AntChain: A Framework for the Gamification of Citizen Science & Environmental Education

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Abstract. Forecasts predict that by the end of 2022 there will be almost 3 billion gamers worldwide[4]. What would be the impact of channelling even a small fraction of these resources into scientific value and ecological literacy? In this work I explore different ways of achieving this. I will create a generic framework for the creation of a citizen science pervasive serious game and employ it to collect myrmecological data. Then, in a collaboration with iNaturalist the framework will be employed to increase citizen scientist engagement in their platform. The work intends to make new contributions to the gamification of crowd-sourced data collection, gamification of learning and gamification of crowd-sourced game development. I will also evaluate the viability of a new paradigm in scientist-volunteer communication. Lastly, I investigate how both blockchain and AI can aid in these goals.

Keywords: Gamification · iNaturalist · Citizen Science · Education · Blockchain

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1 Introduction

1.1 Citizen science

Also known as **crowd-sourced science**, is a type of scientific research conducted, both or in whole, with the involvement of members of the public.
These amateur scientists, can collect large quantities of data across an array of habitats and locations over long spans of time. As such, citizen science projects have been remarkably successful in advancing scientific knowledge, and contributions from citizen scientists now provide a vast quantity of data about species occurrence and distribution around the world. Most citizen science projects also strive to help participants learn about the organisms they are observing and to become familiar with the usual process of scientific progress[2].
This type of scientific research is not new. In fact, the practice goes back at least to the National Audubon Society's annual Christmas bird count, which began in 1900. Nowadays, Cornell scientists who track citizen-science studies have so far found more than two hundred research projects being conducted by researchers in North America[1] .
However, with the advent of technology the practice has been evolving rapidly, opening the path for new ideas relating to the use of smartphones, gamification, AI and blockchain.

1.2 Engaging hobbyists in citizen science

Some citizen scientists usually enjoy leisure activities that are related to the scientific research they help develop. For example, one might be an amateur bird watcher or an amateur astronomer, whose activities already suit a closely related citizen science project.
An example of this are amateur naturalists. Their personal motivations take them into nature to photograph specimens they find interesting. These photographs can then be uploaded into scientific databases, such as iNaturalist[1], a citizen science project and online social network for naturalists.
Unfortunately, this kind of disposition is very personal, as such, there are relatively few active users with prolonged and constant activity[12].

1.3 Gamification of iNaturalist an incentive

Fortunately, iNaturalist's API provides a way to make posts on the behalf of the users. This allows the development of additional mechanisms of incentive for the volunteers.
One of the mechanisms this work explores is that of gamifying the data collection process: instead of posting directly to iNaturalist, the volunteer is playing a game, involving the collection of scientific data. This data can then be posted to iNaturalist if the user deems so[2].

[1] https://www.inaturalist.org
[2] Posting to iNaturalist on behalf of the user must always come with explicit consent and not happen implicitly

1.4 Education in Citizen Science

An additional layer of stimulation can be provided through the acquirement of scientific knowledge through volunteering.
Furthermore, scientific education is an essential part of science, thus it is also central to citizen science[13].
As such, informing the general population about how scientific research is developed not only is beneficial to their personal lives but can help fight scientific illiteracy and make people less prone to misinformation[14].
Additionally, by making it easier for the participant to deepen his knowledge about his subject of interest, his appreciation for the hobby can improve greatly[15].
Furthermore, the volunteer's relation to nature may change[40], which is something of paramount importance given the hardships of climate change we currently face.

1.5 Gamification of Education

It has been shown that by itself, participation in citizen science doesn't necessarily improve the participants knowledge[39]. For this reason, it is necessary to put effort into the delivery of the informative content of citizen science. One fitting way to package this knowledge along with the gamification of the data collection, is the gamification of the learning process itself.
Gamification of learning is a big field of research, which, taking into consideration how the traditional education system has lagged behind technology development, has great untapped potential.[22].
Furthermore, given the wide reach of nature-based games, it is crucial to leverage the citizen scientist's contributions in the production of the educational content itself.
Improving upon the crowd-source model of websites like Wikipedia, gamification can also prove to be a powerful tool.

1.6 Ants & Ant keeping

A naturalist hobby that lately has been growing in popularity is that of Ant Keeping[72].
Members of this community set out to explore ants. These expeditions can be as simple as a walk near their place of residence or an actual planned field trips to areas where species of interested have been identified. The goal of these trips is to document species and the location of colonies they come across with.
Back at home, if needed, they will share these pictures in online chats, such as *Whatsapp*, *Discord* and *Telegram* groups, supplying relevant details such as location, approximate size of specimen, type of habitat, etc. Then, more experienced members provide their help in the identification process.

