiversity studies or citizen science, or enthusiasm for a tool and a desire to share it) to improving their performance (such as saving time on lesson preparation, making lessons more interesting, and using modern teaching methods and convenient tools). Additionally, motives related to students were mentioned. Some teachers saw the use

of apps as an effective way of developing students' new skills, critical thinking and content knowledge (biodiversity knowledge was a particularly common code). Several teachers noted that they use apps to develop students' autonomy, and that their goal includes teaching children digital literacy and the "smart" use of phones.

Many teachers spoke of their efforts to make nature and science activities with apps interesting and relevant to school children - to connect them to their lives and make them active participants in the learning process. They emphasised the importance of engaging in science, fostering interest in nature, teaching children to interact with nature, and using apps as a means to achieve these goals. Participant 6 believes that it can get students excited about *"the cool parts of biology. Biology is not only found in texts, but out there! [...] My theory is that the usage of the app may shift the position of the learner: when reading a text, they feel like a passive recipient; when using the app, they become the active part in the learning process."* As a result, teachers hope to cultivate environmental awareness among students. Participant 10 described his expectations in this way: *"I don't expect every child to become a scientist, but maybe it will resonate with someone and people will at least become more aware of the nature and treat it with care and respect. And maybe they'll understand why it's important to recycle."*

### **4.3. Learning outcomes**

The main codes in this theme were affective and motivational outcomes, cognitive outcomes, and understanding of science relevance. According to the teachers, students' use of citizen science apps led to increased engagement and interest in biology (or at least in the taught topic), causing positive emotions in children (they enjoy using phones in the classroom, perceive it as a game, appreciate the simplicity of identification, and like learning new things about what they see around). Teachers say that using apps makes pupils active participants in the learning process and as a result they have developed an interest in nature, citizenship and biology, which many children maintain after school.

Although affective and motivational outcomes are discussed more frequently, cognitive outcomes, such as acquiring new knowledge and facilitating its memorization, along with developing skills like identifying and photographing samples, are equally important according to teachers.

### **4.4. Advantages over traditional methods, challenges, limitations**

This theme includes codes related to teachers' perceptions of the challenges and limitations of mobile citizen science applications and the benefits in enhancing environmental education compared to

traditional teaching methods. This category is subdivided into the following themes: Advantages over traditional methods, Technical usage issues, Teacher and student skill limitations, Curriculum integration issues. Teachers often compare teaching with the use of applications to traditional methods (such as dichotomous key identification). They mention that identifying organisms using apps does not require mastery of unnecessarily complex skills and allows for quick results. Teachers say that it is convenient when there is no need to go into detail and understand the intricacies of morphology, which is not always necessary for everyone. Using citizen science apps can open opportunities that were previously unavailable due to their complexity or time-consuming nature. Teacher 3 says that apps help him to keep his students engaged in what they need and are interested in, without wasting time on things that are not necessary: *"For example, if you want to make a map of the plants in the forest with children, but you don't want to spend a week just identifying the plants, or if you don't want to bother with pistils and stamens, but you need to know the plants, it seems that such things are very helpful at that moment."*

As a result, many teachers point to the benefits of using applications when working with children who are not confident and motivated. In addition, according to teachers, children are used to phones, whereas books are unusual. Some teachers mentioned that using the app is a reason for them to take the children outside and give them the opportunity to interact with nature. Before the apps came into their lives, they used to teach only in the classroom. On several occasions, teachers stated that they appreciated the possibility of finding and contacting specialists through the applications. In addition, they observe that the applications enable a more careful attitude towards nature. This is important for the pupils, as teacher 3 pointed out: *"We did a project where we needed to find out what insects visit a certain plant. For this, you have to catch these poor bees and bumblebees, then you need to fix them to identify them properly. The children were not ready to do that, but they were ready to take pictures. Insects sit on the flower for a long time, at that moment a child who desperately wants to save the life of this insect catches them with a phone and identifies them with an app."*

Another code is parental involvement. According to many teachers, the simplicity and accessibility of the tool allows parents to get involved, which in turn further motivates the children. However, although teachers note the accessibility and familiarity of children with phones, they often encounter various difficulties in using applications and phones in general. For example, many teachers note that pupils sometimes struggle to take good pictures or to understand the functions of the application. To address this, it is necessary to set aside time to explore the application. Teachers sometimes face difficulties themselves.