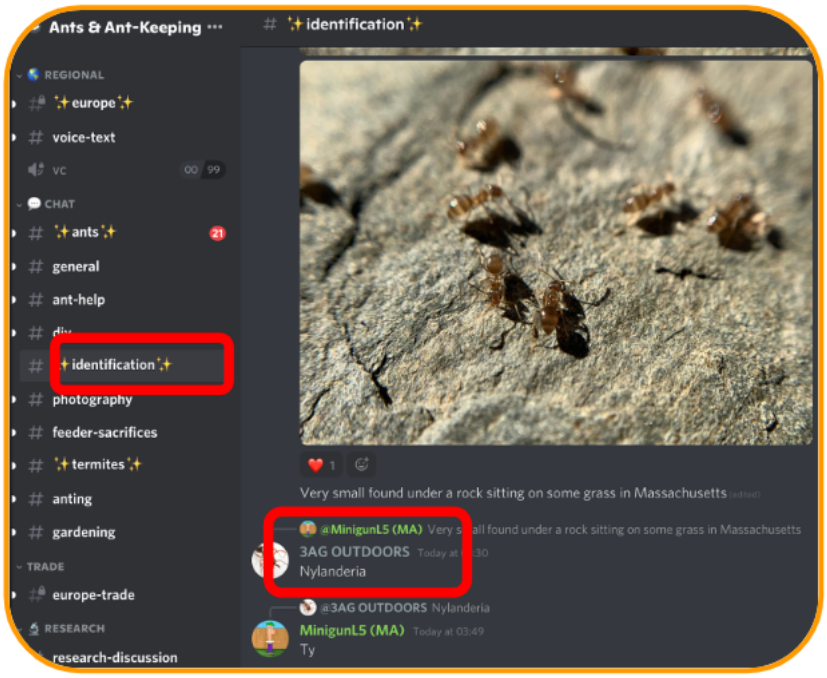

Fig. 1. Example of a user asking for the community's help in identifying an ant species

With this newly acquired information, the hobbyist can then research into the behaviour of the species, learning when and under what conditions the nuptial flights of these colonies take place. For example, in the case of *Messor barbarus* in the Iberian peninsula, colonies spread out over a distance reaching up to 1 thousand kilometers[74], will synchronise over weather cues around October to send out their reproductive alate ants. It is also common place for interesting and relevant scientific papers to be shared and discussed within the communities. Equipped with this sort of information, the practitioner can then go back to the locations he registered, hoping to find a wandering newly mated queen.
The reason for this is that after the nuptial flight, the queen will remove her own wings in order to safely go look for a place to begin her future colony. This is the time window where hobbyists collect queens to take home, getting into the hobby of Ant Keeping.

Given the usual activities and skills of these hobbyists, they make up the perfect target audience for the development and testing of the framework. As such, over the course of this work, I will be making a case study out of these communities, building a game which not only captivates this audience, but also improves their hobby experience.

This case study will involve experiments followed by feedback on different gamification strategies, both for contribution in the data collection and edu-

cational content, any other ideas and suggestions they might have and finally, they will also be serving as beta testers. Lastly, I hope to leverage the existing community and their content makers for advertising and hopefully, making the game viral.

Furthermore, taking in consideration the previous sections, the game experience will be informing and motivating the hobbyists to decrease their environmental impact. These concerns are discussed in the following subsection.

1.7 Environmental Concerns

Usually, if one captures too many queens of a certain species, they will try to trade them for other species of interest. But there are also people who capture great amounts of queens for selling abroad. It is also true that thousands of ant queens fly at once and the chances of survival in nature of each of those is very small, at least compared to when they are tended by hobbyists. Nonetheless, poaching should be discouraged as it may tilt the balance of nature.
Furthermore, by shipping species across the world, there's the risk of introduction of exotic species[63].
This is one example in which the framework can make the difference in raising awareness.

2 Research Questions

Each theme detailed in the introduction raises the following questions which will be researched in this work.

2.1 Gamification in Citizen Science

How can we increase volunteer engagement?
Does gamification actually aid in citizen science's role?
To answer this question it will be necessary to look into the different categories of citizen science to identify the different roles of volunteers and their participation goals. Then, I will be able to conceive different genres of possible gamification routes.
Afterwards, I will need to evaluate these different routes.
In order to meaningfully compare the different gamification possibilities and pick the most suitable one, I will have to characterise each.
To this end, I will investigate which metrics are the most relevant. Some examples can be: short-term and long-term engagement, motivation, enjoyability, grinding efforts[79], etc.
Finally, by assessing the different genres with the chosen metrics, I will decide what kind of gamification course is the most deserving of attention.
By focusing on it, I can break it down in its different dimensions, in order to fine tune them.