Interviewees mention difficulties related to the age of the students: younger children may find it harder to navigate the application, they may not have smartphones or internet access, and they may struggle to fully understand what citizen science is all about.

Problems with internet connection (necessary for the application to work) and weaknesses of the phone, such as limited memory or a weak camera, were among the most frequently mentioned technological challenges. When discussing the limitations of the application, teachers most often mentioned errors in identification and a sophisticated interface. Another notable difficulty mentioned by teachers is the need to get permission from the school or parents to use the phone, as it is prohibited in many schools. Some parents and colleagues complain about excessive use of mobile phones in class.

The interviews also revealed problems with integrating apps into the curriculum. Many teachers mention that while the ease of use and quick results are undoubted advantages, they also have a downside: some teachers felt that the knowledge students gained through these applications was relatively superficial. Therefore, this approach is not suitable for all educational topics and tasks. For example, when students used applications to identify organisms, they often didn't need to examine the organisms in detail, missing important morphological features necessary for traditional dichotomous key identification. Teachers disagreed about the importance of detailed knowledge. Some believed it was unnecessary for students, while others thought it essential for learning to distinguish species independently in the future. For many teachers, the lack of time for deeper integration becomes a problem. They don't have the time or the motivation to find unusual and interesting ways to use apps in the classroom.

#### **4.5 Engaging citizen science**

This section summarises teachers' views on engaging in citizen science activities when using mobile citizen science applications. The interviews suggest that not all teachers integrate citizen science into their teaching when using mobile citizen science applications. Most of the participants only focused on using the apps as a species identification tool and did not even tell the students that they were connected to citizen science or introduce the concept. Among them were teachers who were not familiar with the concept of citizen science, while others simply did not think to discuss it with the children.

Teachers who had been involved in CS activities themselves noted that there was an intrinsic motivation to involve children in these activities. Some even saw their role as recruiting new volunteers for citizen science. However, only two teachers directly invited pupils to participate in CS projects, one

by involving them in a project-related task in class and the other by offering it as an additional activity. In other cases, citizen science served as a complement to the main task of species identification or project work, with teachers educating students about CS concepts and encouraging them to contribute to databases, interact with scientists and understand the importance of their data contributions. Teachers who were enthusiastic about citizen science paid particular attention to this aspect. They taught students how to add observations correctly (e.g. on iNaturalist, observations must include geographic coordinates, date and a high quality photo that can be verified by identifiers). Students were also shown how verified observations could become part of a database and the uses of these databases. Some teachers noted that this influenced students' attitudes towards the quality of their uploaded observations, making them more responsible and improving the quality of their performance in general, as they were motivated by the idea that their data could be useful to others. It was important for the students to understand that they were not just doing a school assignment, but contributing to a common good, knowing that their data would be used by others. Some teachers proudly reported seeing their students continue to add observations, sometimes even involving parents, some particularly motivated students develop a serious interest in citizen science, actively collecting data for projects outside of school. These students began to understand how their work related to larger scientific research and saw it as important and responsible, sometimes even becoming active members of volunteer CS communities.

Teachers who directly involved students in citizen science activities noted that it provided an opportunity to demonstrate how science works, which could influence student motivation. However, teachers who primarily used species identification applications but introduced students to the concept of citizen science felt that younger students might not fully grasp the significance of contributing to real science projects. Teacher 10 stated that he felt that understanding this contribution would come with time and maturity: *"They prefer to do something that has an immediate benefit. Taking photos, identifying animals, finding new ones, or filling out a biological journal. But understanding the long-term perspective of helping science is harder; it comes gradually. Before that, you have to grow up; this understanding does not come quickly"*. Several participants highlighted how real-life examples of citizen science opportunities, such as, for example, participant 4 from Georgia notes that contact with experts through applications made a big impression on students and increased their motivation and interest in the task: *"When the students needed to collect information about different species of daisies growing in the area, they wrote to a person at the university who had the most observations of that group on iNaturalist. The children were very impressed that they could just write to a distant scientist"*.

The interviews also revealed challenges in motivating teachers to engage students in citizen science. The main reasons for lack of motivation included the lack of financial support for this extra work and time constraints. Other issues were the need to fit in with the curriculum and prepare students for exams. Some teachers admitted that the idea of integrating citizen science into their teaching had not occurred to them before, mainly due to time constraints. However, after the interviews, some of them expressed their intention to discuss the concept of citizen science with their students and to explore the possibilities of getting involved in such projects in the future.

## **5. Discussion**

### **5.1. Teachers' strategies for using citizen science applications in teaching**

Overall, strategies for using citizen science applications fall into two categories: either curriculum-based to support students' learning and understanding of specific topics, or (more commonly) extracurricular activities.

Having to follow the curriculum pretty much limits teachers' ability to use apps in the classroom. Therefore teachers are more likely to use applications outside the curriculum. As shown earlier, it can be difficult for teachers to understand how to effectively integrate citizen science into the classroom. They prefer activities that fit into their curriculum and that they know how to assess. Overworked teachers are often unwilling to implement new practices due to time constraints and administrative support (Owen & Parker, 2018). The same can be said for the use of apps. When they are used in the classroom, teachers try to embed them in the curriculum by integrating them into the learning of specific topics in the programme. This approach has not been found in the literature. Less often, they allow themselves to move away from the curriculum within standard lessons, but then they tend to use it to take the children outside and conduct outdoor lessons to 'see what is growing around them'. This is possible in schools where the curriculum is not too strict and teachers have enough freedom. More often, however, teachers use apps in elective courses or on school trips and expeditions, often to familiarise students with biodiversity, where they do not need to be tied to the curriculum.

### **5.2. Teachers' motives articulated for using applications**

The motives that prompted teachers to use citizen science applications in their classes were varied. Personal interests were similar to the typical motives of volunteers in CS projects (Robinson et al.,

2021). Many participants in the study reported that they use these applications themselves (outside of lessons) for species identification and recording their observations in the database. Additionally, the results of this study showed that teachers have additional professional motives—wanting to make lessons more engaging, use modern teaching methods and convenient tools, bring novelty to their teaching with mobile technologies, and engage students with these innovations. Similar motives are mentioned in other studies (Aristeidou et al., 2021).

An unexpected finding from this study was that teachers prefer to use citizen science applications to save time on lesson preparation and during the completion of classroom tasks: they use these applications as illustrative material, sources of additional information, for students' self-assessment, or as quick methods for species identification when performing various educational tasks. For example, teachers appreciated that some applications provided additional information about organisms, such as distribution maps, descriptions, and taxonomic details. This information could be used as supplementary educational material, enabling discussions on broader biological concepts. Among the advantages of these tools compared to traditional identification methods, they note that it requires neither students nor teachers to make significant efforts or have specialised knowledge and skills. This not only saves time and effort but also helps maintain the attention and interest of children who lack these skills or are not sufficiently engaged.