In this phase, surveying the public's opinion may be essential.

2.2 Gamification of education

What kind of content will we teach?
Following the approach of citizen science, is there a possibility for educative content to also be crowd-sourced?
If so, how can educative content be crowd-sourced?
What are the different ways in which this content can be gamified?
How can education help in scientific illiteracy?
Does education improve the hobby experience?

2.3 Bridging scientists to volunteers

A novel aspect of this work, is that of opening a communication channel between scientists and volunteers. By this means, scientists will be able to communicate their research necessities, integrated into the game, and players will be able to follow them for rewards.
This communication channel has a lot to explore. As such, the following questions arise:
Does the scientific community actually have this necessity?
If so, what kind of needs do scientists have in their research?
By getting in touch with different myrmecologists I will be able to answer both of these questions and form a pool of their usual necessities. What is the actual best way to bridge them? Is it by missions in-game? And/or by an actual chat or forum?
It is important to investigate how restrictive or not these needs will be, as in, will there be the possibility of adding new objectives to the missions? Or will there be a pool of missions that scientists can configure and launch?
How will the players be rewarded?
Can NFTs be used as rewards?

2.4 Mitigating environmental concerns

Given that the ant-keeping hobby and its environmental impact has never been studied, I can't make any assumption about it. Nonetheless, as I want to target this community as the initial player-base, I look forward to investigate how some of their behaviours can be discouraged, such as:

- Destruction of wild colonies to take home;
- Mass poaching of queens for selling, especially in poorer countries;
- International shipping of ant species, raising the concern of the introduction of exotic species;

This raises the ensuing research questions:
How can education discourage these behaviours?
How can the in-game mechanics tackle these behaviours?
How to encourage the transition from poached queens to digital colonies?

2.5 Blockchain & NFTs

There is the possibility of integrating the reward system into a blockchain, as opposed to developing a centralized game. In this manner, there can be an in-game market for people to auction their in-game rewards, adding another layer of motivation.
This begs the questions:
Is blockchain integration advantageous?
If so, what is the most adequate blockchain for this work's needs?
What to do if that blockchain is taken down?
What kind of in-game market and trades do we want to facilitate?
How to create an active and lasting in-game economy?

3 Related Work

In the following section I will be detailing articles that relate and support the different questions and core aspects of the framework to be developed during this thesis.

3.1 Citizen science and gamification

Citizen science as science communication Communication is a vital aspect of citizen science, as perhaps hyperbolically stated in [9]: "95% of citizen science is communication". Given the perspective that communication in citizen science is "always" science communication and communication is essential to "doing science"[13], we realise the importance of the role of citizen science in modern society.

Two papers explore this role[16, 11], describing how in science communication the frequency of the terminology such as "public engagement" compared to "public understanding" has been increasing.

All of this highlights the importance of exploring different communication strategies for the success of this work. Fortunately, there are papers and guides that cover these strategies, factors that determine their success, challenges and solutions[10, 9].

Citizen science outcomes in ecological education A literature review on the outcomes for participants of citizen science projects in biodiversity show that it is promising for environmental, sustainability and science education[5, 7, 15, 17, 48]. Moreover, this type of education plays a fundamental role in the fight against climate-change and scientific illiteracy[6].

More specifically, the following six categories were shown to have positive changes[7]:

- content, process and nature of science knowledge;

- skills of science inquiry;
- self-efficacy for science and the environment;
- interest in science and the environment;
- motivation for science and the environment;
- behaviour towards the environment;

The most notable result across projects was that self-reported increases in knowledge, self-efficacy, interest and motivation in the environment were found to be more pronounced, rather than in science[7].

Additionally, relating to participatory action research, an approach to research emphasising participation and action by members of communities affected by that research[17], it has been shown that these projects both provide a deeper meaning to participants' hobbies[15] and also increase the participants' knowledge of biology [39, 40], which are key motivations for this work regarding ant keeping and myrmecology. Besides these positive outcomes, it has been shown that they may not translate directly in behavioural changes[40].

For this reason, additional efforts are needed to curve the possible negative impacts of the hobby. Nevertheless it has been demonstrated that periodical evaluation of individual learning outcomes in a citizen science project, can help project managers improve overall project outcomes, reach new audiences, promote learning opportunities, and increase project longevity and impact[45].

Engaging citizen scientists The success of a citizen science project depends heavily on the engagement of its volunteering citizen scientists[50, 43, 20].

In turn, it has been shown that this engagement depends on a complex framework of factors that dynamically change throughout their cycle of work on scientific projects[38]. These motivating factors can be further split into two types[20, 46]:

- In extrinsic motivation, we perform an activity not because of directly liking the activity, but by enjoyment of a reward won by doing it;
- In intrinsic motivation, we perform an activity because the activity itself feels rewarding;

Both of these factors should be carefully attended to when designing a project[43] and with gamification[27, 48] we are given more options to do so. A study[46] supports the effectiveness of this route to increase extrinsic motivation.

Two ways in which these two factors can partake in my work follow. First, by giving in-game rewards for important but repetitive and eventually boring tasks, we are increasing extrinsic motivation. On the other hand, by including the same tasks in a compelling story, we are adding intrinsic motivation.

But gamification can create tension, as gaming and science can be seen as incompatible areas of activity and has been shown that participants respond differently to this kind of tension[41, 40, 43]. Some volunteers are even motivated to discontinue their participation[43]. According to a review on gamification, there

is a wide agreement about the need for customization of the gaming experience, showing that the efficacy of gamification is greater when the player is given option to choose his path[29].

One relevant finding is that the project must recognise and manage the implicit normative scientific ideals that participants bring with them[41], as results from survey of nearly 11,000 volunteers an astronomy citizen science project show that volunteers' primary motivation is the desire to contribute to scientific research[36].

Fortunately, a framework for volunteer participation in gamified citizen science projects was already developed[20]. Additionally, the human computer interaction in biodiversity citizen science has been explored[8]. Also, there is an overview of the types of climate change games currently available, the benefits and trade-offs of each in the education regarding climate change[48]. Finally, the book [37] covers core game concepts and design patterns to a create fun and captivating social environment.

This approach of giving purpose to a game beyond entertainment, has been coined as "serious games", has the unique ability to channel the power of cultural force into positive change[19].

A curious example of gamification in citizen science was that of Borderlands, a massively multiplayer online game[42].

3.2 Gamification in Education

With this work I also intend to research the gamification of education in the context of citizen science. The main intention is the engagement of a secondary group of citizen scientists: Millennials. And gamification is key to attracting and educating them[44, 22].

Current traditional schooling methodologies have lagged behind technology. As such, given the intense technology use of this group changes in education must follow[77].

One way to fight this is by using gamification to embed interaction in learning. Current traditional education is very lacking in this sense. For instance, one study showed that students in class get to ask a question every 10 hours[23]. In contrast, another study showed that making a game out of learning can change student behaviour[24].

Furthermore, studies in over 400 individual school districts and a meta analysis as well found increases in vocabulary and arts of 24% and 25%, respectively, over control groups. Math problem solving and math algorithms scores were 51% and 30% higher, respectively[22].

Additionally, in a meta study it was shown that inclusion of game fiction and combining competition with collaboration were effective for fostering behavioral learning outcomes[26]. Another crucial point is the importance of reflection and critical thinking is crucial in learning. The article [22], details the necessity of exploring different ways of including it in the gamified learning experience.

Another important social issue that my work plants to tackle is that of problematic gaming habits.
Current forecasts predict that by the end of 2022 there will be almost 3 billion gamers worldwide[4]. According to game designer Jane McGonigal the reason for this is that videogames are fulfilling human needs, which game designers have taken advantage of. He then argues that this can be seen as a form of escapism[28]. Another study proposes that at it's worse, this behaviour can be classified as an actual disorder[76]. A correlation between this disorder and genre of the game as been found[33].
Coming back to education, a study shows that boys given video games, did worse in school, spent less time in other after-school activities, had more behavioral problems and had lower reading and writing scores[32].

This shows the importance of developing games that captivate us in a healthy manner.

Two books are of relevance to this end:

In one, Karl Kapp describes how rethinking learning itself is fundamental to the process of gamification, giving advice and examples to do so[30].
In the other, it is shown how gamers are proficient at problem solving and collaboration, providing lessons of game design to achieve socially positive ends, both in the lives of the players, communities or businesses[28].

3.3 Connecting Scientists to Volunteers

As mentioned previously, citizen science can be seen as a bidirectional channel of science communication[13]. Additionally, gaming has been described as the language of the future[51], given that the act of playing a game can itself be seen as type of communication: by playing, the user is actually interacting through a rule-based language to transmit and receive messages.
Furthermore, the puppet-master genre as described in [49], shows a type of pervasive game[25] where the master devises a mission script for the puppets to take part in as actors.
Lastly, the narrative genre of transmedia storytelling has been shown to have a promising relation to the world of NFTs[58].