Furthermore, teachers expected that the applications would help develop certain skills in children (such as species identification and working with samples) or expand students' knowledge (particularly in taxonomy and biodiversity). Participants in the study hoped to use the applications to make lessons interesting and relevant for their students, increase their engagement, develop interest, curiosity, and autonomy, and help students become active participants in the learning process. Less frequently mentioned was the desire to involve students in scientific research through the applications. Some of these motivations were previously noted only among teachers who aimed to use the citizen science approach in their practice. For example Doyle et al. (2017) pointed that they are often driven by the desire to make education more practice-oriented and give children the experience of participating in scientific research. Since this study focused on the experiences of biology and environmental science teachers, they frequently mentioned their aim to use the applications to develop students' interest in biology, biodiversity, and nature in general, to engage students in interacting with nature, and (indirectly) to influence the development of environmentally responsible behaviour. This is partially similar to Hecker et al.'s (2018) findings that educators see citizen science activities as opportunities for

students to engage with topics that are otherwise inaccessible in the class, with the difference that it is about citizen science applications.

### **5.3. Teacher's perceptions of impact on students**

Overall, teachers' expectations largely align with the learning outcomes they described. These outcomes, associated with the use of the applications, correspond to the literature on the results of students' participation in citizen science: cognitive, affective-motivational outcomes, as well as understanding of science (Jordan et al., 2012; Shah & Martinez, 2016; Ruiz-Mallén et al., 2016;). According to the teachers involved in the study, students enjoyed using phones and applications during lessons. They liked learning new things about their surrounding world because it was easy and felt like a game. This engagement led to more active participation in class, greater involvement in learning and a heightened interest in the subjects being studied, increasing curiosity and autonomy. These are crucial elements in the development of scientific literacy and lifelong learning. Similar conclusions were drawn by other researchers, such as Gray et al. (2012), who noted that integrating these tools into the school curriculum could be an effective way to inspire students to study biodiversity in a fun and engaging manner. Teachers also mentioned that, thanks to the applications, they began to take their students outside more often to conduct lessons in nature. Experiencing nature during childhood influences children's attitudes and behaviours toward the environment, fostering long-lasting positive relationships with the natural world and increasing people's interest and knowledge about nature. Direct experiences with nature are considered vital for forming closeness and emotional connections with nature, which in turn are associated with pro-environmental attitudes and behaviours (Ganzevoort & van den Born, 2019; Wells & Lekies, 2012; Palmberg et al., 2019).

According to teachers, the use of applications has made students active participants in the learning process (where students are not just listening or reading textbooks, but engaging in hands-on activities), leading to a sustained interest in nature and science beyond school activities. Similar educational outcomes are noted when using citizen science approaches in schools (Tsivitanidou & Ioannou, 2020; Aristeidou & Herodotou, 2020). Importantly, this generally leads to the formation of a positive attitude and interest in science, which is a crucial component of science education and can significantly impact scientific literacy (Babalola, 2013). However, to develop scientific literacy, it is equally important to understand the meaning of science and the significance of scientific processes. To achieve this, science must cease to be a distant, abstract concept for students; they need to be acquainted

with real science and learn to act and think like scientists (George & Kaplan, 1998; Queiruga & Saiz-Manzanares, 2018; Şener et al., 2015). Understanding scientific processes and the relevance of science is one of the most significant outcomes of participating in citizen science (Bonney et al., 2009; Aristeidou & Herodotou, 2020). However, participants in this study rarely mentioned it. Such educational outcomes were mainly discussed by teachers who used the applications for project work or citizen science activities. Therefore, simply using the applications does not lead to these outcomes.

#### **5.4. Teachers' perceptions of challenges in incorporating citizen science apps into teaching**

Various technical difficulties described by teachers are often mentioned in the literature (Aristeidou & Herodotou, 2020; Echeverria et al., 2021; Orr, 2010), but complaints about errors in species identification were not found in the literature. Teachers did not always have sufficient knowledge to verify the identification results. However, to address this problem, some teachers used different applications to compare results.

Many teachers face this problem of permission to use phones in school and complaints from parents and colleagues about overuse of phones when they suggest using phones in the classroom (Echeverria et al., 2021; Aristeidou & Herodotou, 2020; Tsvitanidou & Ioannou, 2020). This often led teachers to prefer using applications only in extracurricular activities rather than in main classes. Teachers mentioned issues such as not all students having phones or internet access on their phones. Teachers addressed this by assigning group tasks where not every group member needed a phone.