By marrying these concepts we tap into a new, possibly very promising, future paradigm. In this paradigm scientists take up the roles of masters who communicate their necessities through crafted in-game missions. These missions lead citizen scientists, undertaking the role of puppets, into fulfilling adventures rewarded with exciting digital assets.

In my work I intend to explore this paradigm by creating a channel of communication between scientists wishing the focused help of volunteers. This layer further customizes the needs of individual scientists within the broader context of a citizen science project.

To this end, I will explore the creation of a tool for the scientist to craft generic in-game missions, adding his own personalised objectives and defining rewards according both to difficulty and demand. This directs the participants

to collecting data the scientist is specifically looking for.
On the scientist's side, this process can both be enjoyable and also provide him with a communication platform. On the flip side of the coin, given that citizen scientists know what the data will be used for, in contrast to the way iNaturalist currently works, it can provide them with a better sense of purpose and achievement in their contribution to science. Additionally, they have a way to share their observations, questions and even novel ideas with the professionals they are working with.

Lastly, the concept of BioBlitz[75], an organized event of intense biological surveying in an attempt to record all the living species within a designated area and time period, may also be worth of consideration in the context of this work.

3.4 Blockchain

In [61, 47, 56] several use-cases of blockchain technology are identified, detailing the disruptive potential of the technology in today's most-pressing environmental and social challenges, such as higher education[57, 60]. Developers, investors and governments are urged to tap onto this game-changing value and to address the technology "beyond the myopic context of a financial asset".[56]

One of these technologies, is that of NFTs, first invented in 2017 for game players to trade non-replicable virtual goods[59].
By May of 2021, the total money on NFT sales reached over 34 million in USD, drawing attention worldwide. However, the development of the NFT ecosystem is still in its early stage, having been called pre-mature[54].
The work of [54] is the first systematic study on the current NFT ecosystems, providing an overview of state-of-the-art NFT solutions, their technical components, protocols, standards, and desired proprieties. Furthermore, they provide an evaluation on the security aspect, with discussions on design models, opportunities and challenges.

In my work I intend to use NFT's in two ways. First as a gamification component, this use-case has already been evaluated in several studies, including environmental ones. In [53, 52, 47] potential applications of blockchain and tokenization in sustainable urban development and their ecosystems are discussed. They propose the reconfiguration of the relationship between people and other agents with which we share the environment, such as animals, buildings and plants, improving the quality of life within a deprived urban environment.

The second use case of NFT's relates to the "crowd-sourced development" aspect of the game. When developing a nature-based pervasive game, traditional development patterns which require the full development of game before release become unfeasible. To explain this, consider that there are over 10 thousand described ant species and an estimated 20 thousand total species. The time and money invested in creating an array of different art characters for each of these species and their respective educational facts would be colossal.
As such, I will need to explore a new paradigm of crowd-sourced development[34,

35], where the players can contribute to the game, also being rewarded for it. This presents several challenges that must carefully evaluated. Fortunately, this concept of swam intelligence has already been explored in[55]. Therein, the paper finds that blockchain based social networks may solve some of the problems of current platforms, as they provide a more decentralized and democratic solution. They describe how a voting mechanism and reward system can be implemented to draw in on this swarm intelligence. It further combines these findings with the concepts of "quadratic voting" and "data as labor" presented in [73].

3.5 Mitigating Environmental Concerns

Human activities increasingly disperse insect species beyond their historical ranges[62].
One of these activities, exotic pet keeping, is currently under debate. Governments of several countries are increasingly exploring the regulation, or even the banning, of exotic pet keeping[68].
For instance, when considering interstate ant trading in the USA, you either trade allowed ants or must apply for a permit[71].
This is due to major concerns regarding public health and safety, animal welfare and biodiversity conservation, given that exotic invasions are major threat to global biodiversity[69, 68, 63].
Unfortunately, predicting potential invaders is still a difficult task[69]. Some papers tackle this issue[69], also finding a link between the increasing demand for pet birds in developed countries and avian invasions. As invertebrates used in the pet trade such as ants are increasing in relevance[72], understanding human-mediated dispersal is crucial for predicting future invasions[62] and may also leading to the ease of regulation[63, 67].

In the article "The aquarium hobby: can sinners become saints in freshwater fish conservation?"[70], it is brought to light that due to the damaging impacts of the aquarium trade, many conservationists and academics have the perception that aquarium hobbyists are generally harmful to species conservation. In spite of that, it is desirable to establish common ground between hobbyists and conservationists by showing the benefits of serious aquarium hobbyists in the conservation of freshwater fishes and their habitats.