Teachers who incorporated the citizen science approach mentioned that it takes a lot of time to teach students how to use the applications correctly and upload their observations. Many teachers faced challenges integrating the use of applications into the curriculum, especially in schools with strict programs. They had to balance the curriculum requirements, covering specific topics, preparing students for exams, and the desire to provide students with an engaging, practical learning experience by taking them outdoors or involving them in scientific research. As a result, teachers more often used applications in elective classes where they were not bound by strict obligations. Similar issues have been noted previously (Owen & Parker, 2018), reflecting the inflexibility of the school system.

When teachers used applications according to the curriculum, some noted that the applications were not suitable for all topics, and sometimes they complained that the applications only provided a superficial understanding of the subject matter. Many teachers struggled with the lack of time for deeper integration of citizen science, a common problem overall. Other teachers had difficulties because they

were not very familiar with the concept of citizen science themselves and had not yet thought of integrating it into their teaching.

### **5.5. The extent and ways in which teachers engage citizen science**

The study results revealed different attitudes of teachers towards using mobile applications for citizen science, influenced by their personal experience and interest in citizen science. Teachers with personal experience of citizen science showed intrinsic motivation to engage students in this activity. However, only two teachers mentioned using the applications specifically for data collection in citizen science projects. This finding significantly differentiates the results of this study from others, where the use of Citizen Science applications in education was primarily considered as a means to conduct citizen science (Echeverria et al., 2021; Kelemen-Finan et al., 2018; Jenkins, 2011), and influences other findings.

Four main approaches to integrating citizen science into teaching can be identified:

Teachers often use applications for species identification or to support specific topics in line with the curriculum. While they do not always explain the wider significance of these applications or even introduce the concept of citizen science, they believe that even such limited use enriches the classroom and improves educational outcomes, as applications help students to explore their environment and learn about the world. Previous studies have shown that students generally respond positively to using mobile phones in the classroom, increasing their motivation for learning (Aristeidou & Herodotou, 2020; Rode & Torkar, 2023). Teachers believe citizen science applications have significant potential to enhance traditional fieldwork, biodiversity studies and student engagement in life sciences. This potential was shown in previous research (Echeverria et al., 2021; Unger et al., 2021).

Sometimes teachers used applications to introduce biodiversity during school walks and field trips. They encouraged students to identify what they saw around them while explaining the concepts of citizen science and even provided detailed instructions to motivate data submission. All teachers mentioned this as a very important way to use applications. Although the literature suggests that this approach is not typical for the use of CS applications in education, it is similar to BioBlitz events (Roger, Klistorner, 2016; Lorke et al., 2021), with a key difference being that BioBlitz is usually a specially organised event where participants deliberately collect data for scientific research. In contrast, during these school trips, data collection is incidental and students may not fully understand their role in citizen science and its importance.

While this approach made the tasks more interesting for students, as shown in other studies (Trautmann et al., 2012; Makuch, Aczel, 2018; Jenkins, 2011 Braund & Reiss, 2006), students often did not understand how it related to larger scientific investigations, which affected their motivation. Participation in citizen science activities without explicit explanation, is unlikely to significantly change students' attitudes towards the environment or their understanding of the scientific process. Additional educational interventions are needed to achieve these results (Brossard et al., 2005). Therefore, to maximise the benefits of app-based student learning, it is essential to ensure that students are actively engaged in the citizen science process, understand its aims and objectives, and understand their role in it. Such an approach not only immerses students in a topic area, but also gives them hands-on experience of the process of collecting, analysing and interpreting data as part of a real scientific activity (Owen & Parker, 2018).