In my work I will employ this perspective to explore new ways of conciliating the hobby of keeping exotic pets with its impacts and bringing the community closer to scientific recommendations. Fortunately, due to the scientific involvement of some ant keeping communities, responsible rules are already in place, such as in figure 2, present in the aforementioned discord community.

Lastly, it is common practice for people to condone behaviour when it is seen as dangerous, educating them on the matter, for instance, in the following example someone explains why releasing even natives colonies is a bad idea:

"The thing with keeping colonies, and why i believe in freezing all colonies if you cant keep em, is because a self contained ecosphere like a vivarium or ant colony is essentially a good way for a disease to mutate and become a danger to

animals or environments not readily immune or prepared to deal with the new alien disease or pest. You also introduce an established or new colony into an already working ecosystem which can create an unbalance in food/space/territory which can lead to other established colonies dying or struggling with the introduced colony" - User named *Berb*

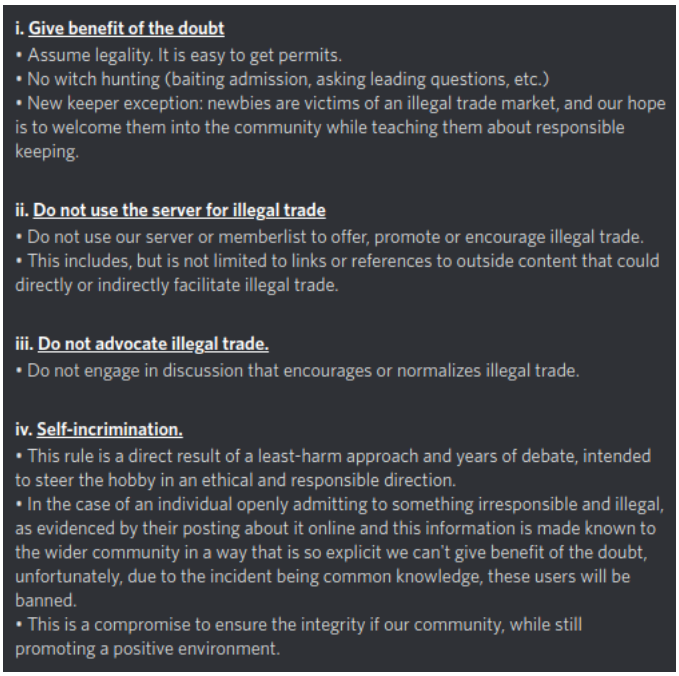

Fig. 2. Ants & Ant Keeping trading rules

4 Solution Proposal

I propose the development of a general framework for the development of citizen science games and its employment to develop an ant-related game, targeting the ant keeping community.
I find it important to emphasize: the game is not intended to motivate the ant-keeping hobby or to supplement it in any way, only to leverage their help in its development and then to serve as a starting point in the popularization of the game.
At this stage, the project will involve the following characteristics.

4.1 Gameplay

Players would go into nature as described previously, motivated through some in-game narrative and missions, they would upload their observations to the game, other players would help them ID the specimen, likewise what occurs in both the aforementioned chats and iNaturalist app. Successful identifications would make the players earn rewards, such as in game currency. After different successful registers of a given species, for example, 10 different observations of *Messor barbarus* colonies, they'd earn a virtual colony of this species. Then, they would be able to add workers to their collection, by making more identification of those. For example, with the first ID, you could receive an ant egg. After 3 additional IDs, it would hatch into a larva, which grows with every additional ID. On the 9th ID the larva would spin a cocoon and become a pupa. Finally, on the 10th ID the larva would finally pupate into an imago, an adult ant. This ant would have randomised traits, each with different rarities. This could also happen with queens and drones, which are male reproducing ants.
These colonies could then be tended to, in the same fashion as the hobby: they'd need to have their water replaced, be given a varied diet and then get cleaned-up. These activities could cost some in game currency, motivating the users to ID & verify the other player's observations.

4.2 Rare collectibles

Following a model closely related to NFT's, such as the famous CryptoKitties, the players are rewarded for their contributions as citizen scientists. These collectables can then be traded, forming an in-game economy, helping the hobbyists transition from a poaching based ant trading hobby to a digital one.
If the game is blockchain based, rare digital ant specimens and colonies could be sold for auctioned prices, increasing player engagement.