Another approach described by teachers involves students using applications to collect data (such as identifying organisms) for their own school projects. According to teachers it allows students to experience the full scientific cycle and feel a sense of agency. This helps them understand what science is and what scientists do. This confirms findings from other studies that engaging in scientific activities and relating them to the students' lives positively influences their understanding and perception of science (George & Kaplan, 1998; Queiruga & Saiz-Manzanares, 2018). Teachers note that using applications makes the work easier and offers some advantages, but the applications do not play a crucial role in this case, just help to do the same tasks better and faster. The more important aspect is that students get to try being scientists while conducting their projects. As participant № 2 from the United States said: "*We could do the same thing without the app, though maybe less efficiently.*". Sometimes, when students were working on their projects, teachers suggested (and helped) them to contact an expert, a "real" scientist, through the application. This made a strong impression on the students, demonstrating the real potential of CS tools and helping them to understand how their work fits into a wider scientific context. As has been shown previously, the very process of conducting a student research project immerses students in scientific practices, and CS can serve as an impetus for developing authentic engagement with science (Koomen et al., 2018).

The rarest approach described by teachers involves direct student participation in citizen science projects. One such project mentioned by teachers was purely contributory: students set up bird feeders, identified the birds visiting them using apps, and collected data for researchers at Cornell University. Another project was specially customised to meet educational needs. The aim was to model

and measure the relationship between abiotic factors and plant diversity on school playgrounds. Students formulated hypotheses, collected data (measuring temperature, soil compaction, moisture, and plant diversity in different areas of the school yard), and then tested their hypotheses against the collected data. The results were posted on the project's website, making them accessible to everyone. The teacher found student participation in this project extremely valuable for students who learned to identify plants, felt like active participants in the scientific process, understood the significance of their actions, and developed interest, engagement, and autonomy. Students saw that they could do science which was interesting and relevant to their everyday lives (e.g. In this case, the students explored the plants in the square near the school and were able to assess their impact on their diversity). This aligns with findings from studies on teaching citizen science in classrooms, which emphasise the importance of student engagement in real science (Aristeidou et al., 2023; Kelemen-Finan et al., 2018).

Citizen science as an educational context has great potential. To make the use of applications even more beneficial for education, it is necessary to familiarise teachers with the citizen science approach. As this study has shown, some teachers enjoy using the applications, but do not realise that citizen science itself can be seen as an educational context. Therefore, training and information sessions for teachers on the citizen science approach could be very beneficial. These sessions could help teachers understand how to effectively integrate citizen science applications into their curriculum, thereby enhancing the educational value of these applications. By doing so, teachers can better facilitate meaningful student engagement in scientific activities, ensuring that students not only learn about science, but also actively participate in scientific processes.

## **5.6. Conclusions**

The study explored teachers' experiences and views on the use of CS apps. The most unexpected finding was that teachers generally used the apps as standalone tools and saw many benefits for teaching and students. They often prefer to use the apps outside of core lessons to avoid having to follow the curriculum and get permissions from administrators and parents to use phones. The extent to which teachers incorporate CS into their teaching varies and is linked to their personal experience and interest in citizen science.

As this study has shown, some teachers enjoy using apps and even participating in CS activities, but often do not realise that citizen science itself can be seen as an educational context, or find it difficult to embed the approach into the school curriculum. However, citizen science as an educational

context has great potential. To make the use of applications even more useful for education, it is necessary to familiarise teachers with the CS approach. Therefore, training and information sessions for teachers on this topic can be very useful. Such sessions will help teachers understand how to effectively integrate citizen science applications into their curricula, thereby enhancing their educational value. In this way, teachers will be better able to promote meaningful student engagement in science, ensuring that students not only learn about science, but also actively participate in scientific processes. Another area of potential improvement could be the adaptation of educational apps (or the development of separate versions of apps) to make it easier for teachers to integrate citizen science into their teaching.

### **5.7. Possible areas for future research**

The results of this study showed that teachers do not often use citizen science apps to integrate citizen science into their teaching, so further research is needed to better understand how using such apps helps to engage teachers and students specifically in citizen science and produce relevant educational outcomes. It was mentioned that the use of apps depends on the school curriculum. This may also be influenced by the education system in a country. This could also be an area for further research. In addition, although the study participants worked with different age groups of students, this aspect was not explored in detail in this paper. However, according to the teachers, the age of the students can have a significant impact on how the students use the apps and the impact they have on them, as well as how they engage with citizen science. More research is needed to explore this issue further. Another aspect that needs to be explored further is the background of the teachers and its influence on their practice in relation to citizen science apps. Some of the teachers in the study had worked in science before becoming teachers. This may have influenced their experience of citizen science and consequently their strategies and level of engagement with citizen science in the classroom. In addition, it may be possible to extend the study beyond biology education. Finally, there could be a shift from the exploration of teachers' views to the exploration of students' views - what are their views on the use of applications? What benefits do they think they bring? How does the use of apps make science clearer and more interesting? To what extent do they feel that using them makes them more like scientists?

## **6. Limitations**

The main limitations are related to the sample selection. Participants were selected based on the criterion of using CS apps in teaching. However, it appeared that some teachers were using citizen

science apps but not using the citizen science approach itself in their teaching. Perhaps a larger sample of teachers using these apps in connection with citizen science is needed to better illuminate teachers' perspectives and experiences of using apps as conduits for citizen science. In addition, although the study included teachers from different countries, of different ages and with different experiences of using apps, the distribution was not even. The study does not allow us to draw conclusions about the influence of these factors on teachers' views on the use of apps. Another limitation is language. The study only included teachers who spoke Russian and English, which also limits the sample. Although the study included teachers from different countries, most of the participants were drawn from the author's primary and secondary contacts. This creates a bias towards Russian-speaking teachers.

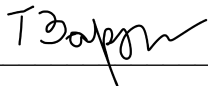
As the study is based on teachers' memories and opinions, there may be a bias in the responses. This study focused on the use of CS applications in schools. However, it did not only focus on formal settings. Non-formal settings were also included in the study, which should be taken into account when interpreting the results.

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## 8. Author's declaration

I hereby declare that I have written this thesis independently and that all contributions of other authors and supporters have been referenced. The thesis has been written in accordance with the requirements for graduation theses of the Institute of Education of the University of Tartu and is in compliance with good academic practices.




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# Appendices

## Appendix 1. Interview protocol

Interview questions which help to answer each RQ (possible follow-up questions are presented as (.1)).

### Background information

1. What is your name and age?
2. Where do you teach (City and country)?
3. What subject do you teach?
4. Which grade do you use the citizen science apps in? (if more than one, please state below)?
5. Do you teach basic level or advanced students?

### What is the teachers' interest for using them in the classroom

6. What was your initial motivation for using citizen science apps in class?
7. What are your main goals in using such applications in your teaching?
  - 7.1 For what purposes do you use these apps with your students?

### How do teachers use CS apps in their classes?

8. Tell me about the apps you use
  - 8.1. What specific citizen science applications do you use in your teaching?
  - 8.2. How long have you been using it?
  - 8.3. What do you find most useful and, conversely, most challenging in their use?
9. What experience do you have with these apps?
10. How do you embed the citizen science apps into your classroom/course?
  - 10.1. Please explain how the usage of citizen science apps aligned with the curriculum?(e.g. in which learning situations do you use these applications?)
  - 10.2. Can you describe specific examples of how you have used citizen science apps in your curriculum?
  - 10.3. For which topics do you most often use citizen science applications in your classroom?

11. What kind of skills or competencies do you hope to develop in your students through the use of these applications?
12. Tell me about how you adapt your classes for teaching with these apps
  - 12.1. How have you been using these apps in your classroom?
  - 12.2. When do you expect your students to work with it (e.g. in class or at home)?
13. How did you talk to the pupils about citizen science when you were using the apps?
  - 13.1. Did the children know that they were helping to collect data for real scientists?
  - 13.2. If so, How did this affect them?
14. Based on your experience, what advice do you have for educators interested in incorporating citizen science apps into their teaching?