4.3 Gamified education

The game can be developed faithfully to myrmecology, balancing its art aspect with actual scientific education. For instance, by allowing species specific behaviours to take place within the virtual colonies, one could learn about real behaviours. For example, Messor barbarus' etymological meaning is "wild harvest", due to the fact that they collect seeds for the making of ant bread. This ant bread is the result of the processing of the seeds both by their mandibles and enzymes that they regurgitate. This ant bread is then given as food to the larvae which can further digest it, for the adult ants to be able to eat it. Furthermore, facts like the meaning of the species name can be present on the game, which may also be crowd-sourced submissions of players. Understanding the names of the species usually helps in the identification process and the memorisation of the name. For example, Crematogaster is an allusion the fact that these ants bend their gaster differently, hence their common name: acrobat ants. These kind of

facts are also not properly registered, which is another way citizen science can happen within the project.

4.4 Connecting scientists to hobbyists

Furthermore, this project can also explore new venues of scientist-volunteer communication. Scientists with certain necessities could deploy in-game missions for the participants to focus on. For example, one researcher might be interested in registers of nuptial flights of a certain species in a certain area.
This type of interaction can greatly benefit both scientist and citizen scientist: On one side, the scientist, who's working both with time and money constraints, can easily recruit helpers. On the other side, the citizen scientists can feel more connected to the data they are gathering, by allowing the player to see articles and scientific development that resulted directly from their help.

4.5 Technical Considerations

For the chatbot, I will be developing the core features of gamification and iNaturalist API interaction in an abstract way. In this manner I will be able to reuse the same code for the different chatbot supporting platforms, such as Telegram, Discord.

Then, starting development of the game I will make a in-depth assessment of the best frameworks, languages and platforms for mobile game development. The work [66] evaluates the different game engines in the context of educational serious games. Unity is a promising option, due to being free and allowing the simultaneous deployment of a 2D or 3D app to Android and iOS.
Then I will also need to consider which blockchain is the most appropriate, as high trading fees can be game stopping.
Nonetheless, the game can be developed in a centralized manner, easily dropping blockchain support if it becomes unfeasible, without breaking the game.

4.6 Development phases

By developing this work in a modular manner and with each additional development building on top of the previous one, we can ensure that if anything doesn't go as expected, value was still produced.
With this in mind, these will be the different phases of development and the value each provides.

In the first phase I plan to survey scientists and the ant keeping communities I am able to find.
For the scientists I intend to collect data on:

- their perceived need of both of scientists and volunteers of a platform like the one described in this work;

- any human computer interaction constraint they might have;
- suggestions to make it a viable solution;
- their usual research data needs;
- their ideas on future research data they might need;
- any additional ideas;

In the case of hobbyists I will collect data on:

- ideas for the gameplay;
- ideas for the reward system;
- things they wish to learn while playing;
- their perceived need of a platform like this;
- their opinion on a crowd-sourced game development;
- their willingness to contribute for rewards;
- their opinion on providing a platform for them to engage scientists;
- any further suggestion;

When this first phase is finished I will organise the results in order to evaluate the different ideas.

In the second phase, I will implement some of them in a modular manner in order to explore the viability of the different core components of this work

This will require another round of testing and surveying of scientists and volunteers.

One core aspect of the game I intend to test is the implementation of a chatbot that gamifies ant identification channels, experimenting with strategies such as rewards, rankings or/and a point system. In the more general channels, it can crowd-source educational value interactively to answer questions when queried, for example, care tips and nuptial flight data for a given possibles. Finally, it might also post to iNaturalist on behalf of the users. This will require the collaboration of the moderators of the communities and the authorisation to use iNaturalist's API. This chatbot will provide important insight into the user's experiences, wishes and complaints. Furthermore, it will offer a new way to structure both the labelling and informational data that naturally occurs in the channel and is eventually forgotten in endless stream that are online chats[3].

Unlike the first round, I also intend to survey the more general population, as the aim of the game is to engage them in citizen science.

Following the ideas present in the related work, this survey will allow me to design the game for the sustained long-term engagement of participants.

Building on top of the previous section, the third phase will consist of the implementation of a working smartphone prototype of the game, integrating all its core functionalities. This will allow me to conduct a beta test in order to make the final design choices and find solutions to any challenge that might arise. At this phase, artistic concerns won't be a priority.

[3] This was actually the initial concern that originated this work.

In the fourth and last phase, I will be developing art-work and respective animations for the game to be playable. This will probably the hardest part in the development of a game like this. I will explore ideas of swarm intelligence, perhaps to vote on AI generated art work in order to allow the game to match the diversity of ant species.