**What are the teachers' perceptions of their impact on students?**

15. How effective do you think it is to use such applications to achieve learning objectives?
  - 15.1 Have you noticed any changes in students' interest and motivation after implementing these applications?
    - 15.1.1.If so, please describe.
    - 15.2 Have you noticed any changes in students' understanding of the learning topics of biological/ecological concepts through the use of these applications? 15.2.1. If so, please describe.
16. Tell me about the new knowledge and skills, gained from participating in the citizen science activities
  - 16.1. How did you evaluate them?
17. Can you share any notable (unexpected) experiences of your students working with citizen science apps in your classes?
18. What advantages and disadvantages do you see in using citizen science apps over traditional teaching methods?
  - 18.1 What do you see as the difference compared to traditional teaching methods?
19. Tell me about any specific examples of successes or interesting results that your students have achieved through the use of these apps (e.g. improved test scores, increased number (or quality) of research projects, etc.)?
20. How would you describe your students' attitude towards using citizen science apps ?

20.1. 23.1. What did they tell you about such activity?

23.2. Please describe your students' reactions to using citizen science apps.

**What are the challenges teachers encounter in incorporating CS apps in the classroom**

21. What was the most difficult/challenging aspect in integrating these applications into your course/programme?
22. 21.1 And how have you dealt with these challenges?

## Appendix 2

**Table 1.** Participants demographics and background information

Participant's Number	Country where school located	Experience in using CS apps in teaching (years)	App	Age	Subject	School level
Participant 1 (P1)	Estonia	2	PlantNet Merlin	43	Environmental science	Primary school
Participant 2 (P2)	USA	5	INaturalist	54	Biology, Science research	High school
Participant 3 (P3)	Russia	6	PlantNet INaturalist, Merlin, Birdnet	40	Biology	Secondary school High school
Participant 4 (P4)	Georgia	6	INaturalist, PlantNet, Merlin	42	Biology, environmental science	Primary school
Participant 5 (P5)	Montenegro	2,5	PlantNet, Merlin	43	Biology	Primary school Secondary school High school
Participant 6 (P6)	Germany	4	FloraIncognita,	30	Biology	Secondary school
Participant 7 (P7)	Australia	5	PlantNet	65	Biology	Secondary school High school
Participant 8 (P8)	Montenegro	5,5	PlantNet, Merlin	34	Biology	Primary school Secondary school
Participant 9 (P9)	Montenegro	2,5	PlantNet, Merlin	45	Biology. Environmental walks	Primary school Secondary school
Participant 10 (P10)	Montenegro	1,5	INaturalist, Merlin	26	Environmental science, zoological club	Primary school

## **Appendix 3**

### **Informed Consent**

#### **Title of the Study: Teacher Perspectives on Integrating Citizen Science Tools in School Environmental Education**

Thank you for inviting us to participate in a study on the integration of citizen science in environmental education.

The aim of this study is to understand teachers' perspectives on the educational potential and actual experiences of using mobile citizen science applications in environmental school education, explore ways of integrating citizen science tools into teaching, to understand how teachers use them in practice, and how they see the challenges and benefits of these approaches.

If you agree to participate, you will be asked to take part in an interview about your teaching practices in relation to environmental education and the use of citizen science. The interview will be recorded to ensure accurate data collection. Your identity will be kept confidential in any published or written data.

Participation in the study is voluntary. You may choose not to participate or withdraw at any time without consequence. Your answers will be kept confidential and no personally identifiable information will be disclosed. The data collected will be used for research purposes only.

If you have any questions or concerns about the study, please contact Tatiana Zarubina at [Zarubina@ut.ee](mailto:Zarubina@ut.ee) or 79055077822.

By signing the consent form below, you are confirming that you have read and understood the information provided above and that you are volunteering to take part in this study.

Participant's Name: \_\_\_\_\_

Participant's Signature: \_\_\_\_\_

Date: \_\_\_\_\_

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