Finally, it is important to stress that the framework will be hobby-agnostic, which means that the effort in implementing an additional game will be mainly spent on the development of art-work.

5 Work Evaluation Methodology

In order to evaluate the impact of the contributions of this work in their differing domains, the following methodologies will be employed.

It is important to note that due to some outcomes being subjective experiences, there will be the need look into different subjective scales for proper evaluation[78].

5.1 iNaturalist engagement

By making use of the already developed frameworks for evaluating volunteer participation such as the one in [20], I will assess the behavioural changes of existing iNaturalist users.
I will be comparing their contribution frequency, the range and nature of their contributions. To exemplify, one might be motivated to make more contributions of the same animal species, instead of species they wish to know the name. Also the range of their contributions might also change due to making observation of species they wouldn't normally take interest in.

Furthermore, I will also evaluate the success of the gamification process by directly asking for feedback.

Lastly, I will also measure new user registrations in iNaturalist, to understand this work's impact on the engagement of new citizen scientists.

5.2 Educational outcomes

In order to explore the different venues of education gamification I will need to track the different educational outcomes of the project and their success.

This can be done both in-game or on external surveys.
In terms of hobbyists, the surveys will evaluate:

- changes in knowledge about the hobby;
- changes in perception of the hobby;
- changes in behaviour relating to the hobby;

In terms of the general population, including hobbyists, I will survey

- changes in their relationship with nature;
- changes in scientific literacy;
- changes in ecological behaviour;
- changes in biology knowledge;
- changes in lifestyle, such as going more outside;

5.3 Outcomes of the scientist-volunteer communication channel

Opening a gamified communication channel between scientists and volunteers is something whose usefulness hasn't been studied yet. As such it will need careful tuning, which in its turn, depends on a appropriate evaluation methodology.

Here I will both depend on statistics generated by the game and also a survey, that covers some of the changes described in the previous section and additional ones, like:

- usefulness of the channel to answer personal science related questions;
- changes in motivation due to a closer relationship with the research they are contributing to;
- changes in personal goals due to working and communicating with scientists;
- changes in personal fulfillment, due to for example, contributing with their personal ideas for research;

Then, I will also evaluate the usefulness of this channel through the lens of the scientist. To so I will evaluate:

- improvement of data collection for their current research;
- new research possibilities facilitated by this paradigm;
- new research ideas put forth by users;
- changes in the enjoyment of their craft;
- long-term interest in this channel;

5.4 Continued monitoring

Following the ideas in [45] as detailed in the related work, I will also need to continuously evaluate the users in order to customize their experience and increase the long-term success of the project.

To do this I will need to develop a practical way of evaluating this in-game, as surveys would quickly become demotivating, possibly leading the players to lose interest in the game itself.

6 Scheduling

The different phases put forth in the proposal will be taking place between September 2022 and May 2023.

My plan is to the work simultaneously on the different components of the thesis. For instance, I can start surveying the public whilst developing different

core parts of the framework. Also I will be writing the thesis during the whole process.

The first phase will take place in September and the corresponding results will be analysed in October.
During these two months I will be working on the chatbot, in order to release it as soon as the surveying is over. Then, with the results of the first survey in mind, I will change the functionality of the chatbot to evaluate different strategies, starting the second round of surveying in November
Also in November, I will extend the bot functionality to allow crowd-sourcing information for querying, structuring the educational content within the community following a gamification approach. This functionality will then be surveyed and improved during the month of November.
As these activities are user and time dependent, I can concurrently start the development of the smartphone app, which corresponds to the third phase of development. This will be the main focus during December, January and February.

This lets the fourth and final phase of development take place in February, March and April. This allows for the beta testing and corresponding surveying to take place. In May I dedicate myself to analysing the results and finishing the written thesis.

7 Conclusions

In this work I proposed the development of a framework for the gamification of existing citizen projects, applying it to myrmecology, thus harnessing the knowledge and dedication of the ant-keeping community.

Having drawn on several novel concepts relating to citizen science, education, gamification and blockchain, the main contributions of this work will be:

- Exploring pervasive serious gaming in citizen science;
- The development of a generic framework for the gamification of naturalist hobbies relating to citizen science projects;
- Research new ways to increase engagement of citizen scientists both through the use of gamification and blockchain;
- Opening a gamified communication channel between scientists and volunteers;
- Exploration of the viability for volunteers to crowd-source parts of the game development, including educative content;
- New ideas to fight the growing exotic pet poaching and trading through education;

Following a collaboration with iNaturalist, the app will be wrapping the platform's data collection process, incentivising user engagement.

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